

Sea Traffic Management – Concepts and Components

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Abstract

This paper gives an overview of all components making up the Sea Traffic Management (STM) concept. STM builds upon information sharing in the whole maritime transport chain, where information is shared as early as possible about intentions and reached states. Sea System Wide Information Management will provide an infrastructure for a regulated and federated approach to information sharing. The functional sub-concepts are described: Strategic Voyage Management, Dynamic Voyage Management, Flow Management and Port Cooperative Decision Making. We will elaborate on how they complement each other and which benefits each of them has in regards to safety, environment and efficiency.

1. Background

In the EU, there are 29 000 port calls and 580 000 vessel movements yearly in the territorial waters of its members, *EMSA (2011)*. Any improvement in efficiency would have a large impact. In the MONALISA project, a study showed that 100M€ yearly can be saved by ship operators and society in the Baltic Sea Region, if the routes could be shortened by 1%. Societal savings, about half the total, come from less costs due to reduced emission. Ship operator savings, the other half, come from reductions in fuel consumption and other costs, *Andersson and Ivehammar (2014)*. The Baltic Sea has around 10% of the total sea traffic in Europe, *Stankiewicz et al. (2010)*, which means that European yearly savings might be closer to 1 billion € and the global savings even more. However, is it really realistic to reduce the distance sailed by 1%? A study by SSPA regarding traffic in the Kattegat analysed the AIS tracks of all large vessels during one month. SSPA then used an optimization tool on each vessel to calculate the fuel optimised route, *Johansson and Markström (2012)*. The analysis showed a potential of 12% savings on bunker consumption due to about 4% shorter routes and other optimisation based on high resolution chart data, ship dimensions, current loading condition, and so forth, *Markström and Holm (2013)*.

The first MONALISA project showed how navigators improved their situational awareness when they had the possibility to see the planned routes of vessels in the vicinity, *Porathe (2012)*; *Porathe et al. (2014)*. Shore based services could further advise vessels on potential congestions ahead, environmentally sensitive areas, safety notices and thus help optimise the route. By exchanging routes, benefits in three important areas are achieved: Safety, Environment and Efficiency.

Information is key in the maritime industry, as in any other. The current information flow is based on point-to-point communication, and actors request information from each other expecting answers. Some asking for information based on the vessel movement are Vessel Traffic Services, Custom Authorities, and ship and cargo owners. Ships in the same area will also want information from each other, *Brodje et al (2010)*. The one responsible for answering all these requests is the captain on-board, Fig. 1, *Svedberg (2013)*. This workload interferes with the focus on the navigational situational awareness. One argument is that the bridge personnel have plenty of time when they are at sea. However, information requests are much more frequent when navigating in coastal waters and exactly where and when navigational safety should be prioritised.

The captain is not entirely alone, ship agents usually take care of the information regarding port calls, and some shipping operators have shore based centres assisting. But as always, the responsibility stays with the captain. The information is usually manually distributed either by voice communication or by e-mail. A lot of the information exists in electronic format. But the level of systems integration between different actors is close to non-existing. There are few if any standards, and communication costs are a concern since satellites often are the only possible means.

As seen in Fig. 1 there are a lot of parties involved, and the picture is not complete. Other key information is generated by linesmen at the quay preparing for the arrival of the ship and by people preparing the loading hose on an oil pier. What is true is that all the parties need information coming from many other parties involved in the successful and safe execution of a sea voyage.

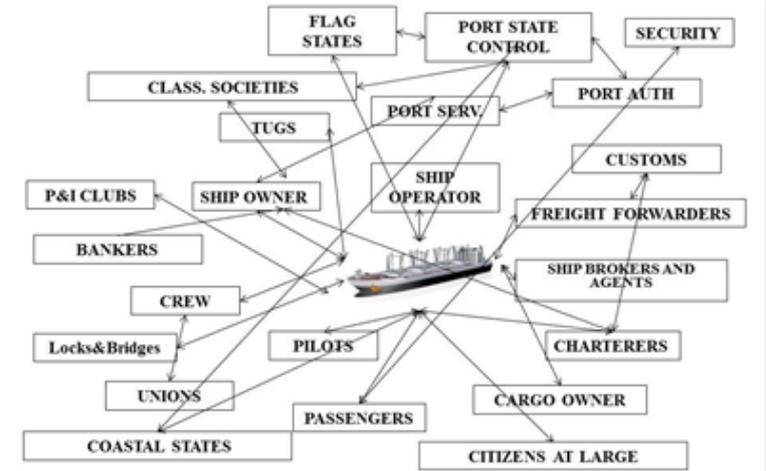


Fig. 1: The information flow to/from a vessel

One key data point that the whole maritime transport chain refers to is the Estimated Time of Arrival (ETA) of a vessel at its port of destination. All planning in the port and the future schedule of the vessel depend on this. In the port pilots, tug operators, terminals, stevedores, hinterland transportation, VTS, port authorities and many others rely on the ETA. The ETA is required to be sent to the ports 24 hours before arrival. The planning horizon is thus limited and long term planning is a difficult task for the ports. And later changes of ETA are not communicated in an organised manner.

There are some IS solutions that help vessels, ports and other actors. AIS was introduced in the 00s to help exchange information between ships sailing in the same limited geographic area, *IMO (2014)*. It makes communication between the ships easier since the identity of oncoming ships is known. Earlier confusion stemming from a foggy radio call “Vessel on my starboard” on VHF – who is the caller, which of the ships on starboard do they mean – is now replaced by “This is M/S MONA calling M/S LISA, what are your intentions?”. And AIS also has the advantage of adding knowledge about ships nearby not detect by radar, around tight corners in archipelagos for example. The solution increases situational awareness, but it does not share information regarding intentions, hence the typical VHF-calls. The port of destination is part of the information but does not contain any indication of planned route or ETA. The true intention of oncoming traffic is still a mystery on the bridge.

AIS information has become the source of new unforeseen shore-based applications. It is often fused with other information sources. VTS uses AIS and radar to monitor traffic, and experienced operators can make educated guesses how the traffic situation will develop, *Brodje et al. (2010)*. AIS information has become the number one source of finding vessel positions, e.g. www.maritimetraffic.com, and many use it to make educated guesses of ETAs in advance of the official report, often requiring manual labour.

In other transport modes, the integration of information flow has come further, replacing the old manual processes, resulting in a higher efficiency. Sea Traffic Management takes some inspiration from the EU-supported SESAR initiative, which aims at improving the aviation transport chain.

The purpose of this paper is to describe the components and sub-concepts of Sea Traffic Management, the effect it will have on the industry, and the opportunities for new services.

2. The Sea Traffic Management Concept

Sea Traffic Management 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, including sea as well as shore-based operations. The operative services of STM are based on streams of data that are created by its actors. By enabling interoperable and harmonized systems, STM simplifies collaboration and the establishment of a common awareness in the maritime industry. In the current definition of STM, the voyage is the central object of analysis and development. Sea Traffic Management covers all actors (both land- and sea based) and their operations from voyage planning and departure to port arrival and evaluation, Fig. 2.



Fig. 2: The different phases of Sea Voyages (inspired by the SESAR project)

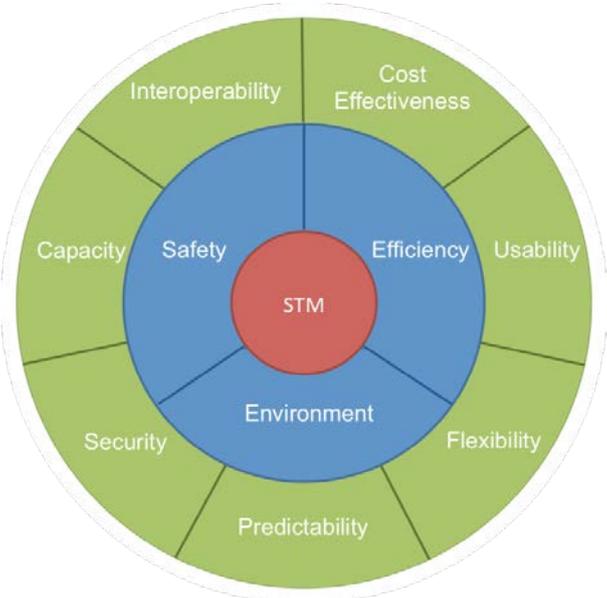


Fig. 3: Sea Traffic Management, main and subordinate objectives

The main focus of STM is to improve voyage safety, sea traffic efficiency and to reduce the overall environmental impact in the maritime sector. Additionally, there are seven sub-objectives that together with the three main ones outline the scope of STM, Fig. 3.

The basic logic behind STM builds upon five core principles. First, a voyage is defined and all attributes are bundled with a unique voyage identifier. Second, the operative intentions of sea- and land based actors are provided to others well in advance and kept up to date. Third, situational awareness is derived from multiple informational sources. Fourth, recommendations of optimized routes are coordinated from authorised service providers. Finally, the fifth principle, secure and authorized service realisation, discovery and distribution are realised through an infrastructure governed by federation(s) relevant of industry members.

3. Four concepts enabling STM

To meet these challenges Sea Traffic Management has defined four concepts: Strategic Voyage Management (SVM), Dynamic Voyage Management (DVM), Flow Management (FM) and Port Collaborative Decision Making (Port CDM). These concepts define how the generated services will be applied and utilized in the different phases of the voyage, from the planning to the port call.

3.1 Strategic Voyage Management (SVM)

The SVM concept goal is to optimize a company's initial planning phase of a voyage. This is done by providing services based on a current awareness of all influencing factors relating to the undertaking and success of the planned voyage. SVM enables the process at the earliest possible planning horizon prior to voyage commencement. The planning horizon can be years, months, weeks or only hours.

Many parameters of a voyage are already planned before an order is issued. At this early planning stage, before the voyage has commenced, there is time to evaluate details of specific alternatives that influence the route and vessel type choices. Main services in SVM are:

- **Fleet Management**
The service helps shipping companies to keep track of all their ship voyages and voyage plans. By planning and monitoring the movements of the whole fleet the utilization can be optimized. This is a service that most shipping companies already have in house or from an external service provider. In an STM world, Fleet Management would connect to other STM services thus improving the performance of the service.
- **Voyage Optimisation**
Public data stream services provided by different entities to support route optimization, including weather, ice conditions, Maritime Safety Information (MSI), Maritime Spatially Planned areas (MSP), distance, speed, traffic congestion, port and crew constraints and requirements as well as bathymetric conditions. Services of DVM, FM and Port CDM will all be input into this service.

Take a vessel plan for the transport of dangerous goods. The services could show information on restrictions or requirements along the route, e.g. that the vessel is required to use a pilot when approaching the desired port. When the voyage plan is ready, it could use other services for nautical cross-checking, service booking and confirmation. The final step would be to "release" the voyage, thus sharing the information with the different service providers like port authorities, pilot services, VTS centres. This action would also request them to confirm or decline their part of the plan or suggest changes. The voyage planner could adjust the plan and the final version could be executed.

Supporting services help assigning a unique identifier for the voyage and specifying the actors with access to the information. Other services help analysing historical voyages in order improve future voyage optimisation and fleet management. Standard voyage plans might be collected in a data base to simplify the planning process.

The STM services are open and could facilitate potential marketplaces where cargo owners, transport providers and possibly other actors can optimise their operations.

3.2 Dynamic Voyage Management (DVM)

Strategic Voyage Management and Dynamic Voyage Management are parts of the STM overall Voyage Management processes. The relationship between these two voyage management processes are shown in Fig. 4, *Svedberg and Andreasson (2014)*.

3.3 Flow Management (FM)

Voyage Management concerns optimising everything regarding one single vessel. Flow Management is optimisation based on many vessels in an area, preferably all. FM aims at increasing the safety of the sea traffic flow, during all planning and executing phases, while taking to account other factors. Optimising traffic is achieved by coordination, not control, always leaving the final decision to the Master. The FM concept will not contradict any regulation on navigational safety, such as COLREG or UNCLOS. Authorities appointed by an NCA of Flag States will solely provide FM services; Port Control (existing organization), Vessel Traffic Service (VTS) (existing organization), or possibly new organisations, *Lind et al. (2014)*. Some of the foreseen services are:

- **Enhanced monitoring in critical areas**
All ships participating in STM will have the ability to follow pre-planned routes that could be automatically or manually monitored and assisted from the FM providers along the route. Deviations from an agreed route will be detected on-board and on shore and measures taken when appropriate. Hence, the system will automatically detect if a ship is leaving its intended track or if a non-participating ship is manoeuvring in “strange patterns”. Input from DVM is necessary.
- **Traffic coordination and capacity management**
Route optimisation could potentially consider traffic in congested waters. Hence, some kind of traffic coordination service will be needed in order to manage all already planned voyages and synchronising those with new voyages. This is mainly performed by using the concept of the ETA window, setting the safe haven in the long track direction and dynamic separation setting the safe haven in the cross track direction. SVM, DVM and Port CDM all provide important data.

Supporting services include

- Having real-time updated traffic image over geographical areas is the basis for all other services. Today, real-time traffic images are established within VTS and Port areas. In EU coastal waters, a near-time traffic image is established by the SafeSeaNet module STIRES. Still, in most areas a real-time traffic image will need to be established.
- Seamless ship reporting within the EU has been mentioned and proposed. Thanks to the continuously updated information, all areas along the voyage will have current information, and new information relevant for the following areas is entered as soon as it is known. No reporting points or reports need to be established, the current information is accessible for all with authorized access.
- Area management is the responsibility to collect local safety, environmental, and other data for a regional area. By securing the latest safety information and managing the static and dynamic no-go areas, route cross-checking and optimization can be enhanced.

3.4 Port Collaborative Decision Making (Port CDM)

Port CDM will be described in more detail in another paper at the COMPIT 2015 conference, *Lind and Haraldson (2015)*, thus only a short summary is in place.

The number of different actors within a port means that an efficient handling of the port call requires a collaborative port environment. Inspired by airport CDM, Port CDM has been identified as a key enabler for reaching the full potential of Sea Traffic Management. Port CDM should provide processes and content for the collaboration between key actors within the port and between the port and its surroundings. The goal of Port CDM is to support just-in-time operations within ports and in relation to

other actors. One driver for Port CDM is to enable high accuracy in predictability leading to, among other effects, optimal berth productivity (as the number of cargo operations divided by the time at berth), *Tirschwell (2013)*. Thus, essential boundary objects between sea and port are Estimated/Actual Time of Berth (ETB/ATB) and Estimated/Actual Time of Departure (ETD/ATD). ATB is defined as the time when the vessel is All Fast (at berth) and ATD as the time when the vessel is All Loose (from berth), *Lind et al. (2014)*. Governance towards ETB and ETD give rise to green / slow steaming as well as to reducing unnecessary waiting times enabling substantial environmental and financial effects.

The STM Port Call Services are based on the notion of states that converge in milestones and define the process of a port call. States are used to describe the resulting state of the different process steps and milestones are referring to states defined in a logically chain, consisting of one or several states and/or activities throughout the port approach process. Different states require different actors to collaborate to move ahead in the process. A graphical example of a generic port call process with, so far identified all possible, states is given in Fig. 5. Dependent on the characteristics of each port different states would be applicable why this more generic chart will be used as a basis for further adaptation.

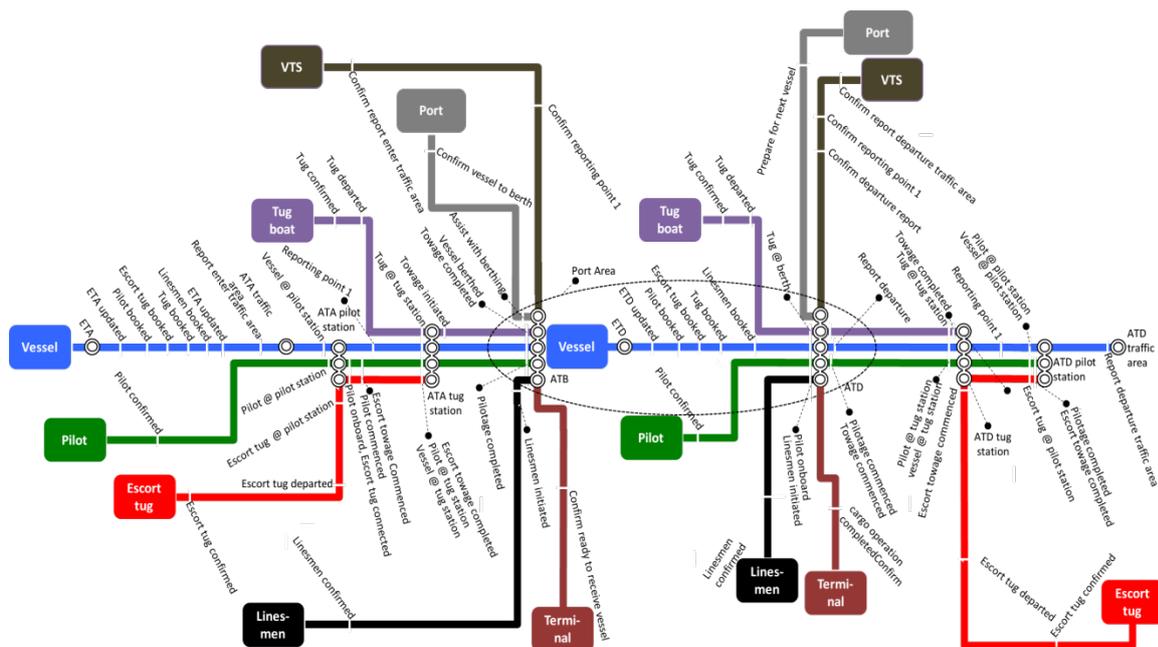


Fig. 5: A port call process, with different actors collaborating to complete each state and milestone, *Lind and Haraldson (2015)*

Port CDM services include:

- **Port Call Synchronisation**
Ports and ships would like to coordinate the approach with the readiness of the port. This enable the vessel to set the accurate speed for just-in-time approach to the “service meeting point” e.g., traffic area/ pilot station. At the same time each involved Port Call Service Provider can plan in advance to optimize turn-around times and resource utilization. This service is used to plan the port call. Vessel traffic in port and quay planning are important input. As well as SVM, DVM and FM information regarding the vessel.
- **Port Call Optimization**
When the vessel have arrived to the traffic area all actors need to coordinate and adjust their actions related to other actors shared intentions and performances, based on the set of states for the particular port call.

- **Port Call Monitoring**
This service provides real-time images of the status (desired, committed, fulfilled actions by different actors) of upcoming and on-going port calls. It provides the basis for coordination through common situational awareness, and optimization.
- **Port Call Evaluation**
The conducted port calls form the basis for evaluation to establish means for optimizing future port calls. Weaknesses can be identified and different states of the port call can be monitored for future calls for example.

4. The infrastructure necessary for Sea Traffic Management

The digital infrastructure supporting STM is described in more detail in *Lind et al. (2015)*, but another short summary is in place.

Today, a lot of digital data streams exist in the shipping domain, yet there are no standards for these streams and no central directory for locating them and the associated documentation. As a result, the effective use of real-time data for shipping management is fragmented, uncoordinated, and not very efficient. Consequently, an unused potential for the exchange of real-time data between key actors exists. Thus, to enable System Wide Information Management at Sea (SeaSWIM), an interoperability infrastructure needs to be established to facilitate the exchange of real-time data, *Lind et al. (2014)*.

“A digital data stream consists of digital elements that describe an event (e.g., a sale, the berthing of a ship), concerning both intentions or the actual occurrence of the event, or the current state of an entity (e.g., the level of humidity in a field, the current mood of a person) that are available real-time. The seven basic elements of a digital data stream are the description of when, where, who, what, how, why, and outcome”, *Watson (2014)*.

The current situation favours an incremental, market-driven approach to the development of SeaSWIM. Step-by-step, these streams can be standardized, documented, and made available to authorized accounts. As mentioned, data streams are the foundation of SeaSWIM, no matter its design. An incremental approach accelerates speed-to-operations and avoids trying to design a centralized system whose requirements will change as the value proposition of STM emerges from use and experience. Thus, SeaSWIM becomes a central repository of data stream details. Core services for publication and discovery of services and identity management of actors fits well in the SeaSWIM infrastructure which need to have governing bodies with credibility and wide general acceptance in order to be trustworthy.

5. Concluding reflections

We have shown how each component of STM will give benefits to different actors within the maritime transport chain. Some important ones were increased safety for vessels and coastal waters due to Dynamic Voyage Management and Flow Management, increased efficiency for ship operators due to Voyage Management and Port Collaborative Decision Making, resulting in improved environment as well. But the main gains are still unknown to us. We believe that by creating an infrastructure where information can flow freely in a secure manner, with open standards and interfaces as guidelines, we will inspire actors, within the transport chain as well as new entrepreneurs, to digitise existing services and invent new ones. Shipping by its nature involves numerous actors, and yet the digital transformation has only happened within companies or in small clusters. Key this transformation in such a conservative industry is to give the data owner complete control of its data. The owner decides what to share with whom and when. Some companies will be very open and others not quite so, and information sharing will become a competitive factor and an efficiency driver. We believe that by introducing STM, the processes in the transport chain will be digitised and transformed. Some actors will

disappear; new actors and functions will emerge. It is an opportunity to build on similar solutions from other industries when it comes to new and/or modified software and IT infrastructure.

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