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1 Executive Summary

The mission of the Analysis and Evaluation (A&E) Activity in the frame of the STM Validation project is to facilitate the validation of the STM concepts, through the quantification of the benefits associated with SMT implementation. Within A&E, methods for evaluation as well as requirements for data collection will be defined and analysed. As a result, A&E will contribute to demonstrate that the actual maritime navigation constraints can be mitigated by STM, improving the business, efficiency, safety and sustainability of the stakeholders involved in the shipping industry.

In the aim of turning the STM concept into services for the improvement of the current maritime traffic management system, the different activities in the project will develop large-scale test beds in which the potential benefits of the concept should be demonstrated. In particular, the concepts of Port Collaborative Decision Making (Port CDM), Voyage Management (VM), Sea System Wide Information Management (SeaSWIM) will be tested. Moreover, the European Maritime Simulator Network (EMSN), created in Monalisa 2.0 project (ML2.0) will allow the use of simulators for modelling complex situations that in real life could not be performed, thus facilitating new valuable evidences. Even though Monalisa 2.0 project discerned the good basis for developing the STM concept further, the different STM services are to be refined and detailed during the STM validation project.

Within the MONALISA 2.0 project, a holistic situation analysis resulted in a report called “STM Definition Phase: The Performance Target” where Key Performance Areas (KPAs) and Key Performance Objectives (KPOs) were defined. This report will be used as a reference basis for A&E primary approach. In addition, the produced documents by the rest of activities about the development of their concepts into services and their clarifications about the descriptions will be used for the formulation of the main hypotheses that will support the validation of Key Performance Indicators (key drivers of STM deployment).

The aim of this document is to describe the process followed by A&E activity, explaining the methodologies used and the sources applied for the development of the Information Environment structure that will be the base to make the different studies devoted to validating STM as the correct tool to improve maritime traffic management.
1.1 Information Environment Architecture

The Information Environment consists on the ensemble of the different methodologies used for the organization of the information expected to be collected during the course of the test beds designed in STM Validation Project, with the aim of analysing and extracting conclusive statements that facilitate the demonstration of the benefits of implementing Sea Traffic Management globally.

The following figure illustrates the steps followed in the construction of the Information Environment for STM Validation. It has five main layers which results will be shown on the graphic interface developed for this purpose, (represented by the screen on the top). Each layer will be described in this document including the required specifications and methodologies for each of them.

This report structure coincides with this architecture. The first layer, **STM Concept** reviews the basis of the need of building up such a system and defines, with the inspiration of the aviation sector, the different STM concepts: Strategic Voyage Management, Dynamic Voyage Management, Flow Management, Port Collaborative Decision Making and Sea System Wide Information Management.

The different STM services have been refined and detailed during the first phase of the project. In this first stage, the responsible of each concept designed the specifications of the services. This is described in the second layer of the Information Environment Architecture: **STM Services**.

In the first phase of the project, A&E has been indirectly involved in the mentioned process in order to gain understanding of the services and to determine which the most relevant objectives are as well as to define the hypotheses that they can fulfil in connection with the maritime sector. These results complete the third layer of the Information Environment Structure: **STM Validation Hypotheses Model**.

According to the hypotheses deducted and considering the data that can 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 is defined as **Information Environment Sources**.

The fifth layer of the Information Environment Structure is titled **Collection, Processing and Analysis of Data**, which explains the methodology for collecting the data from different sources in order to make analyses with the support of different tools and show the results that can fulfil STM validation. Finally, the results will be projected into a **Graphic Interface**, which is the sixth layer of the schema. This layer is defined with the purpose of disseminate the benefits deducted from the evaluation of the data extracted.
Figure 1: Information Environment Architecture. Source: Own elaboration
2 STM Background

Figure 2: STM concept layer of information environment. Source: Own elaboration

2.1 Monalisa 2.0. Concepts

Sea Traffic Management (STM) is inserted in a complex environment where seaborne trade and its business models would be directly impacted by STM implementation. A detailed overview of the global economic and trade current state is needed to establish a baseline scenario that allows the formulation of the STM Vision and Goals. This section depicts this current situation, focusing on the key areas that STM aims to improve regarding maritime transport: efficiency, safety and environmental sustainability. After several iterations of the MONALISA 2.0 project, a refined definition has been provided:

---

Sea Traffic Management (STM) is a concept encompassing all actors, actions, and services assisting maritime traffic from port to port.

STM is a part of the multimodal logistics chain, encompassing sea as well as shore based operations.

The STM concept includes concepts for strategic and dynamic voyage management, flow management, port collaborative decision making, and the service based communication infrastructure concept SeaSWIM.

Sea Traffic Management (STM) is the concept of sharing and using all data from the maritime space in real time, in order to improve safety, environmental performance and efficiency in the maritime transport chain.
---
2.1.1 Strategic Voyage Management

Strategic Voyage Management (SVM) envisions the planning of a complete sea voyage, beginning with an idea that evolves and incorporates various actors connected together through a unique and agreed-on voyage plan. The overall objective of SVM is to optimise the initial planning phase of a sea voyage by enabling a collective and up-to-date awareness of all influencing factors related to the undertaking and success of the planned voyage.

In the beginning of the strategic planning phase, a company identifies the actors who should participate in the different aspects of a specific sea voyage. These nominated actors then help to develop a voyage plan. This company also decides which parts of the voyage plan will be shared and with whom.

The strategic voyage plan includes all the information required for planning and executing a sea voyage, such as a route with arrival times, towage requirements, pilot-pick up, port calls, reporting, traffic avoidance, permissions, weather information, and navigational warnings.

Throughout a voyage’s lifecycle, and beginning with the strategic planning phase, a voyage plan is uniquely identifiable for all nominated actors (see Figure 3).

![Figure 3: A Voyage Plan Lifecycle. Source: Monalisa 2.0](image)

Each voyage plan connects all involved collaborators, keeping them informed of any changes of estimated arrival times, permissions, weather conditions and other relevant voyage information. As a result, all nominated actors have a common, up-to-date situational awareness that enables them to take appropriate action in a timely fashion.

The initial planning of a sea voyage will also be supported by information from previously executed voyages. A library of similar voyages will be made available through the SVM concept to help select and validate suitable routes in relation to current regulations, weather, and navigational warnings.

In international shipping, crossing of boundaries and travelling between continents is the norm and in each state and ocean, different local regulations apply.
SVM will provide governments with the tools needed to describe where and when certain maritime regulations apply to a voyage. Instead of the current manual reporting, standards for geo-located regulations will facilitate the automatic adherence to jurisdictional regulations through a navigational system, decreasing the administrative burden of ship reporting requirements.

Early validation of relevant factors such as route-selection, legal requirements, and weather can then be moved from the bridge to the shore. With a strategic voyage plan covering the maritime component of the journey, it will then be possible to enable a complete transport solution for any shipment end-to-end, from the time it leaves its origin until it arrives at its final destination.

The principal characteristics of SVM are:

- All planned sea voyages are uniquely identified.
- All actors (both sea and shore) nominated to participate in a sea voyage are able to share and update their part in the plan.
- Early shore-based information regarding relevant factors affecting a sea voyage is made available to ensure a holistic view of transportation solutions end-to-end.
- Each planned sea voyage is supported by up-to-date and voyage-relevant information, improving its successful and on-time completion.

Key SVM services include:

- Voyage Information, which will provide other STM services with voyage-related information.
- Unique Voyage ID (UVID) – Voyage Plan Identifier, which will uniquely identify each voyage plan and serve as a pointer to all voyage information.
- Nomination of Collaborators, which will identify all actors involved in a specific sea voyage. Each actor will have different information access rights, which will be assigned by the information's owner.
- Geographical Legal Restrictions for Maritime Operations. This will enable maritime authorities to describe where certain regulations are in place, so a voyage plan can consider them in the earliest planning stages.
- Route Catalogue Services. This will provide maritime voyage planners with a catalogue of previous routes based on past AIS data, and serve as a tool to select routes undertaken by similar types of ships.
- Post-voyage Analysis. Since STM will facilitate the undertaking of all activities needed to complete a voyage successfully, it can also create a summary of the route and other changes, updates, delays and deviations related to a voyage that can be analysed and used for continuous optimisation of best practices and company business rules.
2.1.2 Dynamic Voyage Management

Navigation starts when a planned route is executed. The MONALISA project aimed to add new technology that will speed up and secure this process with real-time access to appropriate data from relevant stakeholders and service providers on an as-needed basis. Today, this process is executed on board with manual updates via telephone, fax, email, pilot books, and charts.

Dynamic Voyage Management (DVM) connects ships, adds intelligent processes, and new tools. DVM provides ship operators with an up-to-date and dynamic flow of information to improve ship efficiency and safety and reduce their environmental impact enabling all authorised stakeholders to be involved with a voyage. This provides a much faster, more secure and transparent way of exchanging information that will optimise the execution of a voyage, reduce airborne emissions, and improve common situational awareness, leading to increased safety at sea. This will be implemented in conjunction with other e-navigation and e-maritime initiatives and services.

DVM starts once a voyage order is issued and a ship assigned, transitioning seamlessly from SVM. Its purpose is to monitor and optimise a voyage plan continuously during a passage and provide guidance for all future tactical actions when course or speed alterations occur. DVM uses the unique voyage ID issued in the SVM phase to connect all relevant data related to a specific voyage. The voyage ID and a standardised route exchange format make it possible for all authorised stakeholders, independent of equipment and manufacturer, to receive, read, elaborate, and transmit routes seamlessly.

DVM uses the strategic voyage plan as a base and assists the Master during a voyage when significant changes are necessary due to such things as technical issues regarding the ship, weather and ice conditions, changes to the availability of berths, tugs, and pilots, traffic conditions, and cargo-related matters. DVM can then iteratively modify the original strategic voyage plan to ensure that a ship operates in the most effective way, using all possible data that affect its voyage plan.

DVM makes such information constantly available, affecting and affected by other processes involved in a ship’s overall voyage plan, such as the strategic voyage plan and Flow Management and Port CDM requirements.

DVM also obtains information from Port CDM and Flow Management services regarding desirable arrival and departure times, managing updated Estimated Time of Arrival (ETA)/Estimated Time of Departure (ETD) by altering the time and speed dimensions of the route throughout the whole voyage. This, in turn, provides opportunities for just-in-time operations, reduced fuel consumption, and minimised airborne emissions.

At the same time, changed sea conditions such as bad weather or ice, technical issues, or traffic, may affect an ETA and the just-in-time process at the port. DVM ensures that this information is updated with other STM services.

DVM also exchanges information with Flow Management regarding traffic conditions when optimising specific routes, affecting and being affected by the shipping traffic patterns in a certain area. Five services are envisioned:
1. **Route Optimisation.** This service will provide continuous optimisation of routes according to cost, safety, and environmental parameters. Improved optimisation will lead to reduced fuel consumption and reduce emissions of GHG and pollutants. Efficiency and cost-effectiveness will also be improved. Better-optimised routes will also have a greater predictability, improving the planning of port services and the overall predictability of the maritime transport system.

2. **Route Cross-Check.** This service will provide an additional check of the port-to-port route replacing verbal shore-side verification and improving existing on board verification practices. This will result in safer routes and reduced administrative burden both on board and ashore. Shore-based operators can also use route exchange to verify that ships’ routes are in accordance with local regulations, conditions, and knowledge. This will lead to clearer communication and safer navigation, thereby reducing the number of incidents and accidents.

3. **Route Exchange.** This service will enable particular route segments to be exchanged with nearby ships and with shore services to improve situational awareness and reduce accidents. The ability to exchange routes is one of the cornerstones of STM and an enabler for several other operational services.

4. **Shore-based Navigational Assistance.** This real-time monitoring service will support on board navigation, add a new tool to existing navigational services, and serve as an alternative to deep-sea piloting, thereby reducing the cost of a voyage. It will also increase voyage safety, especially in confined, sensitive or densely trafficked areas. Navigation in sensitive areas can also be decreased due to better support from operators with local knowledge.

5. **Single Reporting.** This service, utilising SeaSWIM, Voyage Information Service, and Route Exchange, will standardise and automate mandatory ship reporting requirements by facilitating route and voyage information exchange with all interested and authorised parties, such as port agents, ship traffic services, and ship and cargo owners.

Existing Single Window initiatives will gain added functionality through SeaSWIM, which gives all stakeholders the ability to access information related to a ship’s voyage. Improved interoperability will make reporting more efficient and cost effective, reducing the administrative burden both on board and shore side. A lower administrative burden will also help operators focus more on the safe navigation of the ship instead of on reporting, thereby increasing voyage safety.

### 2.1.3 Flow Management

Whereas Strategic Voyage Management and Dynamic Voyage Management consider individual voyages, the goal of Flow Management (FM) is to improve the overall flow of sea traffic through better information and coordination, not control. It leaves all ship decisions with the master and enhances decision-making with information and advice about traffic and safety. FM information will be provided to all ships during the strategic planning and dynamic stages of their voyage.

FM will be the responsibility of administrative entities or possibly commercial service providers approved and appointed by the National Competent Authority (NCA). If related to territorial waters, the NCA would decide which FM services should be implemented, to what degree, and in which geographical areas.
These decisions will be based on risk analyses and only when a clear benefit for the safety of navigation is determined. Four major FM services are envisioned:

1. Enhanced Shore-based Monitoring will be undertaken in specific geographical areas where the risk of collision or grounding is high, enhancing the safety of navigation and environmental protection. A critical area can also be an environmentally sensitive area, for example, where oil pollution could have major consequences. It will automatically compare live shipping traffic with ships’ intended routes.

2. Flow Optimisation is a service that operates both during the SVM and DVM phases of a voyage. A Vessel Traffic Service (VTS) delivering a Traffic Organisation Service (TOS), or an advisory Flow Optimisation Service in geographical areas that have high traffic density and/or particular constraints to a passage could implement it. With flow optimisation, a shore-based operator, monitors traffic using the Enhanced Monitoring Service described above, and can advise a ship to slow down or speed up based on its ETA at specific key waypoints, known as Flow Points (FP). This helps avoid potential traffic congestion and problems further down its route. The service can also re-direct traffic using a “recommended route” communicated to a ship.

3. Area Management and Maritime Safety Information (MSI) will constantly collect and update local and regional information regarding:
   - Legal and environmental requirements.
   - Nautical information, which is today contained in pilot books.
   - Environmental information, such as weather, ice, currents, tidal waters.
   - Navigational safety warnings.

   This service could be organised under today’s system of NAVAREAS and Sub-NAVAREAS and implemented as a digital resource making commonly accepted and standardised navigational geo-references available, thereby improving safety, efficiency, and environmental sustainability.

2.1.4 Port Collaborative Decision-Making

Sea traffic both begins and ends at a port. In order to reach STM performance targets, integration with ports is therefore necessary. Inspired by a similar concept used for collaborative decision making within and between airports (known as AirportCDM), Port CDM 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 involved actors in making efficient collective decisions. This will result in better planning of arrival and departure times and improve how a port interacts with a ship to optimise its port call.

To enable just-in-time operations, the various actors, which are engaged in sea transport-related actions, need to contribute to the creation of common situational awareness. This is achieved by capturing and drawing on information from different sources in a standardised way. Common situational awareness will maximise utilisation of port facilities and resources and optimise the use of energy (fuel/bunker) in steaming between two ports.
Port CDM relies on continuous interactions between the maritime actors involved in a port call -- the actors within a port, and between a port and the stakeholders who deal with it such as, ships, shipping companies, ship operators, ships’ agents, towage companies, pilot organisations, and terminals -- who all need to coordinate closely to execute it efficiently.

Port CDM helps visualise desired states to enable different operators to act in such a way that a port call (arrival, at berth, cargo operations, and departure) can be performed on a just-in-time basis. The overall principle is that involved actors should be able to trust the prediction of when a certain state will be reached and that their performance will thus be just-in-time (not too early, not too late) and at optimal capacity.

Port CDM has three goals:

1. To synchronise ship arrival, departure, and port readiness, enabling green steaming in the latter stage of a voyage.
2. To optimise the use of port resources and ship turn-around time.
3. To provide the information necessary to facilitate just-in-time operations.

To achieve these goals and benefits, all maritime and intermodal actors involved in a port call need to share information about various states and degrees of readiness for a particular ship’s arrival. Estimated time of arrival (ETA), estimates of when certain states of readiness will be reached, commitments related to certain states, and changes to these states over time.

The final departure of a ship is the result of negotiation between port entities and the ship/cargo owner. For example, cargo handling could be planned to be completed the next day and all parties informed accordingly, but if there is an economic reason for a ship to sail as soon as possible, the owners must bear the cost of the stevedores’ overtime so that it can depart later the same evening.

Many such negotiations take place today. Port CDM is a means for sharing information about state changes to enable such re-planning.

The ability to predict accurately when various operations should occur in a particular port call is difficult because of the numerous actors involved and the overall lack of situational awareness. Port CDM will address these deficiencies in several problem areas such as lack of information harmonisation, information redundancy, information reliability, poor predictability, administrative burden, and waiting times.

Port CDM is predicated on the assumption that communication about an upcoming port approach is made as soon as it is known and that changes are communicated as early as possible. A port can only optimise its operations if it receives real-time information about the status of the different activities and transports that affect them and gets updates if their states change. This means that the same measures function both as coordination mechanisms for optimising port operations (and creating readiness for managing necessary activities) and as a means for enabling collaboration/optimisation between different activities.
Different planning horizons are associated with different levels of tolerance for deviation between the estimated and actual reached state (the outcome). This deviation should diminish with time and the closer to the time of an activity’s execution, the smaller should be the tolerance for deviation.
3 STM Services

Figure 5: STM services layer of information environment. Source: Own elaboration

3.1 Port CDM Services

The Port CDM concept aims to contribute to four operational services:

- Port call synchronisation to coordinate a ship’s arrival to the port with the readiness of that port.
- Port call optimisation to enhance the efficiency of different actor’s actions, in time and space, for just-in-time operations
- Port call improvement based on a process analysis of completed port calls to learn how to improve future port calls.
- Port call monitoring for measuring port call performance and improving information sharing.

All of these services are built upon establishing connectivity among port call actors and their systems’ active in port call processes. Port call messages would be shared with others as soon as a relevant event change is captured within any system. It is, however, important to note that validations\(^1\) show that not all data exists in real-time in the systems that are being used for planning and realising actions associated with port calls (Figure 6).

One proposed approach explored within STM, especially as it relates to Port CDM, is an interoperable platform allowing port call actors to distribute and consume port call messages and port call structures (Figure 6). This interoperable platform is proposed to be implemented as a local instance at each port so that each port is conceived as an information hub coping with its particular circumstances. This information hub would be used for data sharing (at event changes discovered or made by a port call actor, updates of intentions, and synchronisation of activities) to all nominated port call actors. Figure 7 depicts the role of the Port CDM message broker as an information hub connecting different systems. In essence, the Port CDM message broker is the “API” to enable cooperation of different port activities.

\(^1\) C.f. results from validation efforts within the MONALISA 2.0 and the STM validation project
As stated above, the overall purpose with Port CDM is to enable port call synchronisation, port call optimisation, port call improvement, and port call monitoring. In the figure below the basis for port call synchronisation and port call optimisation are depicted.

Port call synchronisation builds upon and enables, port call optimisation, voyage optimisation (from the STM concept voyage management), and traffic coordination (from the STM concept flow management). Port call optimisation builds upon that data is shared, updated, and synchronised among different actors. In order to facilitate such sharing and synchronisation, a message broker is required to allow for that everybody can consume each other’s conception of event changes instantly. This would in turn enable the distribution of application services allowing situational awareness for involved port call actors. Situational awareness together with synchronised time stamp sharing enable distributed port calls for the purpose of optimised turn-around processes.

The proposed solution recognises that the maritime sector is a self-organized ecosystem in which accessibility to the port’s information needs to be enabled in a standardised way as required. So far, the different implementations made in the test beds, the port call actors have preferred that the environment allow a flexibility of who takes the responsibility of operating this interoperable platform. A distinction is therefore needed of the solution provider and the service provider of Port CDM.
Port CDM builds on the principle that involved port call actors jointly can provide all the knowledge associated to port calls, but to enhance the predictability of different state changes (such as e.g., time of departure) collaboration via data sharing is essential. Collaboration requires communication building on a unified and precise language, as well on contextual understanding. This is to be operated by the local instance of Port CDM that builds on generic specifications, and possibly on (variants of) a generic kernel that is configured for each port.

In Figure 8, the basic idea of the Port CDM backend is depicted. The Port CDM backend is designed to be a natural information hub for distribution of, and access to, data related to planned, on-going, and conducted port calls. Involved port call actors should be “SeaSWIM” connected. Figure 8 indicates that actors’ connectors, the Port CDM backend, connectivity to approaching ships, and connectivity to previous and next port, should be SeaSWIM compliant.
Studies performed within MONALISA 2.0 and the STM validation project show that port call actors today have an incomplete situational awareness. A Port CDM backend as a message broker facilitates the emergence of enhanced common situational awareness to be consumed by different port call actors. Without an interoperable platform, ports will be in the same situation as today when port call actors act base their perceptions of actual and forthcoming port calls in a fragmented way. A service provider that has a desire to build a service needs to contact each actor who might have relevant data. The Port CDM backend enables connectivity for data sharing among actors. As an example, 20 actors operating in the port only exchanging data with each other requires an unreasonable number of dyadic (point-to-point) relationships. The Port CDM backend is a multi-organizational solution as a response to inefficient patterns of communication.

In different contexts, it is expected that different approaches to operating the Port CDM platform would be possible. For example, at some ports, the port authority has a strong role in relation to other actors, a trusted actor for managing data sharing in the port. In other port environments, the VTS (Vessel Traffic Service) operated by the maritime authority might take the same role. In other cases, because the terminals together are such a strong (compound) actor, they might take on the role. In some cases, it might be wise to let this interoperable platform be operated by a neutral actor. In this context, neutrality is defined as such a trusted actor that nobody would have any concerns of providing, and allow consumption, of time stamps channelled through the Port CDM backend. The expectation of operational contextual diversity has guided the Port CDM concept to allow diverse implementation strategies.

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2 SPIS = Ship-to-port information services, VIS = voyage information services
3 Precisely, \( n^2 \) for \( n \) actors, which is approximately \( n^2 \)
Further, Port CDM builds upon the hypothesis that operational services can be performed with higher efficiency, enhanced safety, and improved environmental sustainability. For this purpose, improvements are measured by using KPIs, such as waiting times, predictability, punctuality, duration time, capacity utilisation, and berth productivity. These measurements build upon analysing shared data prior, to, and after the realisation of the port call.

### 3.2 Voyage Management Services

In the aim of creating the right scenario for testing STM, a set of voyage management services has been developed following the requirements of the voyage management concepts: Strategic Voyage Management, Dynamic Voyage Management and Flow Management. Following, each concept is described.

![Set of Voyage Management Services included in the STM validation project. Source: Own elaboration](image)

#### 3.2.1 Ship-Port Synchronisation

Port CDM will provide a basis for collaboration between key actors within the port and towards its surroundings based on shared situational awareness enabling increased predictability. To enable just-in-time arrivals of ships, Ship-Port Synchronisation is necessary for just-in-time operations and further on integration with hinterland transportation leading to optimised turn-around processes; and to enable improved resource utilisation for all involved port actors and optimised operations.

Information needs:
- Port Call message format.
- AIS (Automatic Identification Systems).
- RTZ 4– Route plan exchange is used in conjunction with ECDIS to IEC 61174.

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4 The route plan exchange format is based on standardizing a route plan. A route plan consists of waypoints where each waypoint contains information related to the leg from the previous waypoint. The route exchange format is a file - RTZ - containing an XML coded version of the route plan.
Use case/functions to be supported:

1. Arrival port identified and authorised to time updates by sharing a Port Call Message.

2. PTA (Planned Time of Arrival) and ETA (Estimated Time of Arrival) are shared frequently with port during ship’s voyage.

3. Ship is delayed and it cannot reach the port in planned time.

4. Designated actor in port (could be Port Control etc.) accepts ship’s requested time of arrival and confirms back to ship.

5. Ship receives ports confirmation of requested time of arrival and updates its PTA accordingly.

6. New PTA is used for monitoring and speed settings

7. Ship arrives typically to PILOT_BOARDING_AREA and sea passage ends; the port is informed of the ships ATA (Actual Time of Arrival) at this time.

8. Berth will not be available if ship arrives at current PTA.

9. Port sends recommended time of arrival to ship.

10. Ship updates its PTA accordingly.

11. New PTA is used for monitoring and speed settings.

12. Ship arrives at PILOT_BOARDING_AREA and sea passage ends, the port is informed of the ships ATA at this time.

3.2.2 Sharing of Voyage Plan

Ships in test bed will share Voyage Plans (VP) with Shore Centres (SC), ports and service providers. The ship/shipping company is the information owner of the VP and as such chooses which actors that should be granted access to the voyage plan.

This is part of the access management functionality in SeaSWIM. Another prerequisite is that ships voyage plans can be identified and that the identification is unique, therefore the Unique Voyage ID (UVID) concept is a cornerstone in STM and the future usage is to act as a pointer to other information that is related to a voyage such as cargo, crew-reporting information etc.

Information needs:
- RTZ.
- UVID.
- ID registry.
- VIS (Voyage Information Services).
- Access management functionality.

Use case/functions to be supported:

1. Ship prepare voyage plan i.e. Route and Schedule.

2. Ship assigns access rights to VP.

3. Voyage plan is made available for authorised stakeholders.
3.2.3 Route Cross-check

The intended voyage plan is sent to a shore-based service provider for cross-checking. The purpose is to include updated regional area information that could affect ships voyage plan. The cross-checking can be done before the ship’s departure or before arrival at a certain geographical area. The cross-check can include but is not limited to, Under Keel Clearance (UKC), air draught, non-violation of no-go areas, MSI (Maritime Service Information) and compliance with mandatory routeing. No optimisation service as such is included in the route validation.

Information needs:
- RTZ.
- AIS.

Use case/functions to be supported:
1. Voyage Plan is shared according to Sharing of VP.
2. Ship requests a route Cross-check.
3. The Shore Centre checks the route and want to suggest a different route.
4. Ship accepts or rejects suggested route.

3.2.4 Flow Management

A shore-based operator is performing flow optimisation through advice to the ships within a defined sea area using an enhanced traffic image, consisting of AIS targets, radar targets and with the planned routes for the STM ships.

As a part of the route schedule, the operator has access to the ship’s ETA to some key waypoint, denoted Flow point (FPT). Based on the above information, the operator is continually assessing the overall maritime traffic situation within his sector of responsibility.

If a developing traffic situation is identified, the operator can recommend a new ETA for the FPT in order to resolve the situation at an early stage. In the case of an MSI (Maritime Service Information) receipt, e.g., a fairway or traffic lane is closed; the operator can use both re-scheduling and suggested route/s, which is a proposed new route segment. In the case of a port approach, the approach could be synchronised with the port call.

Information needs:
- RTZ.
- AIS.
- Flow points.

Use case/functions to be supported:
1. Voyage Plan is shared according to Sharing of VP (use-case 2).
2. Necessary flow points along the VP to be inserted.
3. Ship enters Shore Centre monitored area and enhanced monitoring is commenced used for flow management.
4. VTS/Shore Centre want to suggest a different route schedule using FPT.
   o Ship accepts or rejects suggested route.
   o Not Use Case Event driven functionality.

3.2.5 Enhanced Monitoring

Enhanced monitoring will be supported by adding route information and a monitoring service can be provided in previously unmonitored areas. Shore Centre will be able to detect if a planned schedule is not kept or if ship deviates from planned route. Thus Shore Centre can monitor that ships are following their planned route and also foresee possible dangerous situations and suggest route modifications (geographic and/or speed) due to traffic or other impeding conditions. These tools can also enhance current VTS services.

Information needs/prerequisites:
- AIS.
- RTZ.
- Info on what ships are STM compatible.
- Connection to SeaSWIM by means of SSC (SeaSWIM Connector).

Use case/functions to be supported:
1. Voyage Plan is shared according to Sharing of VP (use-case 2).
2. Ship requests Enhanced monitoring (in service registry).
3. Ship enters Shore Centre monitored area and enhanced monitoring is commenced.
4. Ship deviates from VP (in time or geographically).
5. SC suggests a changed route by sending route proposal.
7. Ship accepts or rejects suggested route.
8. Ship leaves enhanced monitored area and/or enters another Shore Centre area.

3.2.6 Route Exchange Ship-Ship

Introducing route exchange ship-ship will give the intentions of other ships. Nothing in the current “navigational process” will be changed and the master is still responsible. The route exchange will solely introduce a new tool, which helps the OOW (Officer on Watch) to plan ahead, foresee possible dangerous situations and reduce route detours due to traffic conditions.

The route exchange should be used to avoid collision situations and close quarter situations, when in close quarter situations COLREGs are always in force.

Information needs/prerequisites
- New route message (AIS-ASM).
• Information from AIS (Position, Speed, etc.).

Use case/functions to be supported:

1. Indication what ship is part of STM test bed to separate them from non-STM ships.
2. A choice is made to allow others (ships and shore centres) to see new route message (AIS ASM).
3. Voyage is loaded for monitoring.
5. Own ship route message should be visualised on other ships ECDIS/ STM module.
6. Other ship acquires own ships route and displays it on ECDIS/ STM module.
7. Not Use Case Event driven functionality.
8. Not Use Case Event driven functionality.
9. Ship passes a waypoint.
10. Ship sailing between two waypoints (long distance between these waypoints).
11. Another ship is deviating from its voyage plan (in time or geographically).

3.2.7 Winter Navigation

Information regarding the best route, waiting positions, preparations for assistance, position in convoy, time for departures from the port is important for the Icebreaking services. The information should preferably be transmitted directly to ships navigation system.

Introducing route exchange will give both Icebreaker services and assisted ships better information in more automated procedures reducing workload and risk for misunderstandings.

Information needs:

• RTZ.
• Text message.

Use case/functions to be supported:

Note: The ability to send and receive messages is related to several services but the use case and functionality for this is included in the winter navigation table.

1. Voyage Plan is shared according to Sharing of VP (use-case 2).
2. Icebreaker (IB) need to get the ship about to be assisted to a certain position at a certain time.
3. Ship about to be assisted updates VP acc. To IB’s text message regarding arrival time.
4. IB need to get the ship about to be assisted to follow a recommended route from the IB (e.g. Open waters acc. to latest Ice information that IB has).
5. Not Use Case Event driven functionality.
6. Ice-Breakers (IB) need to relay information to ship regarding IB-Assistance, such as towage arrangement, convoy information.

7. Ship being assisted by IB need to send Updated PTA to port (received via text from IB).

3.2.8 Area Management

Introducing area management tool into the maritime domain will give a more graphic overview on areas where ships are not allowed to pass due to e.g. whale nursery areas, military exercises or SAR operations. The areas should be attached with a date attribute so that they disappear when they are obsolete.

Information needs:
- New area exchange format (S-124).
- Date/time of enforcement.
- Date/time of expiry.
- Text Information regarding the area.

Use case/functions to be supported:

Sail race as an example given of Area Management. Other areas of interest could be SAR Areas, MSI Areas, MSP Areas (Marine Spatial Planning), Protected Areas. All of these areas could be used as a clarification when the Shore Centre needs to inform ships about situations/events that concern safe passage in the area alternatively be a clarification to a proposal if SC chooses to send a route proposal to the ship.

1. Sail Race taking place in an Area between two dates.
2. Shore Centre creates area.
3. Shore Centre send out the Area including attributes to ships.
4. Ship receives area.
5. Area displayed on board.
6. Area deleted.

3.2.9 Route Optimisation

The route optimisation tools will be different in nature with a common purpose to provide more information for the navigator on board. The STM concept will provide the means to get the ships’ route optimised from different service providers in a standardised way. The service providers have different focus including best route regarding; the weather forecast, surface currents, fuel consumption, no-go areas regarding draught, areas with sensitive nature, conflicts with other ships routes etc.

Information needs:
- Ships identification/UVID.
- RTZ.
- Ship specific information, different attributes needed for different services. (No standard exists).
Use case/functions to be supported:
1. Voyage Plan is shared according to Sharing of VP (use-case 2).
2. Ship request optimisation (this can happen daily during long voyage).
3. Service provider receives VP to be optimised.
4. Optimised voyage plan is returned to ship.
5. If ship accepts voyage plan and it is set for monitoring.

3.3 SeaSWIM Services

In the aim of enabling the communications, a Maritime Service Infrastructure based on SeaSWIM (System Wide Information Management) principles is provided, as defined in the MONALISA 2.0 project. The service infrastructure builds the basis for the realisation of the test beds in STM Validation Project. This includes on a conceptual level, to define design criteria for what technical solutions and application services need to be meet for interoperable information sharing and service provision for STM.

On a technical level, a communication infrastructure is built up that addresses the need to manage information exchange in a collaborative and secure way. For the test beds, the above described application services, namely Port CDM services and Voyage Management services will be interconnected as well as additional other services in the longer run (Figure 10).

![Figure 10: SeaSWIM enables information sharing between application services such as Port CDM and Voyage management. Source: STM Project.](image)

Thus, the Maritime Service Infrastructure can be described as SeaSWIM services that will ensure interoperability of the STM application services by facilitating data sharing in a common information environment. The SeaSWIM environment enables maritime stakeholders to share certain data and information, in real time and without interpretation over organisational boundaries. In order to achieve this level of interoperability while including a wide range of stakeholders, the scope of what can be communicated is limited to what complies with the SeaSWIM concept, objectives and STM principles.
The specification of SeaSWIM is developed to adhere to some important STM principles:

- Only authenticated and authorised actors can provide and consume STM services.
- The owner of data is the actor responsible for the original creation and provision.
- The owner has full control over the access management for this data.
- The data owner can be the data provider or he/she can outsource the data storage to a data provider.
- STM strives after a service oriented and highly decentralised architecture.
- Usage of open and widely accepted industry standards wherever these exist.

The fundamental objectives for SeaSWIM are:

- Provide and maintain a harmonised/unified way of communicating within the maritime industry.
- Lower the entry barrier for service providers and service consumers to STM services.
- Provide solutions to promote trust in development and usage of STM services.
- Promote open and accessible standards.
- Enable common understanding and a new level of potential interaction and integration.
- Once communication standards are defined, SeaSWIM is able to facilitate the flow of data and information.

The functionalities of the Maritime Service Infrastructure are provided by different components. Besides the SeaSWIM Connector (SSC), two Maritime Cloud components of the EfficienSea2 project (E2) (http://efficiensea2.org/solution/the-maritime-cloud/), namely the Service Registry and the Identity Registry, are part of this common environment (Figure 11).

![Diagram of SeaSWIM interoperable information space and services](image)

*Figure 11: SeaSWIM interoperable information space and services. Source: STM Project.*
3.3.1 SeaSWIM Connector (SSC)

The functionality of the SeaSWIM Connector is to simplify the connection with SeaSWIM services, i.e. Service and Identity Registry. As it provides a standardised interface to the SeaSWIM services, it hides the complexity of interacting and complying with SeaSWIM principles. The Connector is the “single contact point” for the STM services.

The SSC is developed as a reference service for the test beds and for service providers that handles the interaction with the SeaSWIM services. It provides some generic functionality, needed by most services in the SeaSWIM environment, to lower the entry barriers to develop, produce and consume data and information in the common STM environment. Furthermore, the SSC offers standardised means of defining communication end-points and ensures encryption of all data transferred between the end-points.

The SSC assists developers to access the SeaSWIM environment in a compliant way, yet it is not obligatory. Industry stakeholders are free to develop an own equivalent version as long as it follows the SeaSWIM technical specification it is based on.

3.3.2 Service Registry

Behind the connector, the Maritime Service Infrastructure consists of two central components: the Identity Registry and the Service Registry. The Service Registry can be seen as a sophisticated yellow pages phone book or the equivalent of an App Store on iPhone and Google Play for Android. The aim is to easily register, discover and use all relevant maritime services. The Service Registry provides functionality to publish and find services, their functionality and endpoints.

The service registry improves the visibility and accessibility of available maritime information and services. This enables service providers, consumers, and regulatory authorities to share a common view on service standards and provisioned services. The service registry does not provide actual maritime information, but a specification of various services, the information they carry, and the technical means to obtain it. It is not used as a cloud for storage of maritime information.

3.3.3 Identity Registry

The Identity Registry enables secure and reliable identity management and authentication mechanisms. It can be compared with a Central Person Registry or a Central Business Registry. The Registry contains relevant information for authorised stakeholders and enables confidentiality in information transfer processes. All services depend on unique identifiers that define specific users, services and transmitted data objects to avoid conflicts and to provide unambiguous references.

In the following, it will be shown how the SeaSWIM services are used:

- To provide a service, the data or information provider register in the STM identity registry.
- The identity registry ensures unique identities that can be authenticated. Without a valid STM user identity, a user will not be able to provide or consume data within STM.
• With an STM user identity, the service provider can be authenticated as such and register a service in the service registry.

• Registering to become an STM member is also required for users of the STM services, i.e. to search and consume services.

• With an STM identity, the user can also be authenticated by the service registry and search the published services there.

• The user locates the needed service; its description and how to make use of it (e.g. link to a graphical user interface that can be opened in a web browser).

• The consumer and the service provider establish a connection directly, i.e. between user and application service 1, in order to use the service.

• The interaction requires that STM identities are used and are valid. By uploading the user credentials to the SeaSWIM connector, it provides support to ensure that tokens and certificates can be authenticated.
4 STM Validation Hypotheses Model

![STM Validation Hypotheses](image)

*Figure 12: STM Validation Hypotheses layer of information environment. Source: Own elaboration*

4.1 Validation Methodology

According to Brians, et al, (2011), a hypothesis is a “statement about what we believe to be factual” (p.29). It tells us what to expect if we make “properly organised observations of reality.” Van Evera’s (1997) broadly defines a hypothesis as a statement of expectations tested using observations from the empirical sphere (p.9). From these definitions, we divide hypotheses into formal and working hypotheses. (Shields, Patricia and Rangarjan, N. 2013. A Playbook for Research Methods: Integrating Conceptual Frameworks and Project Management).

“Working Hypotheses are suggested or supported in some measure by features of observed facts from which consequences may be deduced. Which can be tested by experiment and special observations, and which it is proposed to subject to an extended course of such investigation, with the hope that, even should the hypotheses thus be overthrown, such research may lead to a tenable theory”. (The Century Company Supplement)

In the aim of characterising the real needs of the maritime industry and linking them with the potential advantages and benefits of the STM services, A&E will gather, organise, analyse and evaluate the data produced in the different test-beds. Based on an interactive and continuous dialogue with the rest of the project activities, A&E will serve as the central intelligence repository of the data and indicators that will link with the STM hypotheses and with the objectives set in the project. Including the potential results of implementing the STM Services, the so-called mechanism is to be built upon quantitative and qualitative information gathered from the simulations and test bed results.

With this purpose, each activity has appointed an Information Manager (IM) who facilitates the understanding of their activity with A&E and who helps to sketch the hypotheses of each service. The role of the IM is to be the main point of contact with the activity, that is, a person who deeply knows the activity and can transmit the primary information and the on-going advances, but that also helps in the validation hypotheses processes.
The starting point of the STM Validation Project consisted of several lines of work in which opportunities for improvement were identified with different levels of qualitative and quantitative evidence. Each Activity set up the specifications of the test beds according to the needs of demonstration for each concept, articulating services through the concrete scenarios. The specification and practical disposal of the diverse elements that compose each service, plus the acceptance and practical implication of the different actors of the industry that will be involved in the test beds has been the main strategic line of work for each of the activities, from one to four.

Consequently, in order to be knowledgeable of the potential outputs from each test bed, the methodology used by A&E starts with the mutual sharing of relevant information through meetings with the rest of the activities so that establishing a common understanding on the services, and how they are linked and built together. In addition, the establishment of the type of data that can be gathered in the process is also an important input for A&E. These aspects are crucial to depart from a common and suitable basis towards validate STM as a whole. At this point, the lack of a well-structured baseline scenario can be an issue in terms of having comparable variables during the evaluation.

With the purpose of evaluating the results of the large-scale test beds performed in STM Validation Project, A&E foresees quantitative and qualitative data gathered from the activities:

1. **Quantitative data** - Data that can be quantified and verified, and is amenable to statistical manipulation. In this sense, some Extract, Transform and Load tools (ETL) will be put in place in order to process data from simulations and real life test beds, having in mind the hypotheses to evaluate the data obtained. The use of quantitative data is oriented to enable comparisons with the available maritime industry information (before and after applying the STM Services). The objective is to use these data in the calculation of Key Performance Indicators, Cost-Benefit Analysis and other related studies.

2. **Qualitative data** – Data that approximates or characterises the STM services but does not offer concrete scientific measures of their attributes, characteristics, properties, etc. Qualitative data describes, whereas quantitative data defines.

3. **Mixed data** – Other aspects that are also to be included in the evaluation will be taken over by the sub-activities in A&E that will use tools that could provide both qualitative and quantitative results.

The bigger the measurable quantitative improvement is, the clearer and simpler the decision for adoption will be for the industry. For that reason, it is extremely important to be able to specify quantitative indicators that relate in a clear and direct way to business decision triggers and to present STM as a whole.
4.1.1 Methodology Phases

4.1.1.1 Service Description

The first common set of information shared from the different activities with A&E has been agreed to be based on the concept of Service. Relating information to the Service concept according to their functionalities will ease the organisation of the available information and the deduction of the benefits expected from them. The descriptions of each service developed are listed in the third chapter of this document.

4.1.1.2 Hypotheses Definition

The process of connecting the research phase with the validation phase has been the main aim of the hypotheses definition process. The proposal is based on the views of philosophers as Dewey and Kaplan that hold that the process by which theory and practical inquiry should be more conscientious about why and what is being done.

Following these thoughts, Patricia Shields and Rangarjan (2013) suggested to base initial questions from empirical concerns, and then to find the right tools to explore such questions. They call these tools micro-frameworks. These concepts can help to make the link between the desired achievement, the questions proposed and the methods used.

A working hypothesis is an educated guess or assumption to start research by developing hypotheses and sub-hypotheses that will create some order about the exploratory topics of the research. Since a working hypothesis is usually employed in a new area of research, or with highly complex questions such as those that emerge when trying to integrate a policy intervention, it usually employs qualitative methods such as interviews, focus groups, participatory research, etc.

In the case of STM, the initial lack of measurements for certain kind of facts and the certainty that what is ought to happen will finally happen are essential for the use of hypotheses as a tool to facilitate the research process, despite proven right or wrong.

Interdisciplinary projects tend to bring together existing models and knowledge from diverse fields. In this context, working hypotheses are a useful tool to bring together this knowledge in the form of plausible hypotheses to investigate. There might be very little practical knowledge on a field, but significant theoretical knowledge, or knowledge from similar cases that might be useful. Working hypotheses is a way to bring all that knowledge to play into a very concrete and practical research question.

Therefore, the aim of section 4 is to define the hypotheses within each STM service in order to find the proper methods of research for each that will provide the evidence to conclude that STM is the right concept for the maritime traffic management. This results will bring to light the holistic benefits of it, as for example the improvements in efficiency, the decrease in pollution, the reduction of emissions, the improvements in safety, etc.

4.1.1.3 KPIs definition

Performance measurement is a process whereby the drivers and results of key activities are measured using different types of information. In the case of STM, holistic measure performance from a financial, non-financial, quantitative and qualitative perspective is relevant to the needs of stakeholders and policy makers.
Performance measurement using KPIs is a process that requires substantial planning and effort to achieve a successful outcome, making sure that concepts and definitions are consistent across the project for comparability and general understanding. Past, current or potential future outcomes must be identified and assured by means of the accuracy of data measurements. Once the process is organised, a timely reporting process will be set up to properly support the basis of the project.

A&E must validate the complete KPIs list with the activities and they must commit to provide the data that defines each KPI from the test-beds. Before that, it is important to define the information gathering processes that will be developed and put in place in order to obtain the data from test beds, simulators and the rest of the identified sources.

4.1.1.4 Baseline scenario

Before the test beds are launched with STM implemented tools, a first iteration should be executed in order to collect the actual values of the different KPIs, which will constitute the baseline scenario for the analysis. A baseline scenario of the four simulations should be laid out for this aim as well.

In the cases in which there would not be the possibility to gather such values, the first value obtained for the test bed with STM implemented Services will be collected as the baseline reference. The differentiation between previous scenarios values and STM implemented service values will allow to distinguish properly the net impacts from evolution effects.

4.1.1.5 Data Collection, Processing, Analysis and Evaluation

As a final ambition, all the data will be captured in a database that will gather all the records in a structured way and that will be used to perform the evaluation of STM. The KPIs results should allow to elaborate reports in order to evidence the benefits of STM in a holistic way, the improvements that should be made when objectives are not being met or need to be changed.

Furthermore, this evaluation should be able to determine the quality and robustness of STM focused on continuous improvement, which can be facilitated by tracking the progress of KPIs overtime. Thus, transparency and accountability of the KPIs are crucial because they will allow stakeholders to independently judge STM performance and to be confident that it enables the achievement of their objectives.

The difficulty in data collection should be the variation in the type and format of the data, financial/non-financial, qualitative/quantitative, etc. This will require systems that are able to handle these data challenges and ideally clean the data to ensure its suitability from the outset. Thus, for data collection, data storage and data management it is critical in order to build a valuable database that can hold this key information.

Once the analysis is defined, it has to be reported. A system that can report the information efficiently, engagingly and quickly will gain the attention of users and stakeholders. In this respect, a graphic interface will be developed in order to show the content of the work developed in this process.
4.2 STM Key Performance Areas

In broad terms, the strategic goals and recommendations for the EU’s maritime transport policy until 2018 of the European Commission Communication (2008) refer to two main issues:

- The ability of the maritime transport sector to provide cost-efficient maritime transport services adapted to the needs of sustainable economic growth of the EU and world economies;
- The long-term competitiveness of the EU shipping sector, enhancing its capacity to generate value and employment in the EU, both directly and indirectly, through the whole cluster of maritime industries.

Thus, the Commission proposes an enhanced quality shipping as a key competitive advantage by improving the environmental performance and maritime transport safety.

The analysis of STM concept will be focused on the high visibility Key Performance Areas that are considered essential in European Transport Policies.
4.3 STM Key Performance Objectives

With the aim of focusing the research within the three abovementioned KPA, a group of objectives are defined as follows:

1. **Increase situational awareness** – Situational awareness consisting in increasing the level of knowledge of what is happening around in terms of where you are, where you are supposed to be, and whether anyone or anything around you is a threat to your health and safety.
   - Holistic
   - Inside the port
   - In navigation

2. **Optimise operational procedures** – Operational Procedures consisting of the different methods and ways of developing the core activity of the stakeholder, which represents a variable cost within companies.
   - Inside the port
   - In navigation

3. **Reduce administrative burden** – Administrative burden consisting of low-value procedures based on obsolete information exchange methods (mostly typing/paper-based procedures) which represent a fix cost within companies.
   - For port stakeholders

   - Holistic
   - Between port actors

5. **Reduce the environmental impact of shipping** – consisting in the quantity of fuel Consumption and GHG emissions to cover the navigational routes and port operations. GHG emissions consisting of the amount of gases responsible for global warming (CO₂, CH₄, CO, etc.) and those associated with human health damage (NOₓ, SOₓ) as well as particulate matters (PMₓ) derived from fuel consumption.

   - In ports
   - In navigation

### 4.4 STM Holistic Hypotheses

In the aim of being able to measure the statements of the holistic hypotheses for STM Validation, the project has identified five areas of analysis:

1. Inside the Port Area
2. Outbound Port CDM – Voyage Management Area
3. Voyage Management Area
4. Inbound Voyage Management – Port CDM Area
5. Port to Port Area

---

**Figure 15:** Main areas of analysis considering STM services. Source: Own elaboration
These areas of analysis will help to define the time/space stamps that are being analysed when conducting the test beds in order to have standard references and to compare them rigorously in the several repetitions.

### Efficiency

**KPO: Enhance coordination of berth-to-berth sea transport.**
- Holistic Hypothesis 1: STM will lead to enhance just in time arrivals and departures.
  - Holistic sub-hypothesis 1.1.: STM will lead to enhance the punctuality of arrivals and departures.
  - Holistic sub-hypothesis 1.2.: STM will lead to enhance the predictability of arrivals and departures.
- Holistic Hypothesis 2: STM will lead to improve the planning of traffic.
  - Holistic sub-hypothesis 2.1.: STM will lead to a reduction in traffic congestion / increase traffic fluidity.

**KPO: Improve communication among shipping actors.**
- Holistic Hypothesis 3: STM will lead to enhance interoperability among multiple systems.
  - Holistic sub-hypothesis 3.1.: STM will lead to enable a secure communication between multiple agents in the maritime transport system.
  - Holistic sub-hypothesis 3.2.: STM will enable the coordination between multiple agents in the maritime transport system.
  - Holistic sub-hypothesis 3.3.: STM will lead to avoid double reporting between multiple agents.

*Table 1: Holistic hypotheses included in efficiency key performance area. Source: Own elaboration*

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
</table>
| Efficiency | Enhance coordination of berth-to-berth sea transport | 1 | STM will lead to enhance just in time arrivals and departures | STM will lead to enhance the punctuality of arrivals and departures
| | | | STM will lead to enhance the predictability of arrivals and departures |
| | | 2 | STM will lead to improve the planning of traffic | STM will lead to a reduction in traffic congestion / increase traffic fluidity. |
| Improve communication among shipping actors | 3 | STM will lead to enhance interoperability among multiple systems | STM will lead to enable a secure communication between multiple agents in the maritime transport system. |
| | | | STM will enable the coordination between multiple agents in the maritime transport system |
| | | | STM will lead to avoid double reporting between multiple agents |
1.

KPO: Reduce the environmental impact of shipping

- Holistic Hypothesis 4: STM will lead to the use of right steaming.
  - Holistic sub-hypothesis 4.1.: The optimal speed in port approach will lead to a reduction in total average fuel consumption.
  - Holistic sub-hypothesis 4.2.: The optimal speed in port approach will lead to a reduction in total average of GHG emissions.
  - Holistic sub-hypothesis 4.3.: The optimal fuel consumption in the latter stages of the sea voyage will lead to a reduction in total average fuel consumption.
  - Holistic sub-hypothesis 4.4.: The optimal fuel consumption in the latter stages of the sea voyage will lead to a reduction in total average of GHG emissions.
  - Holistic sub-hypothesis 4.5.: The reduction in the average of anchorage time of a ship will lead to a reduction in total average fuel consumption.
  - Holistic sub-hypothesis 4.6.: The reduction in the average of anchorage time of a ship will lead to a reduction in total average of GHG emissions.
  - Holistic sub-hypothesis 4.7.: STM will lead to a reduction in total average of fuel consumption in the maritime transport system.
  - Holistic sub-hypothesis 4.8.: STM will lead to a reduction in total average of GHG emissions in the maritime transport system.
Table 2: Holistic hypotheses included in environmental sustainability key performance area. Source: Own elaboration

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental sustainability</td>
<td>Reduce the environmental impact of shipping</td>
<td>STM will lead to the use of right steaming</td>
<td>The optimal speed in port approach will lead to a reduction in total average fuel consumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The optimal speed in port approach will lead to a reduction in total average GHG emissions.</td>
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<td></td>
<td>The optimal fuel consumption in the latter stages of the sea voyage will lead to a reduction in total average fuel consumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The optimal fuel consumption in the latter stages of the sea voyage will lead to a reduction in total average GHG emissions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The reduction in the average of anchorage time of a ship will lead to a reduction in total average fuel consumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The reduction in the average of anchorage time of a ship will lead to a reduction in total average GHG emissions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>STM will lead to a reduction in total average of fuel consumption in the maritime transport system</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>STM will lead to a reduction in total average of GHG emissions in the maritime transport system.</td>
</tr>
</tbody>
</table>

2.

KPO: Increase situational awareness

- Holistic Hypothesis 5: STM will lead to increase common situational awareness among all actors in crowded areas
  - Holistic sub-hypothesis 5.1.: STM will lead to safer navigation in crowded areas

Table 3: Holistic hypotheses included in safety key performance area. Source: Own elaboration

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Increase situational awareness</td>
<td>STM will lead to increase common situational awareness among all actors in crowded areas</td>
<td>STM will lead to safer navigation in crowded areas.</td>
</tr>
</tbody>
</table>
4.5 STM Service Oriented Hypotheses

The service-oriented hypotheses are meant to relate the services included in each concept when they have a direct benefit.

4.5.1 Port CDM Hypotheses

KPO: Optimize operational procedures (inside the port).

- Hypothesis 6: Port call optimization will lead to an optimization of operational procedures within a port call:
  - Sub- Hypothesis 6.1.: Port call optimization will lead to a reduction of time in performing operational tasks during a port call.
  - Sub- Hypothesis 6.2.: Port call optimization will lead to an optimal utilization of the available resources during a port call.
  - Sub- Hypothesis 6.3.: Port call optimization will lead to a reduction in workload for the users during a port call.
  - Sub- Hypothesis 6.4.: The standardization and automation of the processes will lead to a decrease human factor impact during a port call.
  - Sub- Hypothesis 6.5.: Port call optimization will lead to reduce turnaround time of the ship.

KPO: Reduce administrative burden (for port stakeholders).

- Hypothesis 7: The availability of digital real-time information will lead to simplify current procedures of different stakeholders concerning internal management tasks.
  - Sub- Hypothesis 7.1.: The availability of digital real-time information will lead to reduce the time employed in administrative tasks for a port call.
  - Sub- Hypothesis 7.2.: The availability of digital real-time information will lead to a reduction in workload for stakeholders involved in a port call.
  - Sub- Hypothesis 7.3.: The availability of digital real-time information will lead to an optimal utilization of the available resources for the management of port calls.
  - Sub- Hypothesis 7.4.: The availability of digital real-time information will lead to a decrease in human factor variables impact.

KPO: Enhance coordination (between port actors) of berth to berth sea transport.

- Hypothesis 8: Port call synchronization will lead to increase just in time operations in ports
  - Sub- Hypothesis 8.1.: Port call synchronization will lead to a more predictable planning for all actors involved in port call operations.
• Hypothesis 9: Port call monitoring will lead to a better planning of traffic in ports
  o Sub-Hypothesis 9.1.: Port call monitoring will lead to decrease traffic congestion in anchorage areas.
  o Sub-Hypothesis 9.2.: Port call monitoring will lead to decrease traffic congestion in port areas.

• Hypothesis 10: Port call improvement will lead to improve invoicing concerning port dues and fees for different services
  o Sub-Hypothesis 10.1.: Port call improvement will lead to better overall service time calculations, improving the invoicing and reducing overhead costs.

KPO: Improve communication among shipping actors (inside the port).

• Hypothesis 11: Port CDM will lead to enhance the communication between the port agent’s systems.
  o Sub-Hypothesis 11.1.: Port CDM will lead to enhance the coordination between the port agents.
  o Sub-Hypothesis 11.2.: Port CDM will lead to reduce the waiting times of the ship in a port call.
  o Sub-Hypothesis 11.3: Port CDM will lead to reduce the waiting times of each agent involved in a port call.
Table 4: Port CDM hypotheses included in efficiency key performance area. Source: Own elaboration

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimize operational procedures (inside the port)</td>
<td>Port call optimization will lead to an optimization of operational procedures within a port call</td>
<td>Port call optimization will lead to a reduction of time in performing operational tasks during a port call.</td>
<td>Port call optimization will lead to an optimal utilization of the available resources during a port call.</td>
</tr>
<tr>
<td></td>
<td>The availability of digital real-time information will lead to simplify current procedures of different stakeholders concerning internal management tasks.</td>
<td>The availability of digital real-time information will lead to a reduction in workload for stakeholders involved in a port call.</td>
<td>The availability of digital real-time information will lead to an optimal utilization of the available resources for the management of port calls.</td>
</tr>
<tr>
<td></td>
<td>Port call synchronization will lead to increase just in time operations in ports</td>
<td>Port call synchronization will lead to a more predictable planning for all actors involved in port call operations.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Port call monitoring will lead to a better planning of traffic in ports</td>
<td>Port call monitoring will lead to decrease traffic congestion in anchorage areas.</td>
<td>Port call monitoring will lead to decrease traffic congestion in port areas.</td>
</tr>
<tr>
<td></td>
<td>Port call improvement will lead to improve invoicing concerning port dues and fees for different services</td>
<td>Port call improvement will lead to better overall service time calculations, improving the invoicing and reducing overhead costs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Port CDM will lead to enhance the communication between the port agent’s systems.</td>
<td>Port CDM will lead to enhance the coordination between the port agents.</td>
<td>Port CDM will lead to reduce the waiting times of the ship in a port call.</td>
</tr>
<tr>
<td></td>
<td>Port CDM will lead to reduce the waiting times of each agent involved in a port call.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

KPO: Reduce the environmental impact of shipping (in ports).
- Hypothesis 12: Port call optimization will lead to a reduction in total average fuel consumption during port calls.
  - Sub- Hypothesis 12.1.: Port call optimization will reduce the average berthing time of a ship that will lead to a reduction in total average fuel consumption in berthing time.
  - Sub- Hypothesis 12.2.: Port call optimization will reduce the total time spent in ports that will lead to a reduction in total average fuel consumption.
- Hypothesis 13: Port call optimization will lead to a reduction in total average of GHG emissions during port calls.
  - Sub- Hypothesis 13.1.: Port call optimization will reduce the average berthing time of a ship that will lead to a reduction in total average of GHG emissions.
  - Sub- Hypothesis 13.2.: Port call optimization will reduce the total time spent in ports that will lead to a reduction in total average of GHG emissions.

*Table 5: Port CDM hypotheses included in environmental sustainability key performance area. Source: Own elaboration*

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>12</strong></td>
<td>Port call optimization will reduce the average berthing time of a ship that will lead to a reduction in total average fuel consumption in berthing time</td>
</tr>
<tr>
<td>Environmental Sustainability</td>
<td>Reduce the environmental impact of shipping (in ports)</td>
<td><strong>13</strong></td>
<td>Port call optimization will reduce the total time spent in ports that will lead to a reduction in total average fuel consumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>13</strong></td>
<td>Port call optimization will reduce the average berthing time of a ship that will lead to a reduction in total average fuel consumption in berthing time</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>13</strong></td>
<td>Port call optimization will reduce the total time spent in ports that will lead to a reduction in total average of GHG emissions</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>13</strong></td>
<td>Port call optimization will reduce the total time spent in ports that will lead to a reduction in total average of GHG emissions</td>
</tr>
</tbody>
</table>

**KPO: Increase situational awareness (inside the port).**

- Hypothesis 14: Port call monitoring will lead to increase situational awareness.
  - Sub- Hypothesis 14.1.: Port call monitoring will lead to increase safety in port areas.
Table 6: Port CDM hypotheses included in safety key performance area. Source: Own elaboration

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Increase situational awareness (inside the port)</td>
<td>14 Port call monitoring will lead to increase situational awareness</td>
<td>Port call monitoring will lead to increase safety in port areas</td>
</tr>
</tbody>
</table>

4.5.2 Voyage Management Hypotheses

KPO: Optimize operational procedures (in navigation)

- Hypothesis 15: Route exchange ship to ship will lead to an optimization of operational procedures in ships.
  - Sub- Hypothesis 15.1.: Route exchange ship to ship will lead to a reduction in workload for the users during navigation.
  - Sub- Hypothesis 15.2.: Route exchange ship to ship will lead to the reduction of ships detours.

- Hypothesis 16: Enhanced monitoring (with improved tools) will lead to an optimization of operational procedures in shore centres.
  - Sub- Hypothesis 16.1.: Enhanced monitoring will lead to increased utilization of the available resources (operator) in shore centres.

- Hypothesis 17: Area Management will lead to an optimization of operational procedures on board.
  - Sub- Hypothesis 17.1.: Area Management will lead to a reduction of time in performing operational tasks during navigation.
  - Sub- Hypothesis 17.2.: Area Management will lead to decrease misunderstandings/mistakes during the route planning.

- Hypothesis 18: SAR Services will lead to an optimization of operational procedures on board ships involved in SAR operations.
  - Sub- Hypothesis 18.1.: SAR Services will lead to a reduction of time to start the SAR operation after notification.
  - Sub- Hypothesis 18.2.: SAR Services will lead to a better utilization of SAR units in a search area.
  - Sub- Hypothesis 18.3.: SAR Services will lead to less misunderstanding during navigation (better compliance with the Search plan).
- Hypothesis 19: Winter navigation will lead to an optimization of operational procedures on board.
  - Sub-Hypothesis 19.1.: Winter navigation will lead to a reduction of planning time onboard.
  - Sub-Hypothesis 19.2.: Winter navigation will lead to less stuck ships due to better understanding of the direction routes.
  - Sub-Hypothesis 19.3.: Winter navigation will lead to less fuel consumption (IB) when fewer ships are stuck.

*Table 7: Voyage Management hypotheses included in efficiency key performance area. Source: Own elaboration*

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Route exchange ship to ship will lead to an optimization of operational procedures on board</td>
<td>Route exchange ship to ship will lead to a reduction in workload for the users during navigation</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Enhanced monitoring will (with improved tools) lead to an optimization of operational procedures in shore centers</td>
<td>Enhanced monitoring will lead to increased utilization of the available resources (operator) in shore centers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area Management will lead to an optimization of operational procedures on board</td>
<td>Area Management will lead to a reduction of time in performing operational tasks during navigation</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>SAR Services will lead to an optimization of operational procedures on board ships involved in SAR operations</td>
<td>SAR Services will lead to a reduction of time to start the SAR operation after notification</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>Winter navigation will lead to an optimization of operational procedures on board</td>
<td>Winter navigation will lead to a reduction of planning time on board</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Winter navigation will lead to less stuck ships due to better understanding of the direction routes</td>
<td>Winter navigation will lead to less stuck ships due to better understanding of the direction routes</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Winter navigation will lead to less fuel consumption (IB) when less ships get stuck</td>
<td>Winter navigation will lead to less fuel consumption (IB) when less ships get stuck</td>
</tr>
</tbody>
</table>
**Environmental Sustainability**

**KPO: Reduce the environmental impact of shipping (in navigation).**

- Hypothesis 20: Area Management will lead to facilitate just in time visibility of the environmentally sensitive/no-go areas on board.
  - Sub-Hypothesis 20.1.: Area Management will lead to decrease the violation of environmentally sensitive areas.
  - Sub-Hypothesis 20.2.: Area Management will reduce the transgressions (crossing) of no-go areas.

**Table 8: Voyage Management hypotheses included in environmental sustainability key performance area. Source: Own elaboration**

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Sustainability</td>
<td>Reduce the environmental impact of shipping (in navigation)</td>
<td>20</td>
<td>Area Management will lead to decrease the violation of environmentally sensitive areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Area Management will reduce the transgressions (crossing) of no-go areas.</td>
</tr>
</tbody>
</table>

**Safety**

**KPO: Increase situational awareness (in navigation).**

- Hypothesis 21: Enhanced monitoring will lead to increase situational awareness for the shore centres/for ships in monitored areas.
  - Sub- Hypothesis 21.1.: Enhanced monitoring will lead to a reduction of close quarter situations by shore centres intervention.
  - Sub- Hypothesis 21.2.: Enhanced monitoring will lead to an early detection of deviation. (SC)
  - Sub- Hypothesis 21.3.: Enhanced monitoring will lead to a reduction of probability of incidents/accidents.

- Hypothesis 22: Route exchange Ship to ship will lead to increase situational awareness on board the ships.
  - Sub- Hypothesis 22.1.: Route exchange Ship to ship will lead to a decreased collision causation probability.
  - Sub- Hypothesis 22.2.: Route exchange Ship to ship will lead to less crossing collision-encounter candidates.
- Hypothesis 23: SAR services will lead to increase situational awareness on board the involved ships.
  - Sub-Hypothesis 23.1.: SAR Services will lead to a reduction of time to start the SAR after notification.
  - Sub-Hypothesis 23.2.: SAR Services will lead to a better utilization of SAR units in a search area.
  - Sub-Hypothesis 23.3.: SAR Services will lead to less misunderstanding during navigation (better compliance with the Search plan).
  - Sub-Hypothesis 23.4.: SAR services will lead to a reduction of misunderstandings between the participant ships.

- Hypothesis 24: ERNAS will lead to increase use of pilotage services on-line.
  - Sub-Hypothesis 24.1.: ERNAS will provide a sufficient level of situational awareness, for assisting ships from shore.

- Hypothesis 25: Route Cross-check will lead to safer routes through more information provided onboard.
  - Sub-Hypothesis 25.1.: Route Cross-check will lead to less grounding causation probability (no-go areas, air draught).
Table 9: Voyage Management hypotheses included in safety key performance area.
Source: Own elaboration

<table>
<thead>
<tr>
<th>KPA</th>
<th>KPO</th>
<th>HYPOTHESIS</th>
<th>SUB-HYPOTHESES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Enhanced monitoring will lead to increase situational awareness for the shore centers and for ships in monitored areas</td>
<td>Enhanced monitoring will lead to a reduction of close quarter situations by shore centers intervention</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Route exchange Ship to ship will lead to increase situational awareness on board the ships</td>
<td>Route exchange Ship to ship will lead to a decreased collision causation probability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAR services will lead to increase situational awareness on board the involved ships</td>
<td>SAR Services will lead to a reduction of time to start the SAR after notification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ERNAS will lead to increase use of pilotage services on-line</td>
<td>ERNAS will provide a sufficient level of situational awareness, for assisting ships from shore</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Route cross check will lead to safer routes through more information provided on board</td>
<td>Route cross check will lead to less grounding causation probability (no-go areas, air draught)</td>
</tr>
</tbody>
</table>
4.6 Entity-Relationship Model

In the aim of linking the resulting hypotheses model with the data collected and the means to demonstrate their statements, an entity-relationship model has been created in order to provide a database structure for the suitable utilization of the information during the evaluation of STM.

The primary objective of this model is to provide an architecture that will allow the interaction between the different elements involved and that will describe the aspects needed to validate within the hypotheses statements. Hence, the ultimate objective of the translation from a theoretical model to a database model is to connect the data with the defined hypotheses as showed in the following figure:

*Figure 16: Hypotheses´ Entity-relationship model. Source: Own elaboration*
5 Information Environment Sources

![Diagram: STM information environment sources layer. Source: Own elaboration.]

5.1 STM Test-Beds

As specified in the information environment scheme, STM concept will be validated and tested using several information sources from different natures and origins that consist on:

- **STM Test Beds:**
  - PortCDM implementation guidelines have been initiated in eight European ports and it is foreseen to be extended to five more until the end of the project. Some of the data produced by these ports will be provided for the holistic analysis.
  - STM has assigned four leading ECDIS suppliers to provide 300 STM-compliant on-board systems by the launch of a public procurement to further test the interoperability between various systems and providers. Those interactions will deliver quantitative and qualitative data for analysis.
  - Shore services are being developed within some shore centres that will be able to interact with STM compliant ships navigating in their area of influence and that will produce qualitative and quantitative data for the analysis.

- **EMSN simulations** that, by the setting of four different simulation scenarios will test the use of the new services’ functionalities in almost 30 simulated ship bridges to validate and test them in a plausible while controlled environment.

- Other information sources such as the research on legal, business, operational, safety and training perspectives will provide a common framework of understanding of the consequences and limitations of the use of those services in a real context.

The project will foster berth-to-berth validation analysis using special cases in where the ships are regularly calling at STM ports. In order to monitor the key use cases, A&E has made a previous analysis of the test-beds current situation.
5.1.1 Test Beds Current Situation

At this stage, a compilation of data from the ships and the ports included in STM has been made by monitoring the ships included in the test-beds. The data is extracted from the tracking of the 272 STM vessels recruited until June 2017, in order to provide a baseline scenario and to explore the wide variety of possibilities of analyses for the validation of STM concept.

The monitoring period starts on the 10th of March until the 8th of June 2017 and sets the focus on matching the ships calling at Port CDM ports during this period. This analysis allows the extraction of some preliminary conclusions and makes possible the foundation of an evaluation strategy.

![Figure 18: Global position of STM Ships on the 12th June 2017 (272 confirmed ships). Source: marinetraffic](image)

*Figure 18* is showing a static picture of the global position of STM ships on a determined moment. As it can be observed, most of the ships are operating in European waters but some of them are navigating in other areas and, when looking into the data, they do not call at any European ports neither at Port CDM ports.

In the aim of making a closer examination of STM fleet configuration, they have been classified per type of service, categorizing the term “service” into four concepts: regular services, tramp services, cruise services and other services (as nautical services ships). *Figure 19* shows the mentioned classification excluding the 28 Search and Rescue ships foreseen to complete the amount of 300 ships soon in order to have STM’s target fleet completed.
Figure 19: No. of ships per type of services on an amount of 272 confirmed ships. Source: Own elaboration

STM Test Beds - 272 Ships

Figure 20: No. of ships both per type of services and per type of ship. Source: Own elaboration
Considering the distribution among STM target fleet, it is observed in Figure 20 that 47% of the ships are operating tramp services; 46% are operating regular services, while only 5% are operating cruise services. Regarding the different services, also in Figure 20 there is a categorization on the type of vessel included in each service:

According to the recruited ships, further detailed information on shipping operators is provided in the table below. Hence, the ensemble of ships belonging to MSC and Arklow Shipping represent 25% of the ships included in the test beds, whilst Wallenius Marine and Nordic Tankers Trading provide 6% respectively.

As a result, 11 different shipping operators (171 ships in total) are providing 63% of the STM total fleet. This information is extremely important in order to channel the efforts on the main ship-owners that should become the prioritised partners within the STM project. The validation plan should take these agents into account, monitor their reactions facing the new systems and study the way that it impacts on their business model.

Table 10: Ranking of shipping operators per number of ships and Average percentage of the total STM fleet (out of 272). Source: Own elaboration

<table>
<thead>
<tr>
<th>OPERATOR</th>
<th>NO. SHIPS</th>
<th>% TOTAL STM FLEET (OF 272)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEDITERRANEAN SHIPPING COMPANY</td>
<td>50</td>
<td>18%</td>
</tr>
<tr>
<td>ARKLOW SHIPPING</td>
<td>20</td>
<td>7%</td>
</tr>
<tr>
<td>WALLENIUS MARINE</td>
<td>17</td>
<td>6%</td>
</tr>
<tr>
<td>NORDIC TANKERS TRADING A/S</td>
<td>15</td>
<td>6%</td>
</tr>
<tr>
<td>NORLED AS</td>
<td>13</td>
<td>5%</td>
</tr>
<tr>
<td>ANCORA INVESTMENT</td>
<td>11</td>
<td>4%</td>
</tr>
<tr>
<td>ERIK THUN AB</td>
<td>10</td>
<td>4%</td>
</tr>
<tr>
<td>HERNING SHIPPING A/S</td>
<td>10</td>
<td>4%</td>
</tr>
<tr>
<td>STENA LINE SCANDINAVIA AB</td>
<td>9</td>
<td>3%</td>
</tr>
<tr>
<td>AIDA CRUISES</td>
<td>8</td>
<td>3%</td>
</tr>
<tr>
<td>J. LAURITZEN A/S</td>
<td>8</td>
<td>3%</td>
</tr>
</tbody>
</table>

From a ship perspective, a characterization considering the average speed on the fleet has been depicted in Table 11. The average speed for regular and cruise services is set at 21.3 knots, while the average speed for tramp services is 13.5 knots, resulting in the highest speed for passenger vessels and the lowest for tug services.

These considerations should be taken into account when analysing the adjustments in speed for the achievement of concepts as the right steaming or the just-in-time arrival and departure concept, among others.
Table 11: Average service speed (in knots) per type of ship and per type of service. 
Source: Own elaboration

<table>
<thead>
<tr>
<th>TYPE OF SHIP</th>
<th>NO. OF SHIPS</th>
<th>AVERAGE SERVICE SPEED (KNOTS)</th>
<th>AVERAGE SPEED PER TYPE OF SERVICE (KNOTS)</th>
<th>TYPE OF SERVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAX</td>
<td>15</td>
<td>31.3</td>
<td>21.3</td>
<td>Regular services</td>
</tr>
<tr>
<td>CONTAINERSHIP</td>
<td>53</td>
<td>21.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAR CARRIER</td>
<td>24</td>
<td>19.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO-PAX</td>
<td>15</td>
<td>19.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RO-RO</td>
<td>16</td>
<td>19.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSC</td>
<td>2</td>
<td>16.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRUISE</td>
<td>13</td>
<td>21.3</td>
<td>21.3</td>
<td>Cruise services</td>
</tr>
<tr>
<td>CRUDE/OIL PRODUCTS TANKER</td>
<td>2</td>
<td>14.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPG TANKER</td>
<td>12</td>
<td>14.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OIL/Chemical TANKER</td>
<td>11</td>
<td>14.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BULK CARRIER</td>
<td>2</td>
<td>14.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRODUCT TANKER</td>
<td>2</td>
<td>14.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical/Products TANKER</td>
<td>64</td>
<td>13.7</td>
<td>13.5</td>
<td>Tramp services</td>
</tr>
<tr>
<td>CHEMICAL TANKER</td>
<td>2</td>
<td>13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GENERAL CARGO</td>
<td>28</td>
<td>11.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEMENT CARRIER</td>
<td>5</td>
<td>10.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INSPECTION SHIP</td>
<td>1</td>
<td>15.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPECIAL PURPOSE</td>
<td>1</td>
<td>12.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUPPLY VESSEL</td>
<td>1</td>
<td>12.0</td>
<td>8</td>
<td>Other services</td>
</tr>
<tr>
<td>TUG</td>
<td>2</td>
<td>5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARTICULATED PUSHER TUG</td>
<td>1</td>
<td>NC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regarding the holistic analysis, the existence of STM ships calling at STM ports become essential, in order to have the means to analyse the round process of navigation. Therefore, for the already mentioned period, this parameter has been chosen and some results are shown as follows:

Figure 21: Number of different STM ships calling at STM ports. Source: Own elaboration
The figures in the squares above represent the number of different STM ships calling at STM ports. Gothenburg is on the top of the list, with 43 different ships calling in this period, which is followed by Bergen with 26 ships. The port of Barcelona has hosted 23 STM ships and in the same range, it can be found Stavanger (including Tananger and Mekjarvik), and Valencia with 22 ships.

The importance of STM ships calling regularly at these ports needs to be stressed. The focus on berth-to-berth analyses need to take into account all kind of information like the type of ship and the type of service because of the specific characteristics of the voyages to be analysed. With this objective, further analyses on the details of the ships calling at STM ports have been made in the following figures.

*Figure 22* represents a breakdown among STM ships per port in the Mediterranean Testbed, showing additional information about the type of vessel calling at each port. The predominant type of ship is the containership, mainly calling at the ports of Valencia, Venice and Barcelona. There is a strong influence of cruises in this region, which sum up approximately 20 units among the different ports. Car carrier ships supplement the figures and provide a starting point to identify the potential traffics to be further analysed during the project.

In *Figure 23*, a number of different ships calling at STM port in the Nordic test bed is shown. Tramp services dominate the list of ships calling at the Swedish and Norwegian ports. They do not have a stable itinerary and move cargo from export areas to import areas. This type of traffic tends to meet market demands and flows of raw materials and commodities for industries and population as final consumer.
Figure 22: Number of different ships calling at STM ports per type of Ship (Mediterranean Testbed). Source: Own elaboration
As the figure below illustrates, 133 out of 272 ships are calling at least in one STM port and 62 are calling in more than 2 ports. Only four ships are calling equally in both test beds (3 cruises and 1 car carrier).

In the holistic context, the importance of the number of ships calling at two STM ports or more should be stressed in order to provide a deeper analysis of STM concept impact in shipping.

<table>
<thead>
<tr>
<th>NORDIC TEST BEDS</th>
<th>MEDITERRANEAN TEST BEDS</th>
<th>BOTH TEST BEDS</th>
<th>TOTAL STM</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Of ships calling at least in one STM port</td>
<td>77</td>
<td>52</td>
<td>4</td>
</tr>
<tr>
<td>No. Of ships calling at two STM ports or more</td>
<td>29</td>
<td>29</td>
<td>4</td>
</tr>
</tbody>
</table>

To conclude, a table summarising the ships per type of vessel and number of port CDM ports calls is outlined in Figure 25. This information can be useful when needing to pick up a significant use case that could provide the maximum level of data from all the points of study: port call and navigation.
**Figure 25:** List of STM ships calling at more than two STM ports per type of ship.

*Source: Own elaboration*

<table>
<thead>
<tr>
<th>IMO No.</th>
<th>VESSEL NAME</th>
<th>TYPE OF VESSEL</th>
<th>TOTAL PORTCDM PORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8512891</td>
<td>MSC AUGUSTA</td>
<td>CONTAINERSHIP</td>
<td>6</td>
</tr>
<tr>
<td>910699</td>
<td>MEIN SCHIFF 1</td>
<td>CRUISE</td>
<td>5</td>
</tr>
<tr>
<td>932991</td>
<td>MARINUS</td>
<td>CHEMICAL TANKER</td>
<td></td>
</tr>
<tr>
<td>975908</td>
<td>TERNSUND</td>
<td>CHEMICAL/PRODUCTS TANKER</td>
<td>5</td>
</tr>
<tr>
<td>974071</td>
<td>TERN SEA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>911911</td>
<td>AIDASTELLA</td>
<td>CRUISE</td>
<td></td>
</tr>
<tr>
<td>926634</td>
<td>MEIN SCHIFF 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>931789</td>
<td>MSC CHANNE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>915261</td>
<td>MSC CLEA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>916111</td>
<td>AIDACARA</td>
<td>CRUISE</td>
<td></td>
</tr>
<tr>
<td>972158</td>
<td>AIDAVITA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>933488</td>
<td>AIDALUNA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>931760</td>
<td>MEIN SCHIFF 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>933808</td>
<td>TERNHOLM</td>
<td>OIL/CHEMICAL TANKER</td>
<td>4</td>
</tr>
<tr>
<td>977469</td>
<td>IRELAND</td>
<td>CEMENT CARRIER</td>
<td></td>
</tr>
<tr>
<td>919399</td>
<td>TARNDAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>916760</td>
<td>TARNFORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>929312</td>
<td>TERNHAV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>972241</td>
<td>TERNFJORD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>936342</td>
<td>MSC SHAULA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>911101</td>
<td>MSC DYMPHNA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>931129</td>
<td>E.R.PUSAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>979406</td>
<td>MSC LETZIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>970495</td>
<td>MSC JUJE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>970500</td>
<td>MSC CATERINA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>956008</td>
<td>COSTA DIADEMA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>975319</td>
<td>MEIN SCHIFF 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>932108</td>
<td>BERGEN STAR</td>
<td>PRODUCT TANKER</td>
<td></td>
</tr>
<tr>
<td>936666</td>
<td>STAVANGERSFJORD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>996681</td>
<td>BERGENSFJORD</td>
<td>RO-PAX</td>
<td></td>
</tr>
<tr>
<td>917972</td>
<td>MANON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>948332</td>
<td>MSC CRISTIANA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>946329</td>
<td>MSC IMMACOLATA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>916614</td>
<td>ASTORIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>927267</td>
<td>TERNVIK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>936237</td>
<td>RAMIRA</td>
<td>CHEMICAL/PRODUCTS TANKER</td>
<td>4</td>
</tr>
<tr>
<td>937181</td>
<td>ASTRAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>951051</td>
<td>NEPTUNUS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>974798</td>
<td>TERN OCEAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>952139</td>
<td>MSC FLORIANA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>900423</td>
<td>MSC ESHA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>908049</td>
<td>MSC MONICA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>908401</td>
<td>MSC NITA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>920194</td>
<td>MSC DON GIOVANNI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>924049</td>
<td>MSC SHIRLEY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>924043</td>
<td>MSC RHIANNON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>923741</td>
<td>MSC DONATA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>925088</td>
<td>MSC DAMLA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>928259</td>
<td>MSC ELA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>928258</td>
<td>MSC ANS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>931639</td>
<td>MSC HANNAH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>970207</td>
<td>MSC MELINE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>933485</td>
<td>AIDADIVA</td>
<td>CRUISE</td>
<td></td>
</tr>
<tr>
<td>936242</td>
<td>AIDABELLA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>949001</td>
<td>AIDASOL</td>
<td>GENERAL CARGO</td>
<td></td>
</tr>
<tr>
<td>947719</td>
<td>ALICE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>947194</td>
<td>HELGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>972160</td>
<td>SYMPHONY SEA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>972186</td>
<td>RAMONA</td>
<td>OIL/CHEMICAL TANKER</td>
<td>4</td>
</tr>
<tr>
<td>913206</td>
<td>ASTINA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>918338</td>
<td>FJORDDROTT</td>
<td>PAX</td>
<td></td>
</tr>
<tr>
<td>911720</td>
<td>TIDELYN</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.1.2 STM Ports

From the point of view of Port CDM, the main objective is to demonstrate the effects of Port CDM services implementation in the ports included in the test beds. The different iterations of the analysis will foster the refinement of the Port CDM concept based on the experiences lived. Port CDM services are focused on the synchronisation, optimisation, monitoring and improvement of port calls. Hence, the establishment of a better overview of how to improve the overall port call processes in the studied ports will be a final objective within these developments.

As a key aspect of the process, there is the collection of the current procedures performed by the main port actors involved in a port call such as pilotage, mooring, and towage to check how their procedures are improved by the increased common situational awareness. The just-in-time concept in port operations is one of the key Port CDM hypotheses that must be demonstrated throughout this test-bed.

Port CDM should provide accurate data of duration times and resources utilisation during port calls. Statistics will be gathered for the analysis and confidentially treated within STM validation team.

Figure 26: Overview of the ports included in STM test beds. Source: Own elaboration
For the settlement of a baseline scenario for analysis in ports, A&E will produce a summary sheet of each port included in Port CDM test beds. These sheets will contain relevant information about each port such as GPS location, country, type of cargo, accurate information about port services (towage, pilotage, etc.), terminal characteristics, etc... This information will help to understand the dimension, the type and the facilities of each port and will offer support for the analysis of the benefits of Port CDM in the test beds.

Figure 27: Port data sheet sample. Source: Own elaboration
5.1.2.1 Data collection in Ports

The overall scheme about information flows in a port using Port CDM architecture is depicted in Figure 28. The actors involved in a port call transmit the information related to their operations to the Port CDM platform. The `port call finder´ gathers and validates the data, generating a text line in which the information of the port call is collected and stored. The `message broker´ deals with the information sharing with the corresponding actors according to previous authorization, validation and authentication requirements.

![Diagram](image)

Figure 28: Information flows in Port CDM and specific zoom on Analytics for A&E activity. Source: Own elaboration

Duration times:

A focus on duration times forms the basis for making calculations about service times and waiting times for different actors during the port call. Paying attention towards the duration time of the port visit could help satisfying a shipping company needs on the following factors: fast turnaround, just-in-time operations and minimal waiting times.

The main purpose of the analytical service “duration time” provided by Port CDM is to enable the calculation of the time spent on the port visit divided into the different Port CDM process time types. Thus, the duration time (Total Turnaround Time) is the total time spent on the port visit comprising the following port call process times depicted in the following figure:

- Movement Time
- Nautical Service Time
- Stationary Service Time
- Anchoring Time
- Berth Visit Duration Time
- Additional Service Time
- Waiting Time

Figure 29: Port call process time to calculate stages durations. Source: Own elaboration
Based on the PCMF, the identification of the services mentioned in the port call process duration are the following:

*Table 12: Identification of possible services in a port call. Source: STM project*

<table>
<thead>
<tr>
<th>Services Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Services:</td>
</tr>
<tr>
<td>Stationary Services:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

A focus on the duration time is aimed both to inform actors about the amount of time spent on different operations for port calls in the different stages of the turnaround process as a basis to optimise port calls following three dimensions:

- A particular port call (estimates and actuals) divided into the different processes times.
- For different types of port calls sorted by vessel type divided into the different processes times.
- For a desired aggregation, such as for a selected time span, the latest X port calls, (presented as sums, trends and/or correlations) divided into the different processes times.

In order to determine duration times, several different time types are being used as stated in *Table 13. According to these calculations described by Port CDM, the validation is enabled via Port CDM services and the effects are studied based the data extracted from them and the aggregation of it.*
<table>
<thead>
<tr>
<th>Port CDM process times</th>
<th>Methods of calculation</th>
</tr>
</thead>
</table>
| **Arrival Vessel Traffic Area** | The time between the instances of Arrival_Vessel_TrafficArea and Arrival_Vessel_Berth (if applicable)  
The time between the instances of Arrival_Vessel_TrafficArea and Arrival_Vessel_AnchorageArea plus (if applicable)  
The time between the instances of Departure_Vessel_AnchorageArea and Arrival_Vessel_AnchorageArea (if applicable)  
The time between the instances of Departure_Vessel_AnchorageArea and Arrival_Vessel_AnchorageArea plus (if applicable)  
The time between the instances of Departure_Vessel_Berth and Arrival_Vessel_Berth plus (if applicable)  
The time between the instances of Departure_Vessel_Berth and Arrival_Vessel_AnchorageArea plus (if applicable)  
The time between the instances of Departure_Vessel_Berth and Departure_Vessel_TrafficArea plus (if applicable)  
The time between the instances of Departure_Vessel_AnchorageArea and Departure_Vessel_TrafficArea plus (if applicable) |
| **Movement time** | The time between the instances of Arrival_Vessel_AnchorageArea and Departure_Vessel_AnchorageArea |
| **Anchoring time** | The time between the instances of Arrival_Vessel_AnchorageArea and Departure_Vessel_AnchorageArea  
The time between the instances of Arrival_Vessel_Berth and Departure_Vessel_Berth  
The first time of (NauticalServiceObjectX).commenced and the last time of (NauticalServiceObjectY).completed (where X and Y could be the same or different NauticalServiceObject)  
The first time of (StationaryServiceObjectX).commenced and the last time of (StationaryServiceObjectY).completed (where X and Y could be the same or different StationaryServiceObject)  
The first time of [AdditionalServiceObjectX].commenced and the last time of [AdditionalServiceObjectY].completed (where X and Y could be the same or different AdditionalServiceObject). |
| **Duration time** (estimated, calculated, actual) | The first time of [StationaryServiceObject].completed and another [StationaryServiceObject].commenced when at berth/anchorage  
The time by taking the instances of berth visit(s) and anchorage(s) of the time between [StationaryServiceObject].completed and Departure_Vessel_AnchorageArea/Departure_Vessel_Berth (when no more service is to occur within berth visit or anchorage)  
The time by taking the instances of berth visit(s) and anchorage(s) of the time between [StationaryServiceObject].completed and Departure_Vessel_AnchorageArea/Departure_Vessel_Berth (when no more service is to occur within berth visit or anchorage)  
The time by taking the instances of berth visit(s) and anchorage(s) of the time between [StationaryServiceObject].completed and Departure_Vessel_AnchorageArea/Departure_Vessel_Berth (when no more service is to occur within berth visit or anchorage)  
The time by taking the instances of berth visit(s) and anchorage(s) of the time between [StationaryServiceObject].completed and Departure_Vessel_AnchorageArea/Departure_Vessel_Berth (when no more service is to occur within berth visit or anchorage)  
The time by taking the instances of berth visit(s) and anchorage(s) of the time between [StationaryServiceObject].completed and Departure_Vessel_AnchorageArea/Departure_Vessel_Berth (when no more service is to occur within berth visit or anchorage)  
The time by taking the instances of berth visit(s) and anchorage(s) of the time between [StationaryServiceObject].completed and Departure_Vessel_AnchorageArea/Departure_Vessel_Berth (when no more service is to occur within berth visit or anchorage)  
The time by taking the instances of berth visit(s) and anchorage(s) of the time between [StationaryServiceObject].completed and Departure_Vessel_AnchorageArea/Departure_Vessel_Berth (when no more service is to occur within berth visit or anchorage) |

Table 13: Port CDM Process time Methods of calculation. Source: Own Elaboration
5.1.3 STM Ships

From the point of view of navigation, after the procurements launched based on the STM functionalities required specification, the providers are developing the main Voyage Management services that will be implemented for validation in the test beds.

STM compliant ships will exchange information using RTZ message format and AIS systems with STM ports and shore centres. The first route exchange format (RTZ 1.0) was published in Annex (S&T) of the ECDIS test standard IEC61174:2015 in August 2015. The RTZ format is now updated to version 1.1. In the STM Validation Project, the participants will use RTZ 1.1 with an STM extension.

Since the STM Project defined a need of a number of new attributes that was not covered in the Annex S, it was agreed with IEC and CIRM that those attributes could be included as extensions to the standard (see: Guidelines for the use of RTZ format).

In the case of ship-to-shore communication, the route exchange format is too large to be transmitted over AIS application specific message (ASM). However, the current development of VDES (VHF Data Exchange System) will provide an excellent communication channel for STM services to complement internet connection.

Figure 31 represents the implementation process of both procurements since the beginning of the project. Four manufacturers have been selected by the leading organisation that previously set the functionalities requirements to install the STM module in the recruited ships among the fleet disposed by their clients: the ship-owners.

Not only the number of ships provided by each manufacturer is shown in this figure, but also the specific type of ships recruited by each one and the timeline scenario of STM module implementation for each procurement during the rest of the project. This information is essential to show the quantity of data that is going to be delivered in the different phases of the test bed and to remark that each manufacturer will provide different data and possibly in different formats.

At the end, there will be available data from 300 ships with STM module installed. These ships are being characterised by A&E and a summary sheet of each one will be produced. These sheets will contain relevant information about each ship such as the size, the engine power, the fuel consumption, the year of build, the flag…etc. The confidentiality of this information is pending to be confirmed.
Figure 30: Ship data sheet. Source: Own elaboration
Figure 31: Implementation timeline in Voyage Management test bed according to procurements. Source: Own elaboration
5.1.3.1 Data collection in Ships

The data foreseen to be collected from the ships in the test beds will be provided by three means:

- The log in VIS (Voyage Information Service).
- The log in SPIS (Ship-Port Information Service).
- AIS data.

**VIS: VOYAGE INFORMATION SERVICE**

Voyage Management services communications have been built based on Voyage Information Service (VIS) requirements. The main purpose with VIS is to handle the communication around voyage information and the main artefact Voyage Plan (VP) in RTZ format. VIS implements methods to expose new and updated VP’s and to consume external VP’s. VIS also supports subscription of voyage plans. In addition to voyage plans (RTZ), VIS also supports the exchange of the STM Text Message and area message (S124). In the figure below, a sequence example of the information flows between the actors in the exchange of voyage plans is described:

*Figure 32: VIS Sequence Example. Source: STM Project*

This service design is realised using REST (Representational State Transfer). REST is an architectural style, and an approach to communications that are often used in the development of Web services. The use of REST in VIS is preferred over the more heavyweight SOAP (Simple Object Access Protocol) style because REST does not leverage as much bandwidth, which makes it a better fit for use in communication between vessels and shore based representation of the same.
In this VIS project design figure, a double sense scheme of VIS is presented, both on public and private sides. On the left hand, the VIS between the ship and the manufacturer is located in a private REST, which means that the data is under the manufacturer’s control and it may not be provided to the project for A&E.

If a shipping company agrees to transmit the voyage plans of their ships included in the STM test-beds through the SeaSWIM architecture, then these data will be directly available for analysis and Evaluation. The information flow processes have not been agreed today with the ship-owners included by the procurers.

VIS logs raw data exchanged between two services will need to be aggregated and messaged to meet KPIs. KPIs needs to be decomposed to meet measurements, post-preparation of logs and callService requests needs to be further extracted to get the RTZ exchanged.

**SPIS: SHIP-PORT INFORMATION SERVICE**

The main purpose of Ship-Port Information Service (SPIS) is to support the ship system with communication with Port CDM services in port. The service may be integrated into the on-board system or at shore, depending on the situation. The main functionality of the service is to send updates on times at locations (e.g. PTA/TTA, ETA, and ATA) and receive recommendations. The purpose is to support a collaborative decision-making process with the port. The diagram below shows the primary use case for the STM Validation project’s voyage management validation.
The Ship-Port Information Service has one private service side towards the inside application (such as STM Module), and one exposed service side on SeaSWIM. The Ship-Port Information Service is dependent on a SeaSWIM Connector that supports with SeaSWIM specific functionality for authentication and supports with service and identity lookup in Service and Identity Registry. The Ship-Port Information Service consumes the Port CDM services for exchanging port call messages in the Port Call Message format.

Some of the data foreseen to be extracted from these logs are the following:

Exchange of RTZ+TXT+S124 Related To a Unique Voyage ID (UVID)

- **Statistics:**
  - How many voyages per month?
  - How many voyages per ship per month?
  - How many updates of RTZ (from ship) per voyage?
  - How many route proposals were received onboard per voyage?
  - How many exchanges of TXT per voyage?

- **to ship – from ship:**
  - How many exchanges of TXT per ship?

- **to ship – from ship:**
  - How many receptions of S124 per ship.
  - How many interested parties is voyage planned shared with per voyage?
  - How many shares with enhanced monitoring service providers?
  - How many requests for route optimisation?
  - How many requests for route Cross-check?
  - How many requests for pilot routes?
  - How many requests for ice routes?
• WHO -- Interested parties.
• WHEN – Timeliness.
• WHAT – Type of information?
• WHY – Type of service.

Data collected for Further Analysis

• Calculate time/length of route.
• Calculate difference in time/length between originally planned voyage and final voyage (after route optimisation and safety check).
• Identify outliers.
• Identify occasions to further analysis.
• Where two ships cross routes within a certain time?
• Where ship re-plans the voyage?
• Where a ship is within or close to a no-go area?
• Safety hot spots? Congestion hot spots?
• Based on Safety Index.
• Proposed new times from Port > X hours?
• Service Search patterns.

Data combined with Other Sources

• Difference between published route (RTZ) and actual route (AIS).
• Number of deviations from published route.
• Precision of published route.
• Space.
• Time.
• Change in published route (RTZ) and logbook on-board
• Published Route, AIS, AIS Short Message and Observer.
• STM Validation Centre will receive all published routes and the Observer (and log files) is also an information collector and “real time” analyser.
5.1.4 Shore Centres

The STM project is developing tools for some of the shore centres where the STM ships are operating. The development of services such as route Cross-check enhanced monitoring and flow management will be tested and validated with the participation of these Vessel Traffic Area centres. The preliminary list of Shore Centers is:

- **Nordic test bed:**
  - Sweden – Gothenburg
  - Norway – Horten and Kvitsoy
  - Denmark – Aarhus

- **Mediterranean test bed:**
  - Spain – Tarifa

*Figure 35: Draft map of the shore centres included in STM validation project. Source: Own elaboration.*
5.1.4.1 Data collection in Shore Centres

VIS and SPIS will be used as well for the quantitative analysis in the shore centres. Some qualitative data could be collected by making questionnaires to the users.

5.2 EMSN Simulations

The European Maritime Simulator Network (EMSN) concept definition was established during Monalisa 2.0. Integrating a large number of simulation centres into a common virtual platform gives rise to a large number of ship bridges that can interact and can result in realistic scenarios where some behaviours can be observed. In addition to its functionalities, in STM Validation project, the EMSN will be used to test the systems developed by the manufacturers and to test the aspects that are difficult to test in real life, like human factors and ship bridges behaviours.

Thus, EMSN can be the instrument to evaluate the verification of various hypotheses and to provide numerical data that feeds the safety analysis to support the Formal Safety Assessment (FSA) within the project.

Figure 36: EMSN map of simulator centres and scenario locations. Source: Own elaboration
For these purposes, four scenarios are being designed and adjusted during the project: the two general traffic scenarios that will be located in the Baltic Sea and in the English Channel, a Search and Rescue scenario (SAR) that will be located in the Gibraltar Straight and a Winter Navigation Scenario in the Gulf of Bothnia. They are planned for different periods, determined by the development of the STM tools on the bridges as shown in the following timeline, where GEN means General Traffic Scenario, SAR means Search and Rescue Scenario and WN means Winter Navigation Scenario:

![Timeline of scenarios](image)

*Figure 37: Simulations schedule during the project. Source: Own elaboration*

**General Traffic Scenarios**

According to the services providers’ developments schedule, the services ready to be implemented in each of the scenarios will be the following:

*Table 14: Services in each scenario to be simulated. Source: STM Project*

<table>
<thead>
<tr>
<th>SERVICE</th>
<th>SW BALTIC</th>
<th>ENGLISH CHANNEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship-ship route exchange</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Area management</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Enhanced monitoring</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Flow management</td>
<td>?</td>
<td>only for longer scenarios</td>
</tr>
<tr>
<td>Route cross-checking</td>
<td></td>
<td>not in EMSN</td>
</tr>
<tr>
<td>Shore-based navigation</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Route optimisation</td>
<td></td>
<td>not in EMSN</td>
</tr>
<tr>
<td>SAR</td>
<td></td>
<td>separate scenario</td>
</tr>
<tr>
<td>Ice</td>
<td></td>
<td>separate scenario</td>
</tr>
<tr>
<td>PortCDM</td>
<td></td>
<td>(Possibly, to be checked)</td>
</tr>
</tbody>
</table>

**5.2.1 Western Baltic General Scenario Description**

In this scenario, about 30 EMSN own ships are approaching Fehmarn Belt, Western Baltic in good visibility. All ships within the exercise have an individual initial position, route and speed. The routes of all ships end in individual endpoints. For each ship, an individual ETA at the endpoint is given. Participants are asked to navigate their ship safely from the start position along the pre-determined route and to maintain the schedule as closely as possible. If altering course for shipping, participants shall resume the navigation track as expeditiously as possible.
5.2.1.1 Additional Information

1. Routes and Voyage Schedules: The routes and voyage schedules are to be implemented by the local simulator centres for their ships and bridge equipment.

2. Simulated Date and Time: (UTC) at the start of the exercise.

3. Target Ships: No target ships will be used in the exercise.

4. Environmental Conditions:

   Table 15: Foreseen environmental conditions during Western Baltic simulation.
   Source: STM Project

<table>
<thead>
<tr>
<th>ENVIRONMENTAL CONDITIONS</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind direction</td>
<td>270°</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>9 knots</td>
</tr>
<tr>
<td>Gusts</td>
<td>Not</td>
</tr>
<tr>
<td>Wave height</td>
<td>0.5m</td>
</tr>
<tr>
<td>Wave direction</td>
<td>270°</td>
</tr>
<tr>
<td>Visibility</td>
<td>10 nautical miles</td>
</tr>
</tbody>
</table>

5.2.2 English Channel General Scenario Description

In this scenario, about 30 EMSN own ships are simulated in an area South of Southampton representing a certain level of normal traffic in the area. All ships within the exercise have an individual initial position, route and speed. The routes of all ships end in individual endpoints. For each ship, an individual ETA at the endpoint is given. Participants are asked to navigate their ship safely from the start position along the pre-determined route and to maintain the schedule as closely as possible. If altering course for shipping, participants shall resume the navigation track as expeditiously as possible.

Figure 38: English Channel area. Source: STM Project
5.2.2.1 Additional Information

1. Routes and Voyage Schedules: The routes and voyage schedules are to be implemented by the local simulator centres for their ships and bridge equipment.

2. Simulated Date and Time: (UTC) at the start of the exercise.

3. Target Ships: No target ships will be used in the exercise.

4. Environmental Conditions:

   Table 16: Foreseen environmental conditions during English Channel simulation. Source: STM Project

<table>
<thead>
<tr>
<th>ENVIRONMENTAL CONDITIONS</th>
<th>DATA</th>
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<tbody>
<tr>
<td>Wind direction</td>
<td>270°</td>
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<tr>
<td>Wind Speed</td>
<td>9 knots</td>
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<td>Gusts</td>
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<td>Wave height</td>
<td>0.5m</td>
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<tr>
<td>Wave direction</td>
<td>270°</td>
</tr>
<tr>
<td>Visibility</td>
<td>10 nautical miles</td>
</tr>
</tbody>
</table>

Ships Participating In General Traffic Simulations

The ships performing the 30 bridges are standard ships with previously assigned characteristics. This characterization will allow A&E to build up a model in order to make calculations about total distances, times, fuel consumption, etc., that will add valuable data for the macro-analysis of STM Validation Project.
<table>
<thead>
<tr>
<th>SHIP GENERIC NAME</th>
<th>ENTITY KIND</th>
<th>Domain</th>
<th>Country</th>
<th>SUBCATEGORY</th>
<th>Specific</th>
<th>Extra</th>
<th>SIM CENTER</th>
<th>OS</th>
<th>Abrev. Name</th>
<th>Type of Ship</th>
<th>MHO NO.</th>
<th>MWSI</th>
<th>CALL SIGN</th>
<th>FLAG</th>
<th>LOCAL NAME</th>
<th>ORIENS</th>
<th>MAX SPEED</th>
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<tbody>
<tr>
<td>Generic Ship Coastal Tanker Class (&lt; 10,000 dwt)</td>
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<td>Generic Ship Oil Tanker Class (&lt; 10,000 dwt)</td>
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<td>Generic Mini-Bulk Carrier (&lt; 10,000 dwt)</td>
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<td>Generic Ship Combination Class small (1,500 - 3,000 DWT)</td>
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<td>Generic Ship Combination Class medium (3,000 - 10,000 DWT)</td>
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<tr>
<td>Generic Ship Combination Class large (&gt; 10,000 DWT)</td>
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<tr>
<td>Generic Ship Container Class small (&lt; 3,000 TEU, 10.000 dwt)</td>
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<td>Generic Ship Container Class medium (3,000 - 8,000 TEU, 10.000 dwt)</td>
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<tr>
<td>Generic Ship Container Class large (&gt; 8,000 TEU, 10.000 dwt)</td>
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<tr>
<td>Generic RoPax Vessel Class medium (&gt; 100 m, 5000 - 10,000 dwt)</td>
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<td>Generic RoPax Vessel Class small (1000 - 5000 dwt)</td>
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<td>Generic Platform Supply Vessel (&lt; 1000 dwt)</td>
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<td>Generic Platform Supply Vessel (&lt; 1000 dwt)</td>
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<td>Generic Bulk Carriers (20,000 - 40,000 dwt)</td>
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<td>Generic Bulk Carriers (40,000 - 60,000 dwt)</td>
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<td>Generic Bulk Carriers (60,000 - 80,000 dwt)</td>
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<td>Generic Bulk Carriers (100,000 - 120,000 dwt)</td>
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</table>

**Table 17: List of ships participating in simulations. Source: STM project**
5.2.3 SAR in Gibraltar Strait General Scenario Description

Gibraltar waters is a key spot for world maritime traffic, characterised by:

1. An international VTS Area:
   - Westbound controlled by Spanish Tarifa Traffic
   - Eastbound by Moroccan Tangier Traffic
2. An intense ferry traffic between several ports
3. A conspicuous ecological interest merged with dense dangerous goods traffic
4. Changing weather conditions, with frequent dense fog and E gales
5. Intense fishing, especially on South area
6. Among peculiarities, highlights the S-N traffic of precarious crafts carrying immigrants

![Traffic density map in Gibraltar Area. Source: marinetraffic.com](image)

The purposes of the exercise are:

- To test SAR patterns exchange from shore to ship.
- To test the ship-to-ship route exchange in a DTS without main constraints except at E and W borders, where course changes can derive in dangerous situations.
- To develop BRM knowledge on MRCC-to-ship and ship-to-ship communication that can be useful for training.

SAR patterns exchange between shore, ships and aircrafts has been a major issue for years, especially with helicopters. Specific software has been developed, but it will imply more screens, and training as well as the possibility to load directly SAR patterns on ENCDIS using its SAR tools.

The scenario proposal consists of an exercise within Gibraltar waters in which:

- A normal traffic situation is controlled by Tarifa VTS
- An emergency happens, demanding a SAR operation managed by the MRCC
- Some immigrant traffic is detected, affecting the traffic.

SARmap software will be used, probably offline, but perhaps can be also real time.

This scenario has a limit on bridges uses:
• 4 is the maximum for a SAR involving OSC.
• 8 is the maximum for 2 SAR operations at the same time.

The idea is that Centro Jovellanos Bridge will not be a ship but a VTS operator where operators will be real VTS officers.

5.2.4 Gulf of Bothnia Winter Navigation General Scenario Description

The area selected is the narrow in the Gulf of Bothnia separating the Bothnian Bay from the Bothnian Sea (Kvarken). The selection is based on the following reasons:
1. Ice navigation is often difficult due to ridging ice in the area
2. The narrow passage often generates traffic congestions.
3. The ports in the area, Vaasa and Lulea are involved in the STM Validation project as associate partners.
4. The exercise area is bound by the following coordinates: 63° 22’.0 N 020° 00’.0 E, 63° 46’.6 N 021° 20’.0 E.

![Figure 40: Gulf of Bothnia area in where the simulation will be carried out. Source: STM Project](image)

The exercise will consist of the following ships:
• Five northbound ships of which three has ports of call in Sweden (Lulea) and two in Finland (Vaasa).
• Four southbound ships, of which one is coming from Lulea and one from Vaasa.
• One ferry crossing the area, from Vaasa to Umea.
• Two icebreakers assisting the traffic; one from/to ports and another the north and southbound ships.

The scenario proposal consists of setting the traffic situation more congested than usual for the region situation in wintertime (February or March, daytime). The ships have the possibility to form convoys and receive icebreaker assistance if deemed necessary. Due to increasing northerly winds in the area, navigating in the ice field is becoming more and more difficult, and finally, leads to the ships being stuck.
The ships should resolve the situation with the resources at hand. The participating Simulator centres for this exercise and the services applied are the following:

*Table 18: Participating simulator centres. Source: STM Project*

<table>
<thead>
<tr>
<th>Simulator Centre</th>
<th>No of ships</th>
<th>Own ships</th>
<th>Target ships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aboa Mare</td>
<td>3+2</td>
<td>Ice breaker + 2 cargo ships</td>
<td>2 cargo ships</td>
</tr>
<tr>
<td>Chalmers</td>
<td>3+2</td>
<td>1 ferry + 2 cargo ships</td>
<td>2 cargo ships</td>
</tr>
<tr>
<td>SMA</td>
<td>2+0</td>
<td>Ice breaker + cargo ship</td>
<td></td>
</tr>
<tr>
<td>Others?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8+4</td>
<td>2+6</td>
<td>4</td>
</tr>
</tbody>
</table>

*Table 19: STM services to be simulated in Gulf of Bothnia scenario. Source: STM Project*

<table>
<thead>
<tr>
<th>Expected integration of STM Tools &amp; Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shore-to-ship Route Exchange</strong></td>
</tr>
<tr>
<td><strong>Ship-to-ship Route Exchange</strong></td>
</tr>
</tbody>
</table>
| **Enhanced Monitoring Service + Area Management Service** | The icebreaker can arrange convoys (using both VHF and STM tools – is this Enhanced Monitoring Service or just only route exchange?)
- The fact that the ships are in stuck in the ice should be detected from both the icebreakers and Shore Centre.
- The crossing ferry causes some disruption for the ships stuck (the ferry can navigate by her own engine) |
| **Shore-based Navigation Assistance Service** | A ship heading to Lulea port requests “En Route Navigational Assistance” (ERNAS) |
| **Route Optimisation Service + Port CDM**    | ETAs to the ports will change due to the ships getting stuck |

### 5.2.5 Data collection in simulations

A very positive aspect of simulations is that all the data about ships positions and movements can be easily registered and the people performing the exercise are available to make the questionnaires required. Thus, with the foreseen data collection, several analyses can be made in different perspectives:
Numerical Data Collection: the numerical outputs of the simulators will help for the calculation of indicators as:

- Safety Index.
- Environmental Index

![Graph](image.png)

*Figure 41: Example possible output of Safety Index model. Source: STM Project*

Human Factor Data Collection: taking pre-scenario background questionnaires and post-scenario questionnaires can foster the following research:

- **Shore Control Centre (simulators and real life):**
  - In vivo passive recording of HCI and workload using eye tracking.
  - In vivo passive recording of voice communications.
  - Observer recording of task completion and errors.

- **Ships bridges (simulators):**
  - In vivo active recording of workload using participant self-report ratings (random, fixed time interval, event triggered TBD).
  - In vivo passive recording of voice communications.
  - Observer recording of task completion and errors.
  - Post scenario mental fatigue testing using PVT / Stroop effect.
  - Post scenario usability and attitude questionnaire.
  - Qualitative reactive thought aloud interviews using Milestone or eye track where available.
5.3 Other Information Sources

STM is framed in a challenging scenario with multiple actors and players, within the framework of the global trade. This complexity makes STM background an important aspect for the analysis of the data extracted from the testbeds.

Due to the global effects of the maritime transport, a wide variety of legislation about operational, environmental and safety aspects, as well as the business models of the involved actors must be taken into account since they can be impacted by STM implementation. This analysis requires overcoming related challenges.

The already mentioned fourth layer of the Information Environment, defined as Information Environment Sources, has a sub-layer showing these horizontal factors that determine definitely the context.

5.3.1 Legal dimension

The interpretation of the legal dimension within STM concept is highly significant to assure consistency. Studying the effects of STM services and assessing these effects in relation to the current legal framework set out by a broad legal environment is required. Therefore, A&E will include a general overview of the common maritime and international conventions to ensure the compatibility of STM with the current legal framework. The main fields of focus will be the following:

- Navigational Safety and Search and Rescue.
- Crew training and maritime labour rights.
- Environmental protection.
- Liability and compensation.

The existing international treaties that may provide the main legal framework for shipping in relation to the STM proposal will be analysed, being UNCLOS, COLREG and MARPOL the most relevant regulations. From a European perspective, the European Union (EU) arises a large variety of regulations that EU members have to implement in addition to the international regulation and their own legislation. A&E will also present an overview of the EU shipping law and policy, as the analysis of the EU Directives and Regulations that could have a potential effect on STM is also fundamental, along with the way that STM fits into EU policy.

In addition to these regulations, regarding the use of technology for efficient shipping, the importance of ensuring cyber-security in relation to STM services (integrity and data access, among other matters) is crucial for the whole project. Therefore, the examination of the data exchanged, and whether the Directives and Regulations referred to the exchange of personal data apply, the security obligations that STM has to implement and who is bearing these obligations are essential analyses.
5.3.2 Business perspective

Global trade leads to a ship chartering market, where there is a wide variety of sales contracts and different business models that would interact within STM implementation.

It is very important to transmit that the issue is not the carriage itself, in which contracts the parties agree specifically the redistribution of the risks, but the trade behind where third parties may have some interests and could suffer substantial implications from STM implementation. A&E will analyse Charter Parties understood as contracts of carriage of goods by sea in its various forms, but will also consider (to a minor extent) charter party as a contract of hire, as both types would be influenced by STM concept.

A&E will consider the effects on the main forms of shipping contracts and other shipping documents where STM could have an impact. In this sense, special attention will be paid on specific terms regarding dates, time, speed and other specific dimensions influenced by STM deployment. Along with this survey, the evaluation of the potential “knock on” effect on the sales contracts and on the business models of the shipping industry arising from the change of operations under STM concept is fundamental.

The business approach will, consequently, examine potential liabilities of the stakeholders involved, and identify the issues that need resolution, suggesting at the same time recommendations regarding the changes that would be required, considering even the potential need of modifying contractual terms.

5.3.3 Operational aspects

A&E will study the effects of STM on operational aspects of navigation and port operations; it will focus on the STM strategic concepts: Strategic and Dynamic Voyage Management, Flow Management and Port CDM. Thus, the operational aspects must be analysed with the data collected within the testbeds. The focus will be set on the following parameters:

- Information needs
- Operating procedures
- Usability
- Workload
- Situational Awareness

When implementing STM services, several factors must be taken into account like regulations, requirements, recommendations, codes, Safety standards and policies.

In the case of operational procedures in ship bridges, today the standard procedures require to prioritize safety of navigation and the communications and cooperation with shore agents. In this matter, STM will provide additional and automated information as well as assistance in order to ensure making the best possible decisions and to mitigate certain human mistakes before they can cause any harm. All the possible scenarios related to operational aspects affected by STM must be analysed and assessed in this section.
5.3.4 Safety assessment

One of the key output in A&E is the Formal Safety Assessment, that following IMO guidelines focuses on the description, analysis and quantification of potential safety benefits gained and the potential risk reduction by the implementation of STM and its various operational services. The analysis will be attentive to the FSA developed in Monalisa 2.0. in the first place, followed by the analysis of FSA with STM testbeds data and concluding with a cost-benefit assessment.

FSA can be the mean for evaluation on new regulations for maritime safety and protection of the marine environment. Making a comparison between existing and possibly improved regulations, with the aim of achieving a balance between the various technical and operational issues and including the human element.

Following the IMO guidelines for FSA there are five steps to be followed:

1. Identification of hazards
2. Risk analysis
3. Risk control options
4. Cost-benefit assessment
5. Recommendations for decision-making

The recommendations obtained within this assessment will provide additional information to demonstrate the benefits of implementing STM concept in order to receive the support needed by institutions as IMO and ICS among others.

5.3.5 Training needs

In order to guarantee STM implementation success, A&E also analyses the need of competence and training for operational staff on board, in shore centres and in shipping companies. Directly involved with the future deployment of STM tools, their professional skills have to be prepared for the introduction of new technologies.

Particularly, A&E will identify the training and skill needs for the SAR and emergency response operators when supported by improved information and increased technology availability for supporting decision-making processes in the case of emergencies.

As a preliminary step, a questionnaire has been disclosed to collect and treat suitable information on the willingness towards new technologies, the competences of the users, their training level and the usability they find. Data collection is focused on the main following aspects:

- Training and competence needs for new STM services on shore operations,
- Training and competence needs in Port CDM,
- Training and competence needs for new STM systems installed on board ships
- Training and competence needs for new STM services to support SAR operations

The survey is divided into five blocks,

1. New technologies and connectivity
2. Ship navigation
3. Communications
4. European Maritime Simulator Network
5. Port CDM

The blocks are addressed to a target group of professionals that are all called to be the main users of Sea Traffic Management services. Based upon identified effects, the proposed changes to the STM concept will deem the necessity of further developments in terms of competences and training.
6 Collection, Processing and Analysis of Data

As mentioned before, A&E is responsible for creating a common framework for information sharing between the different concepts of STM. Based on it, all the processes regarding data collection, loading, filtering and analyses reporting are here defined, produced and tested. With this aim, there is the need to use three types of tools:

- **Process management tools** to define the information flows with the quality required.
- **Operational tools** to access capture and load data from and to the repositories created.
- **Analysis tools** to perform all the agreed analyses to produce the analysis reports.

In this section, the tools chosen are defined and described, providing an overview of the reasons by which they are required for the purposes of the analysis and evaluation.

### 6.1 European Short-Sea Shipping Line Database: VESSL

Valenciaport Foundation is currently developing a unique tool that 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. This tool is called VESSL, Valenciaport European Short Sea Shipping Lines Database, and it is being developed by Valenciaport Foundation team with the objective of providing a solution to the lack of information of the regular services in the maritime connections calling at the ports included in the TEN-T comprehensive network.
The planning methodology for the Trans-European Transport Network (TEN-T) structures a double layer network architecture, establishing a comprehensive and a core network. As the multimodal basic level of the TEN-T includes all transport modes, for instance, maritime as well as their connecting points and their corresponding traffic information and management systems.

![Comprehensive and core ports network. Source: European Union](image)

The comprehensive network arises from updating and adjusting the TEN-T defined in Decision N° 661/2010/EU of the European Parliament and the Council of 7 July on Union guidelines for the development of the trans-European transport network. The European Union selected those seaports, which are open for commercial traffic under the following criteria:

- **Passengers** – ports connected to the land component of the comprehensive network with an annual traffic volume exceeding 1‰ of the total annual EU maritime passenger traffic (calculated with average data from all Member States using EUROSTAT 2009, 2010 and 2011).
- Freight – ports connected to the land component of the comprehensive network with an annual traffic volume – either for bulk or non-bulk cargo handling – that exceeds 1% of corresponding total annual cargo handled in EU ports (using the same EUROSTAT statistics that represents 2.22 million tons per year for bulk cargo and 1.27 million tons per year for non-bulk cargo).

- Seaports located on islands, on condition that they provide accessibility at NTUS 3 or archipelagos level.

- Seaports located in outermost regions or peripheral areas provided their road-distance from another TEN-T port, is at least 200 km on road.

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

![Figure 44: TEN-T core network and corridors. Source: European Union](image)

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

Core network corridors were introduced to facilitate the coordinated implementation of the core network. The main challenges are:
- Remove bottlenecks
- Build missing cross-border connections
- Promote modal integration and interoperability

They also aim at:
- Integrating rail freight corridors
- Promoting clean fuel
- Foster innovative transport solutions
- Advancing telematics applications for efficient infrastructure use
- Integration of urban areas into the network
- Enhancing safety

Nine core network corridors are identified in the annexe to the CEF regulation\(^5\) based on their benefit for TEN-T development. These are Scandinavian-Mediterranean, North Sea-Baltic, North Sea-Mediterranean, Baltic-Adriatic, Orient/East-Med, Rhine-Alpine, Atlantic, Rhine-Danube and Mediterranean corridors.

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

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As a result, short sea shipping also includes feeder services: a short-sea network between ports with the objective of consolidating or redistributing freight to or from a deep-sea service in one of these ports, the so-called hub port.

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

- **Regular Shipping Services Data**: name of the service, sea carrier, actual schedule, itinerary of ports, main ships operating the service, type of traffic, number of port calls, number of different countries where the service is being provided, frequency, seasonality, etc.

- **Ports Data**: The ports included in the different itineraries are characterised in detail by country, sea, coordinates, continent, geographic area, Ten-T Corridor comprised, UN Locode, among other details.

- **Ships Data**: IMO number, name of the ship, ship type, ship operator, shipyard, MMSI number, flag, GT, DWT, year of build, dimensions, cargo capacity, total power, group of engines configuration, service speed, fuel consumption, etc.

- **Distances Data**: port-to-port distance for every two ports in a service is calculated and registered. A smart selection of waypoints to cover the distance from port-to-port is included in the database.

- **Times Data**: figures like the navigation time, port call time, etc. are calculated and registered.

- **Engine characteristics Data**: data from prime and auxiliary engines of the ships operating in regular services are collected and registered.

- **Bunkering Data**: related to the ports and estimates the market price of the different fuels including LNG (Liquefied Natural Gas), HFO, MGO, MDO, etc.

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

VESSSL will collect a huge variety of information for more than 200 core and comprehensive ports in 23 Member States (Bulgaria, Cyprus, Croatia, Greece, Spain, France, Italy, Malta, Portugal, Romania, Slovenia, Belgium, Germany, Denmark, Estonia, Finland, Ireland, Lithuania, Latvia, Netherlands, Poland, Sweden and United Kingdom). More than 2,500 ships characterised; more than 3,000 couples of port distances; more than 450 different ship engines, and thousands of transit and port call times will be collected in this repository.

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

1. Search on websites related to the ports under study: Port Authorities, Port Terminals, Shipping Agents, National Maritime Administrations, research studies, UNCTAD reports, etc.

2. Port-to-port monitoring of vessel movements using AIS information, since AIS is compulsory standard for all vessels that are part of the SOLAS Convention.

3. Search for information on specialized ferry and containership websites, maritime press, etc.

4. Identification of ships, sea carriers and ship owners. Where ships are allocated to specific services by monitoring their movements and contrasting this information with the official players. Specific datasheets for each vessel are elaborated using search engines, publications from several maritime entities, Equasis database, IHO Fairplay, classification societies’ information, etc.

5. Identification of the sea carrier and downloading or requesting of the updated services’ schedules. This information is treated, prepared and analysed to find out the way of modelling into the database. When the shipping companies share their services publicly and once the operator is identified, the most complete and reliable source of information is chosen and accurate information is collected.

The large number of ports under study and the vast amount of information and variables to be considered in the database has resulted in an exhaustive monitoring process of information, which is essential in terms of future evaluation, meeting the expected analysis objectives. The information is continuously updated, validated and standardised in parallel to the search for information.

The result of this compilation of data is a SQL database containing essential information about the morphology of the Short Sea Shipping situation in the European Union. It will permit to extrapolate the data extracted in STM test beds into a macro level and that will permit to provide general results of the potentiality of applying STM.

Potential reductions in both port call and navigation times, fuel consumption and consequently, GHG emissions will be calculated during the analysis and its consequences analysed both for the society and for the environment in the whole European Union.

The verified results obtained will provide criteria for the shipping actors to make decisions regarding their business models and the adaptation towards the future by adopting STM concept. Decisions such as fleet management, resources utilisation, and optimised strategic voyage plans could be enhanced by the use of this smart tool: Valenciaport Short Sea Shipping Lines Database (VESSL).
Figure 46: VESSL Database interface snapshot
6.2 Ship Navigation Monitoring Tools

There are many types of navigation tools installed on ship’s bridges in order to facilitate navigation in any condition. A ship navigation officer has a wide range of possibilities to plan and navigate a voyage at sea simpler and safer. Thanks to the advancement in technology, seafarers are trained to know the functioning and operation of navigational equipment that allows accurate data for the voyage and ensures a smoother voyage.

There are more than 20 navigational equipment, both old and new which are present on all merchant ships such as gyro compass, Radar, Auto Pilot, ARPA (Automatic Radar Plotting Aid), Echo Sounder, ECDIS (Electronic Chart Display Information System), AIS (Automatic Identification System), LRIT (Long Range Tracking and Identification System, VDR (Voyage Data Recorder), etc.

All new equipments are now required to have mandatory AIS integration in order to receive guidance and instruction on interpreting AIS radar and chart information. At present, Radar, AIS and ECDIS are integrated into a single tool with different functionalities.

STM project focuses on the abovementioned technologies and the future improvements and great potential of their use, exchanging accurate information automatically from ship to ship and ship to shore. This integration becomes a great tool in helping to improve safety at sea and reducing crew’s workload.

A brief summary of the functionalities of these tools is detailed below:

- The AIS (Automatic Identification System) is a shipboard broadcast system that acts like a transponder, operating in the VHF maritime band that is capable of handling over 4,500 reports per minute and updates as often as very two seconds. It uses Self-Organizing Time Division Multiple Access (SOTDMA) technology to meet this high broadcast rate and ensure reliable ship-to-ship operation. This system is designed to be capable of providing information about the ship to other ships and to coastal authorities automatically. In 2000, IMO adopted a new requirement for all ships to carry AIS system under Regulation 19 of SOLAS, Chapter V (Carriage requirements for shipborne navigational systems and equipment). The regulation requires AIS to be fitted aboard all ships of 300 GT, upwards engaged on international voyages, cargo ships of 500 GT, and upwards not engaged on international voyages and all passenger ships irrespective of size. The regulation requires that AIS shall:
  - Provide information about IMO No, name, type, position, course, speed, navigational status and hazard cargo information among others.
  - Receive automatically such information from similarly fitted ships; monitor and track ships.
  - Exchange data with shore-based facilities.

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The information contained in each AIS-data packet can be divided into the following two main categories:

- Dynamic information automatically transmitted every short period, depending on the class of transponders installed onboard.
  - MMSI (Maritime Mobile service identity number) is a nine digit number used by maritime digital selective calling (DSC), AIS and certain other equipment uniquely used to identify a ship or a coast radio station. They are regulated and managed internationally by the International Telecommunications Union in Geneva, Switzerland, just as radio call signs are regulated. The format and use is documented in Article 19 of the ITU Radio Regulations and ITU-R Recommendation M.585-6, available from the ITU.
  - AIS navigational status such as “under way using the engine”, at anchor, not under command, restricted maneuverability, constrained by her draught, moored, aground, engaged in fishing, under way sailing, etc.
  - Rate of Turn, right or left.
  - Speed over ground (in knots).
  - Position coordinates (latitude/longitude) provided by the integrated GPS.
  - Course over Ground.
  - Heading.
  - Bearing at own position.
  - UTC time.

- Static & Voyage related information. This information is provided by the vessels’ crew; updating correct information regarding each voyage. IMO promulgate Resolution A.917 (22) Guidelines for the onboard operational use of shipborne automatic identification systems.
  - IMO number associated to vessels’names.
  - Call Sign.
  - Type of cargo.
  - Dimensions (length/beam/draught).
  - Type of positioning system.
  - Destination.
  - ETA (Estimated time of arrival).

Finally, AIS messages 6, 8, 25 and 26 provide “Application Specific Messages” (ASM) that allow competent authorities to define additional AIS message subtype. The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA-AISM) now establishes a process for the collection of regional application-specific messages.
At present, AIS is used for, for instance, to avoid collision, aground, to monitor and control fleets, to provide additional traffic awareness and information through vessel traffic services, to enable maritime security, aids to navigation, to coordinate SAR operations, to investigate accidents, to track fleet and cargo, etc.

- ECDIS (Electronic Chart Display and Information System) is a development in the navigational chart system used in naval vessels and ships. It enables easier crews to pinpoint locations and attain directions. ECDIS complies with IMO Regulation V/19 & V/27 of SOLAS convention as amended, by displaying selected information from a System Electronic Navigational Chart. Besides enhancing navigational safety, ECDIS reduces workload by performing automatic capabilities such as route planning, monitoring, ETA calculation and ENC (Electronic Navigational Chart) updating. Modern ECDIS has the capability of data recording for further analysis. The ECDIS utilises the feature of the GPS to pinpoint the navigational points and interfaces with other navigational equipment such as GPS, RADAR, ARPA, etc. One of the great advantages of ECDIS is the availability of electronic charts reducing workload that takes hours into a few minutes. The navigation officer also can plan and summarise the passage much faster than before. Information about waypoints can be exported and imported into an Excel format when compiling Voyage plan. It increases the accuracy and the speed of reporting formalities onboard. Moreover, ECDIS enables the user to see vessel position in real time and in an unattended, secure and reliable way.

- RADAR are used by the ship to identify locations and other ships and land in the area. A marine radar with automatic radar plotting aid capability can create tracks using radar contacts. Radar enables range and bearing for position fixing, navigational aids, collision avoidance and search and rescue devices. Most radars today are capable of interfacing with other navigational equipment such as GPS, electronic compasses, logs, sounders, weather instruments, engine instruments and autopilots. Accidents can be prevented in the oceanic areas and the coast guards and other authorities can use them to monitor the traffic in the small radar range.

- GPS (Global Positioning System) is a satellite-based radio navigation system developed and operated by the U.S. Department of Defence (DOD). GPS permits sea users to determine position, speed and uninterrupted time anywhere in the world with a high accuracy. GPS consist of three segments: space, control and user
  
  - Space – provided by at least 24 operational satellites in six circular orbits.
  
  - Control – consist of a master control station in Colorado Springs, with five monitor stations and three ground antennas located throughout the world. The updated information is transmitted to each satellite via the ground antennas, which also transmit and receive satellite control and monitoring signals
  
  - User – receivers, processors and antennas that allow land, sea and airborne operators to receive the GPS satellite broadcasts and compute their precise position, speed and time

The use of this type of communications is very expensive, for instance, the estimated cost of a call using this type of systems is more than one US Dollar per minute and over 5 US Dollars per megabyte transmitted.
- LRIT (Long-Range Identification and Tracking) – provides the global identification and tracking of ships. The obligations of ships to transmit LRIT information and the rights and obligations of SOLAS Contracting Governments and of Search and Rescue services to receive LRIT information are established in regulation V/19-1 of the 1974 SOLAS Convention. LRIT is a satellite-based, real time reporting mechanism that allows unique visibility to position reports of vessels. Cargo vessels (over 300 GT), passenger vessels (carrying more than 12 passengers or High-Speed Crafts) are required to participate in LRIT. A ship’s LRIT equipment must transmit position reports at 6-hour intervals unless a more frequent interval is requested remotely by an LRIT Data Centre. The difference between LRIT and AIS is that LRIT requires the active, willing participation of the vessel involved.

- VDES (VHF Data Exchange System) is a radio communication system that operates between ships, shore stations and satellites on AIS, Application Specific Messages (ASM) and VHF Data Exchange (VDE) frequencies in the Marine Mobile VHF band. This is seen as an effective and efficient use of radio spectrum, building on the capabilities of AIS and addressing the increasing requirements for data through the system. AIS is a component of VHF Data Exchange System that operates using the Gaussian Minimum Shift Keying (GMSK) modulation scheme, other components of VDES will use higher capacity modulation schemes.

Thus, the information collected from Satellite-AIS and LRIT are mutually complementary, during open sea navigation, the information can be collected and managed in order to aid navigation across deep-sea routes.

STM project is focused in AIS-ASM to provide accurate information between ship to ship and ship to shore. These data exchanges would occur in coastal waters. The information included in this type of message can be displayed in ECDIS in real time. Consequently, AIS tool is essential for any data analysis of the vessels included in the test-beds.

![Figure 47. ECDIS and AIS integrated snapshot. Source: http://www.marinetrace.com](http://www.marinetrace.com)
Several different AIS data sources are expected during the validation process:

- Historical, accurate and real time data from STM vessels along the project period, with a particular focus on those periods when the STM services will be installed on ship’s bridges. These periods will be properly analysed from the point of view of the implementation of the STM module in ship’s bridges.

- Yearly STM port calls data from AIS sources (port level and shore centre level) to build times schemes along the STM vessels calls. This information provides relevant information about anchoring times and waiting times during a port call. Port services included during a port call can be monitored and this data can be analysed in order to find out the resource utilisation management due to STM services implemented.

GPS information about the tracking of the vessels during their voyages will be included in the analysis to find out the improvements of the use of STM services in navigation. The same concept will be taken into account when simulations data is stored. Moreover, specific information collected from Shore Centres will lead to better understanding of the advantages by using STM services during navigation. Services such as “enhanced monitoring” and “route Cross-check” might be evaluated using this compiled data. Voyage plans from sea carriers that provide vessels to the project will be collected and deeply analysed in order to see those changes in criteria during navigation evaluating the possibility of requiring sea carriers information about VDR (Voyage Data Recorder). The main aim with this data collection is to appraise and compare both non-STM services and STM services applied scenarios.

### 6.3 Analysis and Evaluation Tools

Under the scope of the STM project, A&E is performing an initial Exploratory Data Analysis (EDA) in order to find out whether the available data are suitable to achieve the proposed analytics goals. To this extent, it is necessary to carry out typical steps in data analytics projects such as ETL (Extract, Transform and Load), Data Mining and Visualization.

In this context, the objective of this section is to show some of the existing tools in the market that will allow carrying out the analysis process. These sections cover the main tools allowing performing data analysis from a statistical point of view: Databases, ETL, Analytics, and Visualization.

#### 6.3.1 Databases Tools

A database is an organised collection of data. It is the collection of schemas, tables, queries, reports, views, and other objects. The data is typically organised to model aspects of reality in a way that supports processes requiring information.

##### 6.3.1.1 Microsoft Access

Microsoft Access is a pseudo-relational database engine from Microsoft. It is part of the Microsoft Office suite of Applications. It also includes Word, Outlook and Excel, among others. Access uses the Jet Database Engine for data storage. It is used for both small and large database deployments.
This is partly due to its easy-to-use graphical interface, as well as its interoperability with other applications and platforms such as Microsoft's own SQL Server database engine and Visual Basic for Applications (VBA).

6.3.1.2 Microsoft SQL Server

Microsoft SQL Server is Microsoft’s relational database management system (RDBMS). It is a full-featured database primarily designed to compete against competitors Oracle Database and MySQL. This solution is based on a relational model. SQL Server supports T-SQL and ANSI SQL query languages. However, SQL Server also contains T-SQL, its own SQL implementation. SQL Server Management Studio (SSMS) is SQL Server’s main interface tool, and it supports 32-bit and 64-bit environments. Examples of some features include: XML data type support, dynamic management views (DMVs), full-text search capability and database mirroring.

6.3.1.3 Neo4j

Neo4j is an open-source NoSQL graph database implemented in Java and Scala. Use cases include matchmaking, network management, software analytics, scientific research, routing, organisational and project management, recommendations, social networks and more.

Implementing the Property Graph Model efficiently down to the storage level. As opposed to graph processing or in-memory libraries, provides full database characteristics including ACID transaction compliance, cluster support, and runtime failover, making it suitable to use graph data in production scenarios.
Particular features:

- Materialising of relationships at creation time, resulting in no penalties for complex runtime queries.
- Constant time traversals for relationships in the graph both in depth and in breadth due to an efficient representation of nodes and relationships.
- All relationships are equally important and fast, making it possible to materialize and use new relationships later on to “shortcut” and speed up the domain data when new needs arise.

Neo4j Presents a compact storage and memory caching for graphs, resulting in efficient scale-up and billions of nodes in one database on moderate hardware.

6.3.1.4 MySQL Database

MySQL is an open source relational database management system (RDBMS) based on Structured Query Language (SQL).

MySQL runs on virtually all platforms, including Linux, UNIX, and Windows. Although it can be used in a wide range of applications, is most often associated with web-based applications and online publishing and is an important component of an open source enterprise stack called LAMP. As the relational database management system and PHP as the object-oriented scripting language. (Sometimes Perl or Python is used instead of PHP).

6.3.1.5 MySQL vs Neo4j

![Diagram of relational databases and Neo4j]

*Figure 49: Relational Databases. Source: Own elaboration*

According to relational databases, it stores highly structured data in tables with predetermined columns of certain types and many rows of the same type of information, and, thanks in part to the rigidity of its organization, it requires developers and applications to strictly structure the data used in their applications.
In relational databases, references to other rows and tables are indicated by referring to their (primary) key attributes via foreign-key columns. This is enforced with constraints but only when the reference is not optional. Joins are computed at query time by matching primary and foreign-keys of the many (potentially indexed) rows of the to-be-joined tables. These operations are compute and memory intensive.

Relationships are first-class of the graph data model, unlike other database management systems, which requires inferring connections between entities using special properties such as foreign keys, or out-of-band processing like map-reducing. By assembling the simple abstractions of nodes and relationships into connected structures, graph databases enable the building of sophisticated models that map closely to our problem domain.

Each node (entity or attribute) in the graph database model directly and physically contains a list of relationship-records that represent its relationships to other nodes. These relationship records are organised by type and direction and may hold additional attributes. Whenever running the equivalent of a JOIN operation, the database just uses this list and has direct access to the connected nodes, eliminating the need for an expensive search / match computation.

This ability of pre-materializing relationships into database structures allows Neo4j to provide performances of several orders of magnitude, especially for joining heavy queries, the minutes to milliseconds advantage that many users leverage. The resulting data models are much simpler and at the same time more expressive than those produced using traditional relational or other NoSQL databases.

6.3.2 Extract, Transform and Load Tools

ETL is a process with three steps:

- Data extraction, where the data are extracted from homogeneous or heterogeneous data sources.
- Data transformation, where the data are transformed for storing in the proper format or structure for the purposes of querying and analysis.
- Data loading, where the data are loaded into the final target database.

6.3.2.1 Pentaho Data Integration (Spoon)

Spoon is the graphical designer of Transformations and Jobs of the ETL system in Pentaho Data Integration (PDI), also known as Kettle (recursive acronym: Kettle Extraction, Transformation, Transportation and Load Environment). It is designed to assist ETL processes, which include Extraction, Transformation, and Data Loading.

The Graphical User Interface (GUI) allows to design Transformations and Jobs that can be executed with Kettle tools (Pan and Kitchen). Pan is a data transformation engine that performs many functions such as reading, manipulating, and writing data to and from various data sources. Kitchen is a program that runs works designed by Spoon in XML or in a database catalogue.

The works are usually scheduled in batch mode to run automatically at regular intervals. Whereas Transformations and Jobs can be described using an XML file or can be placed in a Kettle database catalogue. Then Pan or Kitchen can read the data to perform the steps described in the Transformation, or run the works.
To sum up, PDI facilitates, through a flow of steps, the Extraction, Transformation and Load of data for the construction, update, and maintenance of Data Warehouses.

![Pentaho Data Integration (Spoon) snapshot]

**Figure 50: Pentaho Data Integration (Spoon) snapshot**

### 6.3.3 Analytics Tools

The following tools apply statistical techniques in order to analyse the data prepared by the previous ETL step.

#### 6.3.3.1 Orange Canvas

Orange Canvas is an open source data visualisation and data analysis tool, through two simple predictive models and a Monte Carlo Simulation.

It is a comprehensive, component-based framework for Machine Learning and Data Mining. It is intended for both experienced users and researchers in machine learning, who want to prototype new algorithms while reusing as much of the code as possible, and for those just entering the field who can either write short Python scripts for data analysis or enjoy the powerful, easy-to-use visual programming environment.

Orange includes a wide range of techniques, such as data management and pre-processing, supervised and unsupervised learning, performance analysis and a range of data and model visualization techniques. On the other hand, it has a visual programming front-end for explorative data analysis and visualization. Orange Canvas is a visual, component-based programming approach that allows to quickly explore and analyse data sets.
Figure 51: Orange Canvas snapshot.

The latter is composed of widgets that communicate through channels; a set of connected widgets is called a schema. The creation of schemas is quick and flexible, because widgets are added on through a drag-and-drop method.

Orange can also be used as a Python library. Using the Orange library, it is easy to prototype state-of-the-art machine learning algorithms.

6.3.3.2 IBM SPSS

SPSS consists of an integrated series of computer programs which enable the user to read data from different sources to manipulate them in various ways and to produce a wide range of statistical analyses and reports, together with documentation.

The system of SPSS modules provides a whole series of additional capabilities to those existing in the base system. Some of the available modules are:

- Regression Models.
- Advanced Models:
- Reduction of data: for creating synthetic variables from collinear variables by means of Factorial Analysis.
- Classification: allows grouping of observations or variables (cluster analysis) using three different algorithms.
- Non-parametric tests: to perform different statistical tests specialized in non-normal distributions.
- Tables: allows giving a special format to the outputs of the data.
- Categories: multivariate analysis of normally categorized variables.
- Joint Analysis: analysis of data collected for this specific type of statistical tests.
- Maps: geographical representation of the information contained in a file.
- Exact Tests: allows performing statistical tests on small samples.
- Analysis of Lost Values: Simple regression based on imputations on missing values.
- Complex Samples: to work for the creation of stratified samples, by clusters or other types of samples.
- Classification Trees: to formulate trees of classification and / or decision with which it is possible to identify the conformation of groups and predicting the behaviour of its members.
- Data Validation: for making logical revisions of the information contained in a "sav" file and obtain reports of the values considered atypical.

![IBM SPSS snapshot](image)

*Figure 52: IBM SPSS snapshot.*

Finally, it allows using the programming language Python for a better control of diverse processes within the program that until now were realised mainly by scripts (with the language SAX Basic). There is also the possibility of using Microsoft.NET technologies to make use of SPSS libraries. Moreover, there is another software named PSPP, and open source, which can be used as an alternative to SPSS.
6.3.4 Data Visualization Tools

An important step of every analytics process is the visualisation of the data and the definitive results of the statistical analysis.

Tableau is a dynamic, interactive reporting, business intelligence, data visualisation software tool. This type of software is used primarily for analysis, prediction and forecasting through the use of interactive visualisation via charts, graphs, and other analytic tools - allowing a larger audience to find answers in data.

It offers all the core features required in a Business Intelligence System. Its user interface is easy and can be accessed even by the non-experts. It allows us to drag and drop data so that it can analyse it the way you want to. It can easily connect to data and create dashboards quickly. It follows a new approach to BI so that we can produce fast analysis and insights from data.

Tableau is designed to meet the requirements of anyone who needs to analyse and explore business data, being an executive, analyst or manager. It is a highly featured software and includes a shareable dashboard, interactive reports, and scalability. It can conveniently share information from anywhere and can strengthen analysis by adding additional layers of data and incorporate multiple sources of data to utilize as much data as possible.
7 Graphic Interface

The ultimate objective of developing a graphic interface is the dissemination of STM Validation project results while showing transparency within the validation methodology. The website will support the STM Sea Traffic Management project as a central point of information on:

- Project Objectives
- Project Status Updates
- Updated content
- Project Documentation

![STM analysis and evaluation website snapshot.](image)

The requirement for this new website is to be responsive in design, with strong branding, adhering to brand guidelines modernised design/user interface, a focus on the user experience through improved information architecture, navigation and user journeys. This is the methodology used for the development of this tool:

1. Discovery: The first step is to discover and define the exact needs and goals of the project. The objective of the Discovery phase is to clearly state the objectives for the project and identify all of the key information needed to design the solution.

2. User Experience: this process enables to get a deep understanding of the business and users. Users are identified as well as goals and architecture defined.
3. Design & Specification: This may comprise of one more of the following stages where the design phase begins:

   - Information Architecture: During this phase, the data requirements of the project are identified, analysed and modelled. This includes the identification of all information types, structure and classifications.
   - Navigation & Structure: Good navigation is fundamental to usability and accessibility - users should be able to find information easily. During this phase, the navigation structure of your website will be set out and primary, secondary and internal linking strategies will be defined.
   - Prototyping: Prototyping and wireframes provide an opportunity to visualise and interact with the planned design at the earliest possible stage of the project.
   - Usability Testing: During usability testing, real users interacting with the prototype will be observed. This allows observing their interactions, understanding their goals, seeing where they have problems and coming up with solutions.

4. Visual Design: During the visual design phase, the design team will create the look and feel for user interface elements. This will include creating design concepts for the homepage and key site pages. For all other applications, this will involve the design of the look and feel of the application user interface screens.

5. Development: During the development phase, the website is built. This phase is where all the agreed design specifications are implemented to yield a fully functional product. This requires the bringing together of all the designs and specifications, together with database development, application coding and integration with any third party software and systems.

6. Data Migration: In case of upgrading, replacing or improving on an existing system, all relevant data will be migrated and transferred to the new solution. This stage comprises of data export, cleansing, validation and import into the new system.

7. Testing: The objective of the testing phase is to improve quality. During this phase, the entire website/application will be tested to identify any issues or bugs and to ensure that your project is ready for deployment.

8. Deployment: Once all functional and quality tests have been approved, the website is ready to go live. This involves deploying the project to a suitable hosting platform/server. For mobile applications, they are submitted to the relevant App Store/Market.

9. Core Features & Functionality:
   - Blog / News: The website will have a fully featured blog/News section to enable content editor’s post and publish relevant articles and stories. Editors will be able to organise, categorise and archive blogs. Blogs will also support comments and social sharing.
   - Video Content: The website will support embedded or natively hosted video.
- Forms: We will create the necessary forms to enable the capture of user data or feedback. A form builder will be available to administrators to enable them create and publish forms. Forms will have a security feature to protect against automated bots.

- Newsletter & Marketing Database: Newsletter signup will be integrated with industry leading email-marketing software such as Campaign Monitor or MailChimp to enable the communication with subscribers.

- Banners: configurable banner functionality to enable the creation of custom call to actions. The banner will support images, videos, messages and CTA's.

- Search: powerful search feature on the website to enable users search and filter relevant information quickly and efficiently. There are plugins called Search Everything and Relevanssi that provides more in-depth search functionality and integrates easily into the WordPress platform.

- Social Media: Social media will play a key role in increasing brand and project awareness. We will use it to engage and communicate with our audience using established social networks - Twitter, LinkedIn, YouTube and LinkedIn. We will also implement social sharing capabilities across the site and visitors will be encouraged to share and promote content across their network.

- Search Engine Optimisation: developed with SEO in mind from the outset by developing standards compliant sites and advising on content structure and Meta content. Administrators will be able to edit and manage the Meta content for each page through the content management system that will ensure that Title and Description tags are kept up to date and optimised for the necessary keywords. We will install a leading WordPress SEO plugin that will help keep content search engine friendly maximise our placement in Google’s organic listings. A comprehensive site audit will be carried out to ensure that link equity is preserved and that there are no negative SEO impacts. We will perform all the necessary redirects and rewrites when necessary.

- Google Analytics: Google Analytics will be used to measure website traffic, key performance indicators, goals and campaigns.

- Google Maps: We will use Google maps and Google places to promote venues and locations.

- Photography: We will ensure the appropriate licences are in place for their use.
7.1 Website Structure

The structure of the website regarding contents, will have six sections that cover the information environment structure including:

1. Analysis and Evaluation Overview; in this section, the information environment scheme is displayed and each of its layers explained in detail. The information is extracted from this report from the sections 1, 2 and 3.

2. Validation Hypotheses Model; this section explains the methodology used to define the hypotheses that set the expected results within STM concept, adding the results obtained for the three different perspectives:
   - STM Holistic Hypotheses.
   - Port CDM Hypotheses.
   - Voyage Management Hypotheses.

3. Information Environment Sources; this section is dedicated to the description of the different sources of data, how they are configured and the formats of data that they will provide.
   - STM Test Beds.
     - Ports.
     - Ships.
     - Shore Centres.
   - EMSN Simulations.
   - Other Information Sources.

4. Analysis Catalogue; in this section, there will be a list of analyses that are foreseen to be made by the analysis and evaluation team during the validation.

5. Reporting: this dynamic section will show the key results of the analyses during the project, showing with graphic supports the benefits deducted from the data extracted in the test beds and simulations and taking into account the other information sources.

6. Deliverables: this section will compile all the deliverables from the milestones comprised in Analysis and Evaluation Activity.

4. In the aim of setting up the baseline scenario of the test-beds defined in STM, A&E is developing a characterization sheet for each port included in the test-bed and for the STM compliant ships. This information will be uploaded on the website and will be a mean for analysis once the data is coming from the devices.

5. In addition, the specifications and particularities of the shore centres will be described as well as the simulator centres included in the exercises. In this respect, the ships included in the simulators will be characterised as done for the real ships in order to be able to make a theoretical/controlled analysis model.
6. The ensemble of this information will be shown in this graphic interface, acting like a mirror of the STM status and findings.

Figure 55: Preliminary structure STM A&E activity website snapshot.
Figure 56: Validation hypotheses model. Website snapshot.
Figure 57: Ships included in test beds. Website snapshot
Figure 58: Ports included in test beds. Website snapshot
Figure 59: Reporting section. Website snapshot
Figure 60: Deliverables section. Website snapshot
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