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LIST OF ABBREVIATIONS

STM	Sea Traffic Management
EMA	Estonian Maritime Administration
ETA	Estimated Time of Arrival
SMA	Swedish Martime Administration
SOP	Standard Operating Procedure
UC	Use Case
VTS	Vessel Traffic Service
VTSO	Vessel Traffic Service Operator
CPC	Common Performance Conditions
CQS	Close Quarter Situation
ECDIS	Electronic Chart Display and Information System
HMI	Human-Machine Interface

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Executive Summary

Vessel Traffic Service Operators (VTSOs) employ their experience and problem-solving skills in order to uphold safety in the controlled traffic area. Human Factors studies focus on the conditions of that work – whether technologies, organizations and interfaces to other stakeholders are adapted to VTS operator activities and needs. For the VTS, the purpose of Sea Traffic Management (STM) services is to allow digital communication and information sharing between the VTS Centre and ships in the controlled area, with an emphasis on simple creation and sharing of ship routes.

The aim of this evaluation has been to uncover Human Factors hazards associated with the introduction of STM services developed in STM BALT SAFE WP4, directed towards route creation, sharing and associated safety functions.

Analyses have concentrated on three levels of interaction within the sea traffic system:

1. The VTS operator and her immediate working environment (usability and ergonomics of VTS systems and tools affected by STM implementation).
2. The organization of VTS collaboration with other actors in the port and its surroundings.
3. Interaction in the greater context of ship traffic (including both STM and non-STM ships).

The evaluation was performed using qualitative methods in a process consisting of three main stages – A first analysis using heuristics from the domain of Human Reliability Analysis, an interview study with sea traffic system stakeholders, and a VTS simulator study.

Results indicate that maritime administrations should employ a consistent design process that caters for local VTS Centre characteristics and the needs of their operators. As work with STM continues, technical development should be augmented with an iterative development of VTS system user experience and usability. Aspects of STM that are already known to require a human factors validation are, but not limited to:

- That the new information provided to operators through the STM services is presented in a way that does not introduce confusion or obscure information (e.g. cluttering of routes, poor visibility of ships/routes/geographical features).
- That alarms and/or alerts are relevant, useful and communicated effectively. Irrelevant alarms or alerts can disturb the work of the VTSO, and even if only relevant alerts are provided, the sum of all alerts can still produce a poor working environment (e.g. with regard to noise).
- That STM services are coupled with sufficient support for notetaking and/or marking. With a larger bulk of information available to the operator (e.g. around possible future hazards) comes a larger need to support the operator attention and memory.
- That the implementation of STM functions accounts for information management over several work shifts.
- That predictive tools (e.g. prediction of future ship movements and associated conflicts) factor in prediction uncertainty, so that the operator is given a truthful representation of possible traffic development.
- That there are means of communication suitable for use with the STM functions. Even though chat functionality was excluded from the STM BALT SAFE scope, some informants hold that other means of communication than VHF might be necessary if the ship is to send its route before reaching the VTS area.
- That dynamics in VTS-ship interaction may be affected as new forms of communication develop. For example, even if the purpose of the VTS Centre is

only to “inform” ships about traffic conditions, creating and sharing routes via STM services might be regarded as something more than a friendly suggestion. This invokes a discussion around VTS authority and responsibility in the event of an incident that needs to be continued.

Evaluation data suggests that the use of STM functionality is not appropriate for all operative conditions, and that implementation must be calibrated against the practical needs of local VTS operators. Here, a balance must be struck between allowing for local adaption of STM services and offering a uniform STM interface towards vessels moving between different control areas.

A final aspect of adaptation is the relation between VTS technical functionality and how these functionalities are put to practical use. Seeing that STM services could expand the operator time horizon and allow them to work more proactively, technical development should be combined with a review of local VTS procedures, making sure that the VTS operational approach (e.g. procedures for ship interaction or the functional level of VTS implementation) matches all the capabilities afforded by STM.

1 Introduction

In similarity with many other industries, shipping is seeing a steady rise in new digital technologies aimed at increasing operational efficiency, as well as safety. The STM BALT SAFE project is concerned with the introduction of Sea Traffic Management (STM) services. Although these services target several stakeholders in the sea traffic system, this project focuses on STM implementation for the Vessel Traffic Service (VTS). STM BALT SAFE builds on the methods, results and the maritime service infrastructure developed in previous projects like MONALISA 2.0 and Sea Traffic Management Validation project. At the peak there were 311 [1] STM compatible ships in traffic. However, due to changes in supply-chains and business setups, as of 2021 there are only roughly 40 known STM-compatible ships sailing the seas.

For the VTS, the purpose of STM is to allow digital communication and information sharing between the VTS Centre and ships in the controlled area, with an emphasis on simple creation and sharing of ship routes. Firstly, sharing more detailed route information between the VTS and ships is meant to support shared situation awareness between stakeholders, creating a clear and common reference for ship navigation. Secondly, more detailed and digitally represented route information allows for the introduction of new automated functions, such as alerts for route conflicts. On the other hand, the introduction of any new technology will often have both benefits and drawbacks. Technologies that are introduced without sufficient consideration to end-user needs may not live up to their full potential. While STM services are meant to increase sea traffic safety further, it is important to study all their potential effects, both positive and negative, on Vessel Traffic Service Operator (VTSO) working patterns and practices.

VTSOs employ their experience and problem-solving skills to uphold safety in the controlled traffic area. Human Factors studies focus on the conditions of that work – whether technologies, organizations and interfaces to other stakeholders are adapted to VTS operator activities and needs. The aim of this evaluation has been to uncover Human Factors hazards associated with the introduction of STM services developed in STM BALT SAFE WP4, directed towards route creation, sharing and associated safety functions (see section 2.1 for a summary of associated Use Cases). VTSOs employ their experience and problem-solving skills to uphold safety in the controlled traffic area. Human Factors studies focus on the conditions of that work – whether technologies, organizations and interfaces to other stakeholders are adapted to VTS operator activities and needs.

This document reports findings from a three-stage qualitative analysis of hazards that could potentially be associated with STM introduction. The first section of the Results chapter presents an interview study and heuristic analysis of STM-related hazards. These results were used to structure a simulator study, aiming both to expand and provide more detail to the previous inventory of hazards. In the discussion, findings are used to suggest evaluation approaches and foci that will become relevant as STM progresses towards final implementation.

1.1 VTS and STM in the literature

The strategic potential of vessel traffic management under the umbrella of STM services has been under a lot of interest recently, with empirical research, training sessions, exercises and design simulations taking effect in VTS areas, particularly in Europe. The Bulgarian user cases and simulations, with a clear ambition to improve vessel traffic management in inland waterways, especially in the Bulgarian river systems, national, as well as transnational conditions, is a case in point [2]. The study further elaborates on the potential of information systems, informatics with design thinking that can assist other stakeholders in their respective operational mandates with Vessel Traffic Management Information Systems (VTMIS) as the information facilitation point [2]. In fact, the potential of developing algorithms on predictive data for actual navigational decisions in VTS contexts has been under scanner since the 1980s, initiated by the Naval Academy in the United States [3]. Winding our clock back to the present, other studies such as [4] capture similar strategic potential of vessel traffic surveillance and traffic management in Egypt.

While it is true that VTSOs have demonstrated willingness, commitment, and interest to use vessel traffic management as part of their operational mandate, as captured in previous empirical studies involving VTSOs from multicultural and multinational backgrounds, nevertheless, it has also been observed, expressed, and concluded that safety is a construct [5]. This means that perceptions of safety, and judgements on safety are prone to differ widely based on several socio-cultural-psychological factors which are mostly non-technical in nature [6]; [7]; [8]; [9]; [5]. This means that although the technical basis of the information and data to make a safety-related judgements may be the same for all, the judgement itself and therefore the outcome will vary due to the non-technical socio-cultural-psychological factors also popularly known as the human factors (HF). Adding to the complexity is the lack of shared mental models in various VTS areas which stem from various other factors such as the expectations, norms, patterns, local & regional regulations etc. which play a significant role not only in making safety judgements alone but also in operationalization of the vessel traffic management as a STM service in VTS areas [10]; [11],[12]; [13]; [14]; [15]; [16]; [5].

[17] in their empirical study investigate prospects and the need for central coordination of maritime traffic and opens the field for vessel traffic management supported by STM services. They argue in favor of a much-needed central coordination which vessel traffic management has the potential to offer, despite the existing nuances of operational contexts, mandates, and regulations in VTS areas and outside. In addition, they make comparisons with air traffic control (ATC) which plays a significant role in surveillance as part of securitization against possible asymmetric threats. [18] in their empirical study take a step further to establish two approaches to grasp the potential of vessel traffic management in the STM umbrella. The first approach is the reactive one, which is about developing the required digital readiness for the automation that is inevitable, and the second one is proactive which is tailored towards cultivating overall safety and security in sea traffic, starting with the VTS areas.

[19] in their study on vessel traffic management investigate into the reliability and availability aspects of vessel traffic management information systems (VTMIS). More precisely, the empirical study makes information design proposals on how hardware and software systems for VTMIS can be made more reliable and available for the VTSOs. This clearly addresses the concerns around trust worthiness of the information, how to make it more robust and reliable, simultaneously catering to the ship user and VTSO needs.

The empirical study conducted by [20] make interesting supporting conclusions with scope for further research. The study focuses on the STM validation project with assessment of frequency, type of interactions between ships and VTSOs supported by user perception of the VTSOs. The conclusions demonstrate that STM services in general, especially in context of route planning, can significantly improve marine traffic safety. More precisely, shifting the responsibility of route planning and route exchange from the ship master to VTSOs during outstanding yet common marine traffic situations such as traffic congestion or interaction between STM and non-STM ships, can contribute to overall improved management of marine traffic as well as increase traffic safety. The rationale behind this claim is based on mitigation of miscommunication, which is achieved via chat functionality, i.e. closed loop communication among VTSOs. One potential identified risk from the user perspective, i.e. from participating VTSOs, was occasional overload of chat information which may cause distraction. This can in fact negatively impact performance, response, decisions, and situational awareness of the VTSOs. Nonetheless, if distributed workload is achieved while using the closed communication loops between the VTSOs and ships, it can dramatically improve the realm of sea traffic management.

To summarize, vessel traffic management as a part of STM service offers benefits in the long run. According to the empirical studies conducted so far, it is established that this is a multi-dimensional playing field. See more in [21] From a systems perspective, vessel traffic management can be treated both as an information system as well as a socio-technical systems. The empirical study by [22] supports this by investigating the information requirements on one hand and capturing the complexity of socio-technical interactions and HFACS on the other. While the reliability, usability and availability of the information captured in vessel traffic management do reveal genuine concerns on how to meet the user needs, however, there is a huge interest, commitment, and support in the overall idea of achieving improved traffic management, reducing accidents and/or incidents, achieving protection against threats and gaining traction in automation and digitalization.

1.2 Use cases of STM BALT SAFE

This report presents an evaluation of the following use cases, related to STM BALT SAFE WP4. More information about the use cases is available in the report D6.2.0 [23].

- WP4 UC1 Close quarter situation (CQS) predictor
  - The functionality available to the VTSO is close quarter situations in the form of overtaking, crossing and head-to-head.
- WP4 UC2 Cross track error alarm
  - The function will raise an alarm when the cross-track error of an STM ship against its shared voyage plan exceeds the cross-track error in the route (or a value determined by the VTS operator).
- WP4 UC3 Route proposals
  - VTSO able to propose routes to ships.
- WP4 UC4 Forbidden meetings
  - Similar to close quarter prediction but associated with areas rather than situations.
- WP4 UC5 Automated route cross-check
  - Automatically checks a proposed route against potential risks e.g. grounds, small passages etc.

1.3 Changes to the validation

At the project outset the validation as it relates to WP4 was to entail pre-, during- and post-deployment validation. As deployment was impaired in the project for reasons described above the validation was limited to pre-deployment study, questionnaire, and a single simulation evaluation.

1.4 VTSO Human Factors analyses in previous iterations of STM-projects

1.4.1 MONALISA and MONALISA 2.0

The MONALISA project with a consortium of 7 partners and a budget of 22 million euro, was performed during 2010-2013 and demonstrated route planning and route sharing, which is the forebearer of STM. It also worked with hydrographic data quality, as the predecessor of the FAMOS Projects, and continued the work on global maritime data sharing. MONALISA did focus on VTS operations.

MONALISA 2.0 defined the STM concept. It assessed the strengths and weaknesses of the current maritime ship- and transport systems, operations, and interactions, and defined a target concept and key performance indicators for four STM strategic enablers: It also developed the route Exchange standard and the European Maritime Simulator Network.

Ship-to-ship route exchange via AIS, sometimes referred to as S2SREX, is one of the first STM applications and has been evaluated in earlier STM development projects such as MONALISA 2.0 and STM Validation. In STM BALT SAFE, the focus has been on the potential effects of Ship-to-ship route exchange on the work of the VTSO.

1.4.2 STM Validation (Baltic Sea and English Channel EMSN simulations)

The STM Validation Project demonstrated the STM concept in large-scale test beds in both the Nordic and Mediterranean Seas. The key strategic enablers of STM were tested and validated. The project ran from 2015-2019 (project extension from December 2018 to June 2019). The project encompassed:

- About 300 ships
- 13 ports
- 5 shore-based service centers
- 13 connected simulator centers in the European Maritime Simulator Network – EMSN

1.4.3 Previous STM service research findings

The study by Aylward et al. [20] based on STM Validation project results is of high relevance for the present task. Key findings from this study were therefore used as a comparison material in the interpretation of STM BALT SAFE evaluation results. In this section, several relevant themes from this previous study are reviewed.

1.4.3.1 Chat functionality

The chat function allows sending and receiving written messages between two parties, either ship to ship or ship to shore (VTS). In this paper, the results are only provided between ship and VTSO (and vice versa). The chat function offers a private conversation forum between the two parties, in this current study chat function is included in the pre-implementation-interview and reviewed in the results. The study found that VTSOs used the functionality to supplement suggested routes sent from the VTSO to the vessels. The VTSOs often felt it necessary by to explain why the route suggestion was sent i.e. what prompted the suggestion. In the simulations the chat service was also used for providing information about location and timing for a pilot pick up. An interesting point that Aylward et al. make is that VTSOs in the simulation appreciated the chat function and thought it decreased workload. However, in previous simulations focusing on ship operations in bridge simulators, many had provided mostly negative feedback on the chat functionality, saying that it drew focus from the situation at hand and directed the eyes to the screen instead.

NB. The chat function was originally to be evaluated in the STM BALT SAFE project as well but was later omitted. However, since the function has been discussed previously it is also part of the Appendix A, which is further described in section 2.1.

1.4.3.2 Ship to shore route exchange and route cross check

There are two situations in which a route may be shared from ship to shore: (1) A ship plans a route to a port and sends it to the VTS for “review,” the VTSO may accept the route or send an improved route suggestion, and (2) a ship shares its monitored route with the VTS station. The study found that this functionality might increase VTSO workload as additional future scenarios can be predicted. However, the responses in the post simulation questionnaire also showed that this could have to do with the way the simulations were executed, as all routes of all participating simulated ships was available at once. Instead in reality the routes would be checked on a continuous basis.

1.4.3.3 Route based prediction tool

This prediction offered VTSOs to anticipate close quarter situations based on a ship's reported route and current speed. Aylward et al. writes in their article that *"The route prediction tool was one of the least used services during the simulations; it was used 18 times in the English Channel and 11 times in the Baltic scenario. The post-scenario questionnaire results indicate that this service ranked mostly "good" in terms of user-friendliness, and the potential impact on workload, and mostly "fair" in terms of appropriate information*" (p.327)

1.4.3.4 Route proposal (and shore based navigational assistance)

Route proposals was one of the more appreciated features in the study. They point to the fact that even in simulated situations where a high traffic flow and congestions was the case, VTSOs preferred the route suggestion tool over VHF-radio (Very High Frequency). These observations were later corroborated by the post-simulation questionnaire where this functionality received high scores on user-friendliness. However, results for workload swayed toward the negative scale for the same functionality.

1.4.3.5 Enhanced monitoring (cross track error)

In this study the vessel had to share its planned route, then the VTSO had to set cross-track distances considered safe for that vessel. The VTSO then gets an alarm for out of bounds vessels. However, this function was the least used in the simulation and as such the researchers could not draw any conclusions of its user-friendliness nor effect on workload.

1.5 Terminology

Verification, validation, and evaluation are terms commonly understood differently by different actors. In the context of the STM solutions here presented, the following definitions are used:

- *Verification* – determine whether a solution meets the specified requirements. Simply expressed: determine if the solution is built right according to pre-defined specifications (e.g. functional requirement specifications or standards).
- *Evaluation* – assess the general characteristics of a solution with respect to its intended purpose.
- *Validation* – determine whether the use of a solution results on the desired effects. Simply expressed: determine if the solution was the right one to develop.

These definitions are somewhat different from the ones presented in D6.1 [24], where no distinction between validation and evaluation was made.

2 Method

Human Factors evaluation in STM BALT SAFE has followed a sociotechnical perspective [25] with the ambition to understand how the interaction between people, organizations and technologies affect safety in the sea traffic system. To that end, analyses have concentrated on three levels of system abstraction:

1. The user and her immediate working environment, focusing on usability and ergonomics of VTS systems and tools affected by STM implementation.
2. The organization of VTS collaboration in the port and its surroundings, including other stakeholders such as port personnel, pilot services and icebreaker services.
3. Interaction in the greater context of ship traffic (including both STM and non-STM ships), focusing on VTS/ship communications, working practices for route planning and navigation and potential goal conflicts in sea traffic management.

The evaluation was performed using qualitative methods in a process consisting of three main stages – A first analysis using heuristics from the domain of Human Reliability Analysis, an interview study with sea traffic system stakeholders, and a VTS simulator study. The following chapters provide more detail around the methods used for each stage.

2.1 Heuristic analysis

As a first step, the evaluation team analyzed STM service descriptions using existing STM BALT SAFE documentation, applying Common Performance Conditions (CPC) [26] as heuristics to guide the identification of potential hazards. CPC is a development of a set of heuristics used in Human Reliability Analysis (HRA) called Performance Shaping Factors. These heuristics represent a wide array of factors that might influence safety-critical work negatively, spanning from the Human-Machine Interface, through the operator's immediate working conditions, up to the organizational context of work.

The aims of this analysis were to spur a first, open discussion around hazards and to create themes for the interview study that was to follow. This work resulted in a matrix of potential hazards connected to the introduction of STM, which can be found in Appendix A. As data collection and analyses progressed, the matrix was continuously re-assessed and elaborated.

COMMON PERFORMANCE CONDITIONS (CPC)
Availability of resources
Training & competence
Quality of communication
HMI & operational support
Availability of procedures & plans
Conditions of work
Number of goals and conflict resolution
Available time and time pressure
Circadian rhythm and stress
Team collaboration quality
Quality and support of the organization

Figure 1 - Common Performance Conditions used for heuristic evaluation

2.2 Stakeholder interviews

The evaluation team carried out 15 (fifteen) interviews lasting around 1 hour each, involving VTS operators from Sweden, Finland and Estonia, Swedish pilots and the Estonian Ice-breaker service, as well as representative for VTSOs in IALA a master mariner with STM experience and a previous VTS coordinator.

Role	Nationality	Role	Nationality
IB coordinator	EE	Captain 1	SE
IB captain	EE	VTS Coordinator	SE
VTSO 1	EE	Pilot 1	SE
VTSO 2	EE	Pilot 2	SE
VTSO 3	FI	Pilot 3	SE
VTSO 4	FI	IALA VTS repr.	N/A
VTSO 5	SE	CEO, Ship owner	SE
VTSO 6	SE	Sustainability manager, Port	SE
VTSO 7	SE	Sustainability manager, Ship owner	SE

Figure 2 - List of interview persons for hazard identification

Interviews were performed using a semi-structured approach, with the previously mentioned matrix of hazards providing a basic structure. Questions covered potential hazards proposed by the evaluation team, while also leaving room for the informant's own reflections. At the beginning of each interview, depending on the interviewee's prior knowledge, an introduction was given to the STM services and their envisioned use. Questions dealt with all services deemed relevant for the role of the individual interviewee, but they also probed what dynamics the introduction of STM services might create in the overall traffic system. New themes that emerged during the sessions were used to develop the set of questions used in subsequent interviews.

Results from the interview study were used to further populate the hazard matrix, adjusting some existing themes while also adding new ones.

2.3 Simulator studies

Simulation scenarios were planned during three workshops together with the Swedish Maritime Administration. The first aim of these workshops was to test preliminary findings against the experiences and knowledge of participants from the administration. Secondly, participants worked to determine how the evaluation team's observations could be translated into operational scenarios for the simulations.

The simulator sessions, two separate rounds, took place in the Swedish Maritime Administration VTS simulator in Gothenburg. Each round was carried out over three days, where the first half of the time was dedicated to learning the system and the VTS area (all exercises were carried out in the Gothenburg archipelago and harbor). During this part, the scenarios were designed with the purpose to train operators in the different STM VTS Standard Operational Procedures (SOPs), which are further described in Appendix A of D4.3 [27]. The other half of the time was spent performing 'applied exercises' on scenarios created with the purpose of evaluating the STM services. Each scenario was carried out at two different VTS stations simultaneously and the VTSOs were working in pairs to facilitate working with a new VTS system and, in some instances, working in an unfamiliar VTS area. Sometimes a VTSO would man a VTS station together with a project partner – someone familiar with the VTS work, but not a VTSO. Test group compositions are presented in Figure 3 below.

Week 1	
Swedish VTS Area 1	2 persons
Swedish VTS area 2	1 person
Finish VTS area	1 person

Week 2	
Swedish VTS Area 1	1 person
Swedish VTS area 2	1 person
Estonian VTS area	3 persons
Norwegian VTS areas	3 persons

Figure 3 - Simulator test group compositions

The STM software available in the simulator did at this point not offer full STM functionality as described by the STM Use Cases in section 1.2. Tools existed for:

- Sending of routes from ships to the VTS. In the simulator, the routes had to be sent as the exercise started and because of the length of each session (30 or 60 minutes), the ship normally had to be in or near the VTS area when sending the route.
- Display in the VTS station of multiple shared ship routes (with manual route crosscheck)
- VTSO manipulation and proposal of received routes (on a separate computer and screen)

- Route deviation and Close-Quarter Situation indication through color change of the ship icon and a notification in the alerts window (however, alert settings were not identical at both simulator VTS stations, and the color indication was also used for all other types of activated alerts).
- Prediction of close-quarter situations and forbidden meetings (Predicted Rendezvous), i.e. a slider tool projecting future movements of ships along their communicated routes. Predictions were only made using the ship's current speed. For non-STM ships, the current vector was used for predictions.

All sessions were recorded on video, with one camera capturing the operators at their workplace, and a screen recording tool capturing events on the VTS simulator screens. Voice communication was also captured using the same tools. See setup in Figure 4 - VTS simulatorFigure 4 below.

Figure 4 - VTS simulator setup

During the sessions, participants were equipped with a form for notetaking and were encouraged to note any spontaneous observations, negative or positive, around the functioning of STM services. In addition, two questionnaires were administered during the three simulator days. The first of these questionnaires was geared towards the perceived usability of the STM services in the existing implementation, while the second questionnaire focused on potential safety implications of STM introduction. These questionnaires can be found in Appendix B and C.

After finishing the third day of simulations the participants were invited to a group interview where the evaluation team posed questions based on the hazard matrix, the results from the two surveys and on observations from the simulator sessions. The group interview conducted after the first round included the whole group of VTSOs, while the second week the group was divided in two.

2.4 Limitations

Given how few VTS operators had prior experience of STM functionality, individual interviews and simulations were chosen over a complete HazId-setup. Through correspondences prior to and after interviews, as well as during simulations, many benefits of a more interactive investigation such as a HazId were still achieved.

During the first simulator week the participating group was smaller than desired, due to issues with recruitment caused by the situation with COVID-19. During this week there were also issues with the software, causing some disturbances and at times making the

Route Proposal service inoperative. Disturbance was caused by simulator environment technicalities, i.e. ship models' and routes' relationships to IMO numbers.

Furthermore, in contrast to the STM BALT SAFE vision of service functionality as described in [24], the following was not included in the software:

- There was no function that would enable the VTS operator to define CQS differently considering the size of the ships and their location (e.g. open water, fairway).
- Forbidden meetings were not automatic, but instead to be performed manually with a prediction tool, looking at the restricted area.
- Route Crosscheck was not automatic, but instead had to be performed manually.

3 Results

3.1 Charting of potential hazards

Development of a matrix representing potential hazards associated with the introduction of STM services began at an early stage, starting with a heuristic analysis informed by project partners, with complementary information coming from a stakeholder interview study (see *Chapter 2 Method*). This matrix describes hazards on many levels of system abstraction, ranging from the VTS operator's immediate working environment up to interactions among different stakeholders in the sea traffic system. It also examines the process of STM implementation, e.g. touching upon hazards connected to verification/validation and the adaptation of STM services to individual VTS stations. This section provides short descriptions of those hazards that were deemed the most relevant after calibration against the Swedish Maritime Administration and operative stakeholders.

3.1.1 VTSO workstation ergonomics

As STM services make more information available to the VTSO, care must be taken to make this information usable and accessible. Several general remarks were made by interviewees saying that increased visual route and ship information could clutter the display, causing delays and increased workload for the operator. For example, depending on the particular Human Machine Interface (HMI) implementation, the toggling of routes on and off could become a repetitive and disruptive practice. An issue related to this would be if the difference between STM- and non-STM ships is poorly represented on display, seeing as interaction between the two would likely be somewhat different. Likewise, when a lot of route information is displayed on-screen, it could become more difficult to discern non-STM ships. On the subject of auditory and visual alerts, according to interviewees, increasing the amount of alerts would warrant more attention to issues such as noise.

3.1.2 VTS operational routines and workflow

Issues concerning workstation ergonomics are closely tied to the subject of operator workload, where a few different themes appeared during interviews. Firstly, it seems likely that VTSO interaction will differ somewhat between STM and non-STM ships. This could entail two sets of work practices that need to be implemented simultaneously, which could introduce a higher workload in VTS operations. There were general remarks during interviews that more alerts could affect the order in which operators address potentially hazardous situations, and if alerts are given more prominence, then they should also be timely, so that attention is guided towards the most important tasks at hand. For example, it is quite possible that alerts may appear for future situations that the operator must assess or act on later, and a system could support this pairing of alerts and future actions. Operators already use written notes as an aid, but with more information to process, notetaking could become more strenuous and difficult to structure.

A final theme that emerged in connection to operational routines was connected to VTS organization. Interviewees commented on the fact that VTS is implemented differently in different countries, corresponding to different levels of authority in the traffic system – as an information service, navigational assistance service or traffic organization service [28]. New tools available to the VTS, such as STM, may increase the ability of the service to identify hazardous situations. On the other hand, the extent to which ships adhere to VTS input may depend on its authority, stemming from national legislation.

3.1.3 Proactivity in VTS operations

According to several interviewees, one of the main visions of STM implementation is to increase foresight and proactivity in VTS operations, detecting hazardous situations such as route deviations or close-quarter situations earlier, thus enabling earlier intervention.

While additional route information allows operators to look further into the future, enabling them to be more proactive, the total amount of information to assess increases. At the same time, information regarding potential events far into the future would likely be associated with uncertainty. Here, there is a hazard that operators spend too much time trying to assess a bulk of information which is to some extent unreliable. A similar pattern could emerge for alerts connected to possible future ship movements. Alerts could be given for situations that, in the end, resolve themselves through normal ship route adaptations or ship-to-ship interaction. This seems to imply that the practical implementation of STM-associated alerts will have a large impact on their perceived usefulness, and, as a consequence, VTSO trust and usage of alert information. A lack of trust could in itself lead to operator double-checking of information, thus increasing workload.

During interviews, the evaluation team also proposed a development often associated with digitalization in control environments such as control rooms or cockpits. With increasing automation and associated alarms, the work of operators may approach a “driving to alarms”, i.e. where operators mostly react to partially untransparent system actions, giving less room for operational strategy and situation awareness. However, interviewees responded that operators often have quite a large influence over alert conditions and thresholds, allowing them to tailor alerts to the needs associated with their working context.

3.1.4 VTSO-ship interaction

Interviews suggested that the work of a VTSO is heavily dependent on voice communication. Communicating with ships over VHF radio not only allows the stakeholders to make agreements that prevents hazardous situations. For example, it also allows the VTSO to gauge the status of a ship’s crew and command, e.g. whether an officer-on-watch is aware of the traffic situation, fully awake or even sober. With increasing digitalization and new ways of sharing that information, the evaluation team suggested that the use of VHF radio might decline or lose its importance. This was partially disaffirmed by interviewees, who believed that operators will probably continue using radio communication because of the many different functions it fulfils. Furthermore, interviewees noted that if STM services enable text-based or graphical communication of routes of traffic information, then that would decrease the risk of misunderstandings, something that can sometimes be an issue with VHF communication. VHF signal quality may sometimes be poor, and one interviewee also stated that “It is difficult to see that some of the seafarers fulfill the STCW requirements on proper English. It has happened that the officer-on-watch has to go wake up a sleeping captain so that they instead can make themselves understood“. On the other hand, if more information was to be communicated peer-to-peer instead of being broadcast to all stakeholders listening to the VHF radio, then information could perhaps become less accessible or obscured for certain actors.

As a more general remark, some interviewees commented that the quality of STM-assisted VTS-ship interaction will depend on how STM services are implemented and used on the individual ship, something that could also be affected by technical issues such as poor connectivity. Depending on the way STM functionality is implemented in the ship’s Electronic Chart Display and Information System (ECDIS), bridge workload could be affected negatively. It was also noted that the working culture can differ greatly between ships. In certain contexts, navigators follow the pre-defined route very closely, maybe even to the detriment of situation-based navigation. Here, one hazard suggested during interviews is that a such a navigator would follow a route suggested by the VTS without taking local conditions (e.g. other ships or hindrances) into proper account.

One issue that was discussed in several interviews was the timeliness of VTS interaction with ships in the traffic area. According to one interviewee, operators are trained to be mindful of the operative circumstances that a ship is facing, and that during an incident, there is a point where the crew should be left alone to focus on managing an acute situation. One hazard, suggested by the evaluation team during interviews, is that alerts produced by STM services might lead the operator to react without this discretion, causing untimely interaction with the ship. This hazard, according to interviewees, would depend heavily on the operator's training and the practical implementation of alerts in the user interface. On the other hand, it was also argued that one of the core purposes of STM is to support early intervention, and that STM functionality should instead decrease the amount of late, untimely interaction with ships. On the other side of the spectrum, as mentioned above, there is also the risk that the VTS uses information produced by STM services to make predictions with too much uncertainty, issuing information to ships that in the end proves irrelevant. Countering for this hazard, according to interviewees, is a matter of adapting STM practices to local conditions.

3.1.5 STM implementation

Interviews included several persons who had personal experience of prior technical modifications of VTS equipment and software, where there had been no effective communication between manufacturers and the end users (i.e. VTS operators). Interviewees noted that there may be a need to adapt new digital services to local conditions on the individual VTS Centre, e.g. with regard to local traffic density, geography, existing equipment or technical readiness. Few interviewees had experienced any structured user requirements elicitation during the development of STM services, and this was perceived as an important point to consider as STM implementation proceeds.

3.2 Simulation Evaluation

The initial goal of the simulator study was to investigate how the handling of specific operational scenarios was affected by STM services, in particular the operator's handling of events for STM and non-STM ships respectively. However, this plan was changed for different reasons. The work of going through the videos and comparing situation by situation was judged unreasonable in comparison to the data it could provide. The participating VTSOs were unfamiliar with the system used in the simulator and expressed that the user interface was not as expected. This also affected the relevance of looking at specific events in the recordings, since it proved very difficult to distinguish the impact of STM services in themselves from disturbances related to system usability (such as screen clutter).

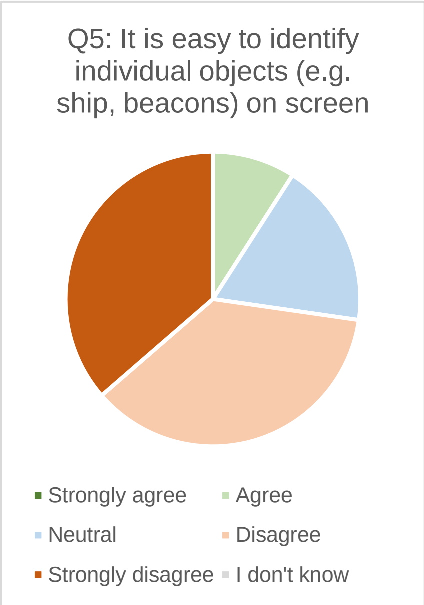

Figure 5 5- Questionnaire result - only one participant chose a positive answer related to object identification on screen.

In response to this, the evaluation shifted its focus to other qualitative purposes. The simulation was instead regarded as a way for the participating VTSO's to get a full understanding of the STM concept and what its implementation could entail. Based on a common understanding of STM, it became easier to discuss potential risks and benefits. This is also expressed by one of the participants in one of the discussions:

> *It's the first time to see how the system works. Before, we just imagined or maybe read some booklets or papers [about STM]. But to use the system, it gives you a real feeling. As you see we have some criticisms and some good things, and we already can imagine how the system should be changed to be more user friendly. (…)*

This section presents results from simulation interviews and questionnaires. The questionnaires and response distributions can be found in Appendix B-E.

One participant explained that in his opinion, the main reason for accidents is uncertainty. With STM the ships will give very precise information about their intentions and reduce the uncertainty very much, meaning that safety should improve with the use of STM.

In the questionnaire (see Figure 6) all participants either stated that STM is likely to reduce accident risks or that they do not know. One participant completed his answer with a free text answer saying that to answer that question he must use STM in a VTS area that he is familiar with.

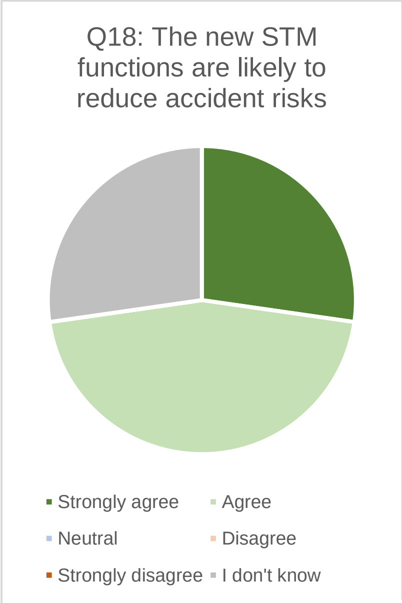

Figure 6 6- Questionnaire results

3.2.1 User interface and usability

While the purpose of the simulations was not to evaluate any specific solution or user interface, given the potential safety impact of poor usability, this was still introduced as a topic in questionnaires and interviews. According to participants, some important aspects that need to be designed carefully in any STM compatible VTS system are, but not limited to, the following:

- Ship and chart symbol sizes: in relation to screen size, other symbols and, for ships, in relation to the ship's size.
- Route visualization:
  - Quick identification of the route for a specific ship.
  - Quick identification of which route belongs to which ship.
  - Ensuring that overlapping routes are easily distinguished
  - Is it of interest to see the part of the route already travelled?
- Distinguishing between STM and non STM ships: you should not waste time searching for information that is not provided, i.e. searching for routes for a non-STM ship.
- Configuration possibilities and flexibility in use (e.g. for prediction time limits and alert thresholds). in order to meet the different needs of the different VTS areas.
- Ergonomic implementation of alarm and alert sound and visualizations, so that they do not disturb the flow of work or become a working environment problem.
- Smart implementation of alarms and alerts, ensuring that they are relevant and that their call for attention stand in proportion to their importance and urgency.

3.2.2 Influence on situation awareness

On the whole, the participating VTSOs could see that STM would improve traffic situation awareness and that it provides a good overview of where all ships are going. In the questionnaires, only one participant had something negative to say about the impact on traffic situation awareness (see Figure 7).

However, there is also a fear that STM routes may be treated as an objective reflection of reality and that change of plans might not be accounted for – as mentioned in the section **Error! Reference source not found.** above. One participant even said that perhaps you have a more realistic view when you look at the traffic without the routes because then you are more open for changes and that there is a risk that you would assume that a ship is going to follow its route, with a negative effect on vigilance.

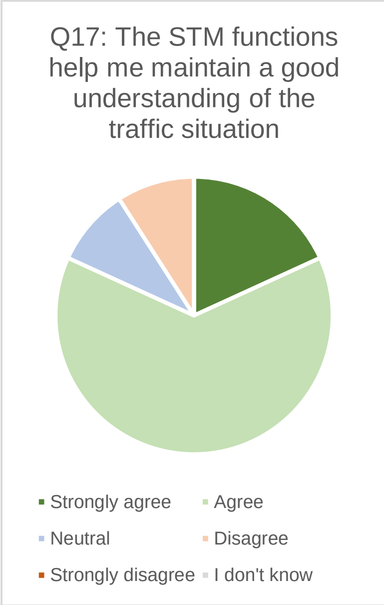

Figure 77 - Questionnaire results

3.2.3 Impact on workload

In the questionnaire, most of the participants responded that the STM services would help to reduce workload (see Figure 8). Although some found them to increase the workload, that is not necessarily a problem. It was said that this is an additional tool and additional information, which makes the workload increase, but it can at the same time improve safety and reduce pressure by allowing more proactivity. However, the usability of the system plays an important part, and although STM as a concept might outweigh the negative impact on workload, that might not be the case if the system is lacking in usability and user experience. It should also be noted that assessments of workload during simulations are likely to have been severely affected by contextual factors, i.e. several operators working in an unfamiliar traffic area, making their first acquaintance with STM functionality, in a system that did not reflect an interface in commercial implementation. But although some find it increasing the workload, that is not necessarily a problem. It is said that this is an additional tool and additional information, which makes the workload increase, but it can at the same time improve safety and reduce the pressure.

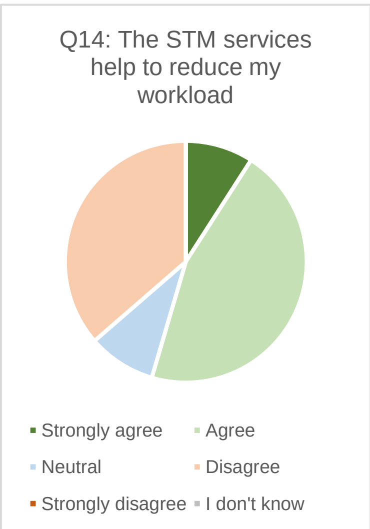

Figure 8: Questionnaire results

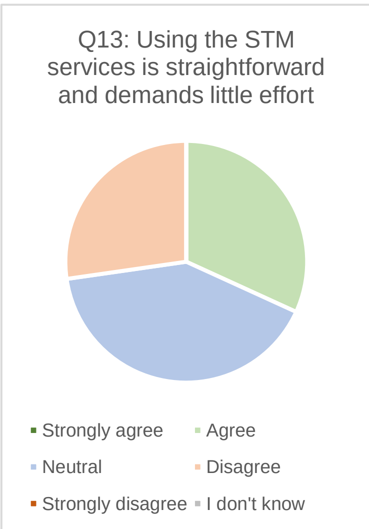

Figure 9: Questionnaire results

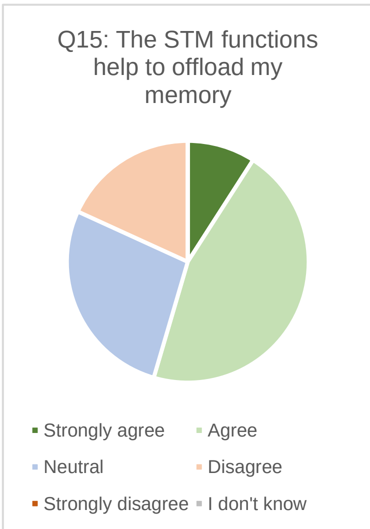

Figure 10: Questionnaire results

3.2.3.1 Alarms and alerts

The most important thing regarding *alarms is that the alarms showing is relevant for the operation, otherwise it is useless.*

In order for alarms to be relevant, based on operator feedback, it is clear that they must be filtered with some intelligence. For instance, in some of the current VTS systems it is possible to create alarm zones, but with the limitation that *all or no* ships will set off the alarm. In such a case, some types of ships could be allowed in that zone but still trigger alarms. If STM is to bring additional alarms and/or alerts, this 'all or nothing' is not desired. For instance, a pilot boat approaching a waiting ship should not trigger a collision course alert, and the relevance of a route corridor deviation is dependent on the surrounding waters and traffic. The presentation of alarms was also mentioned:

I think you must work with the visualization of alarms so that it is not only one level – instead it could be gradual so that if a ship is making a small deviation, we don't get a full alarm. Especially if you are working in the system at the moment. If the system catches you using the mouse, zooming and following the ship, only a small visualization is necessary.

And:

It depends how they are presented to the operator. Either there will be sound alarms or there will be visual. If it goes beep beep beep, we will switch it off, but if it's just switching a color black to red, then I can see that she's off the route but it's not disturbing me. That would be okay. I would like that, but if it's something big and red and blinking, I won't like it.

3.2.3.2 Route sharing

3.2.3.2.1 Incoming routes

In the simulated scenarios, most ships would send their route when they reached the VTS area, but this would probably not work in reality, according to the participating VTSO's. They say that to be able to check routes, they would have to receive them beforehand, perhaps 24 hours prior entering the VTS area. Low-intensity periods can be used to check incoming routes. It is also pointed out that if the VTSO is to approve routes, there must be support for change logs, so that an operator on the next shift can see what is already agreed or changed. Another aspect of the wish to get routes in advance is that they would not ask a ship to change the route while they are sailing in the VTS area. If a ship would have to sail differently once already in the VTS area, that would be managed through verbal information and not through route sharing or editing.

3.2.3.2.2 Route proposals

One participant, working in an Estonian VTS area, shared his experiences from a couple of winters when the entire VTS area was covered in ice:

From the first reporting point we had to give ten or twelve waypoints. Mariners are usually from all over the world, and they understand the number pronunciation differently and you often have to do a lot of work to give the waypoints. You repeat, repeat, repeat and finally they understand. So, if you are doing this, the other traffic is not getting so much attention. (…) Twelve waypoints is a huge amount of numbers. (…) Often, we have people from winter navigation updating the routes because wind, weather or ice conditions have changed and they recommend new routes and we have to contact them again. It was just a couple of hours ago that we gave them twelve waypoints and now we *have to give them another ten new waypoints. It's very time consuming. We could surely use that [route proposals] there.*

It is also mentioned that route proposals could be very useful when showing where a specific pilot station or anchor point is located. As opposed to asking a ship to edit a route while sailing in the VTS area, using route proposals to show the way to an anchor station, is something that might be considered while the ship is already in the VTS area.

3.2.4 Impact on communication

In the questionnaire, only one participant disagreed with the statement that the STM functions make communication with ships easier (see Figure 11). Participants believe that STM would reduce radio navigation and that ships would not have to communicate their intentions over VHF in the same way, and naturally that their intentions would also be clearer. They do not see that things as reporting points would disappear – the reporting point also serves a function of checking that the officer is not sleeping and that the ship has changed to the correct frequency.

Some mentioned a couple of times that they see a benefit of introducing a chat function, but that chat communication should not be allowed, or at least would not be suitable, while sailing through the VTS area. Then VHF should be the only option.

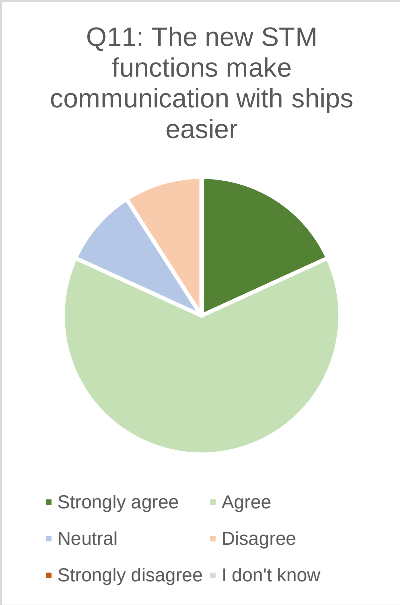

Figure 11 -11 Questionnaire results

3.2.5 Standardization and flexibility

Related to route sharing, there were also discussions about whether the routes should be flexible or standardized. Standardized routes could be quality assured and could be very useful when foreign vessels reach the VTS area for the first time:

If there are new vessels coming from abroad that have never been to Norway before, you cannot assign them to make routes for Norwegian areas. Then they must be able to select standardized routes. (…) The agent will select "from" and "to" and will be given routes that are approved.

Competence among VTS operators varies globally, and some participants believe that some VTSOs in other regions would not have the competence for making nautical routes, in which cases pre-made routes could be useful.

But introducing standardized routes would also come at a cost:

The problem with standardized routes is that you would limit the flexibility that the fairway and navigation actually offer. You would get everyone on top of each other… it.

It is also mentioned that some VTS areas are much affected by weather and wind and that it would not be feasible to have one route that would work during all conditions. Regardless of whether routes should be standardized, standardized with fixed workarounds, or completely flexible, all variants come with their own challenges and risks.

3.2.6 Predicting traffic and proactivity

The questionnaire shows that all participants agree that STM would help the VTSO to be more proactive, see Figure 12.

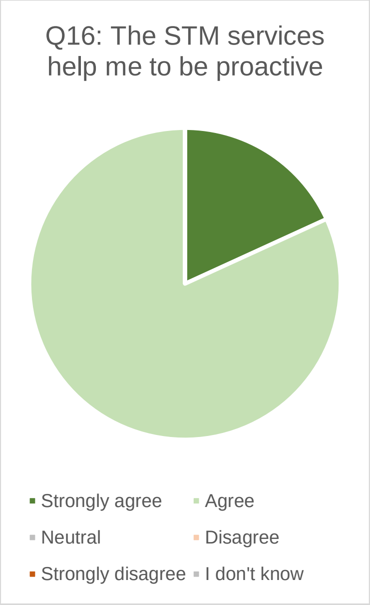

Figure 1212 - Questionnaire results - Participants think STM will improve proactivity

In the simulator, a tool existed that allowed the operator to predict traffic movements. It would use the ship's current speed and direction if it was a non STM ship and the current speed and route if it was an STM ship. To be able to use routes when predicting was very appreciated and most of the participants said that this could possibly be the most used STM feature. One group was asked how far ahead you can predict:

- *Ten minutes perhaps…*
- *The further out on the sea, the longer ahead you can look. In the harbor, shorter.*
- *In our area it is three to four hours from the south border to Oslo. If everyone would plan their routes correctly, I think I would use it to see what the traffic in Oslo will be. And then it would be predictions three to four hours ahead.*

It is clear that risks related to predictions, or rather false predictions, increase with time. For instance, the wind could cause a ship to lose speed and thus change the traffic situation. One participant also discussed whether a VTS operator could risk being *too* proactive:

(..) Say a vessel is leaving from Immingham and sends me the route, while another vessel sends me their route and tells me that they will departure from Gothenburg in 24 hours. The two vessels would then meet in this created no-meeting zone north of Böttö [a zone created for the sake of the exercises]. I can see a situation where the VTS operator tells the vessel leaving from Immingham to slow down right now for five minutes because you are going to meet another vessel in 24 hours in a no-meeting zone. That would not, to me, be providing the correct information at the correct time.

The same participant later brings up another example of information at the wrong time:

If you see, let's say that in three hours, some vessels will meet in a no-meeting zone, then it gets stuck in your head, and you can't forget it. You keep checking. Check, check, check and then forget something else. So too proactive information might also be bad. (…) You keep simulating the situation and then after five minutes you simulate it again.

3.2.7 Distribution of responsibility

In discussions around route proposals, some participants raised the issue of responsibility in the case of an incident. It was argued that if VTSO's receive the ability to create, alter and prescribe routes, if this functionality is not matched with clear rules and regulations, then they may be held accountable if a route that they have recommended leads the ship into an incident. For example, one participant stated:

I'm afraid that it might cause a situation where someone mistakes that the responsibility might be on the VTS to check the route, when it's de *facto the ship. And you shouldn’t rely on anyone else besides the ship’s crew.*

In another group it was also said:

> *If we’re going to share all these routes, there needs to be a disclaimer this big [extends his hands]. Here are routes. Use them – maybe. If you dare.*

4 Discussion & conclusions

4.1 User adaption of STM services

Even with the limited range of nationalities and VTS areas represented in this study, it is clear that STM usage is bound to vary between both nations and regions, depending on factors such as local geography, traffic patterns and differences in national VTS regulation. Evaluation data suggests that the use of STM functionality is not appropriate for all operative conditions, and that implementation must be calibrated against the practical needs of local VTS operators. Here, a balance must be struck between allowing for local adaption of STM services and offering a uniform STM interface towards vessels moving between different control areas.

The evaluation also suggests that VTS services depend on effective collaboration between several local stakeholders (e.g. the Pilot Service, Port Services and Icebreaker Service). If these actors do not share a common understanding of operative conditions, then both efficiency and safety may suffer. When discussing local adaptations, it is also important to make a more detailed evaluation about the information needs of these stakeholders, and whether their interfaces towards STM services demand special attention.

Another important aspect of adaptation is the relation between VTS technical functionality and how these functionalities are put to practical use. Seeing that STM services could expand the operator time horizon and allow them to work more proactively, technical development should be combined with a review of local VTS procedures, making sure that the VTS operational approach (e.g. procedures for ship interaction or the functional level of VTS implementation) matches all the capabilities afforded by STM.

Regardless of how technically advanced the STM services become, their true functionality will be determined by how well they are adapted to VTS operator needs. Even though the objective of STM development is to enhance traffic system safety, a product that is poorly implemented with regard to usability and ergonomics may not live up to its full potential. On the contrary, if more information is made available to operators without making that information perceivable and usable, workload may increase and situation awareness may decrease, producing a negative net effect on safety.

Hazards related to workstation ergonomics mentioned in section 3.1.1 are very dependent on the specific software used. For that reason, several of these hazards could not be discarded, but will instead need revisiting at a later stage. Interviewees reported negative experiences from past VTS technical development, where system suppliers have acted with little regard to operational needs. This is a well-known but completely avoidable phenomenon in systems development. It is important that maritime administrations employ a consistent design process that caters for local VTS Centre characteristics and the needs of their operators. As work with STM continues, technical development should be augmented with an iterative development of VTS system user experience and usability. The following section describes central aspects of STM services usability and ergonomics that demand further studies in future development.

4.2 Need for continued Human Factors validation

As STM services reach a higher level of development, it will gradually become easier to identify and evaluate effects on safety associated with Human Factors. While the first step towards effective implementation is to employ a user-centered process, it is equally important to engage in a continuous process of verification and validation, taking all relevant STM stakeholders into account. It is likely that some issues only become apparent when the services have been fully integrated in operations, and ideally, at that stage there should still be room for feedback and system revisions. Aspects of STM that require a human factors validation are, but not limited to:

- New information provided to operators through the STM services should be presented in a way that does not introduce confusion or obscure information (e.g. cluttering of routes, poor visibility of ships/routes/geographical features).
- Alarms and/or alerts should be relevant, useful and communicated effectively. Irrelevant alarms or alerts can disturb the work of the VTSO, and even if only relevant alerts are provided, the sum of all alerts can still produce a poor working environment (e.g. with regard to noise). Several different information levels might be necessary, for instance a visualization in form of a color change for non-urgent events and audible alarms for immediate danger. It also appears that users need access to advanced alarm/alert filtering depending on factors such as ship attributes, environmental conditions and surrounding traffic.
- STM services should be coupled with sufficient support for notetaking and/or marking. With a larger bulk of information available to the operator (e.g. around possible future hazards) comes a larger need to support the operator attention and memory.
- STM functions should be useful over the course of several shifts. For instance, if routes are sent in advance, the VTSO first looking at the route and the VTSO assisting the ship in the VTS area might not be the same. Functionality such as a change log might be necessary so that ship interactions are traceable across shifts.
- Predictive tools (e.g. prediction of future ship movements and associated conflicts) could factor in prediction uncertainty, so that the operator is given a truthful representation of possible traffic development. As long as this functionality is employed manually by the operator, it can be used in periods of low intensity with few negative effects. If, on the other hand, predictive tools are automated to an extent, that could result in a much large volume of alerts for situations that, in the end, resolve themselves without operator intervention.
- There should be means of communication suitable for use with STM functions. Even though chat functionality was excluded from the STM BALT SAFE scope, some informants hold that other means of communication than VHF might be necessary if the ship is to send its route before reaching the VTS area. If this communication is implemented as a chat function, then such communication may not always be suitable for ships sailing through the VTS area. Some hazards observations related to chat functionality have been included in the hazard matrix (see Appendix A).
- Dynamics in VTS-ship interaction may be affected as new forms of communication develop. For example, even if the purpose of the VTS Centre is only to “inform” ships about traffic conditions, creating and sharing routes via STM services might be regarded as something more than a friendly suggestion. This invokes a discussion around VTS authority and responsibility in the event of an incident that needs to be continued.

4.3 A nautical perspective on results

While the simulations were carried out in the Gothenburg archipelago, participants in post-simulation interviews often based their reflections on their own VTS operational context. To broaden the perspective even further, additional operative conditions with a bearing on STM were identified based on the evaluation team’s professional experience, which is presented in this section.

One limitation for the VTSO, with or without STM services, is that he or she might lack the complete external environment and traffic awareness of a specific vessel. For example, situations can occur such as a hard wind impeding the planned turn radius of the vessel. This can be difficult to predict for the VTSO and consequently make route proposals difficult. Another example is if a STM vessel is caught in dense fog; then navigational ability of the STM vessel is depending on Collision regulation 19, which instructs how the vessel should interact with another during fog. A route proposal from the VTSO can be given for good visibility that can contradict the wider margins that the STM vessel must follow in this case. Hopefully the handshake will take care of the vessel's situation, but there can be some risks connected to this type of exchanged ambiguous information. Different view can have an impact on the usage of the route planning and proposal due to COLREG R 19.

Furthermore, it is also well established that VTSO does not have full control or awareness of the movements of smaller ships and boats in the area. Thus, from a VTS route proposal point of view, we cannot rule out the possibility of “an element of surprise” that STM vessels or other vessels make a small turn, which goes unnoticed to the VTSO. Given these risks that VTSO awareness are subjected to, it could still be argued that there are overall benefits of using STM functions, seeing that they contribute to overall safety of vessel traffic.

Another navigational example could be a STM vessel sailing over the Baltic Sea towards Helsinki. The STM vessel is scheduled to cross a Traffic Separation Scheme (TSS) area about which it lacks information and traffic awareness. STM route exchange can be useful in this case because it will help the vessel manage as well as plan the time of crossing with lower number of vessels at the time of crossing, thereby avoiding any potential CQS. Thus, VTS with its complete traffic and Maritime Safety Information (MSI) picture in the TSS area, contributes in this case to an overall vessel traffic safety management. This can be achieved by either slowing down or increasing the speed of the STM vessel, which can be easily recommended by the VTSO in the TSS area. Another area where STM services such as route proposals could be argued to strengthen the safety of navigation is in areas of innocent passage where pilot obligation cannot be prescribed, for example in the Öresund region “VTS Sound”.

The time horizon of using the STM services may be divided into short and long-term. The short-term has a more navigational perspective, while the long-term has a more traffic safety perspective. Starting with the short-term navigational perspective, where users onboard of STM vessels need quick solutions, VHF traffic communication may be preferred over a STM solution. Interestingly, there are also usability and familiarity aspects that play significant roles in setting this preference. To put this further in context, historically speaking, when VHF traffic communication was introduced, it was also perceived as a challenge and argued to have increased risk much like the perceived risk in CQS. Thus, with the introduction of STM services and route exchange, one may believe that the needs of VHF traffic communication will be decreased or may no longer be seen as necessary as before. However, what is observed in the simulation is a more short-term approach to navigation to avoid immediate impending navigational risk. To summarize, users are more likely to access a simpler solution, which they are more familiar with, which is to pick up the VHF for voice communication. If we instead look at the long-term traffic safety management perspective and consider a low traffic density and low workload case outside archipelago navigation, there is more time to manage routes in advance. Naturally, how long in advance the route is managed, will be determined by critical factors such as traffic circumstances, workload, and onboard navigational skills.

4.4 Conclusions per use case

This section presents conclusions related to specific use cases. Hazards are followed by suggested ways of addressing or eliminating them in future development of STM.

4.4.1 UC1 Close quarter situation

No automatic prediction of close quarter situations was evaluated.

4.4.1.1 Semi-automatic close quarter situation prediction

- A slider tool that is projecting future movements of ships along their communicated routes is found to be useful. For predictions in the nearest future, it is also possible to consider non-STM ships, provided that they continue with a heading similar to their current vector.
- Predictions are associated with a certain level of uncertainty, due to factors associated with both with the ship itself and overall traffic system dynamics. One prospect might be to visualize this uncertainty, as a way of supporting operator attention and decision-making.

4.4.2 UC2 Cross-track alarm

- The relevance of a cross-track alarms is dependent on circumstances such as ship characteristics, surrounding environment and surrounding traffic.
  - The cross-track might need to be dynamic, and change based on the surrounding circumstances.
  - The level of attention that the alarm (or alert) claims could also increase with the deviation and in relation to surrounding circumstances.
- In interviews, some have claimed that in existing systems, “loose boundaries” have been set to avoid triggering too many alerts. System adherence needs to be further evaluated. As an example, one interviewee said: *“In vetting, it is said that ships must not go beyond cross-track error. Then ships bypass it by setting an excessive cross-track error.”*

4.4.3 UC 3 Route proposals

- Route proposals are seen as a useful service that can reduce misunderstandings due to voice over VHF communication.
- To decrease workload, the VTSO could be provided with a library of pre-defined routes. However, this can introduce risks such as choosing routes that are not suitable for the type of ship, or due to other factors such as weather conditions.
  - Consider adding tools that help the VTSO avoid such risks.
  - It is necessary that the VTSO is always allowed to make manual adjustments to pre-defined routes as well as proposing routes without using a route library.
- VTSO competence varies globally and the education and/or experience requirements for the role might not be high enough to be suitable to draw nautical routes.
- The VTSO might be reluctant to send route proposals (and approve routes) if it is not clear who is legally responsible.
  - Introduce clear regulations stating what level of information route proposals (and approvals) are.

4.4.4 UC 4 Forbidden meetings

No automatic predictions of forbidden meetings were evaluated.

4.4.4.1 Semi-automatic forbidden meetings predictions

- By seeing the ships’ routes and being able to predict the traffic, STM is seen as a helpful tool to avoid forbidden meetings and improve safety.

- With traffic prediction, uncertainty increases the further into the future the VTSO sees.
  - Further research how the VTSO could be supported in dealing with uncertainty. For instance, for traffic predictions long ahead, the system could visualize how speed adjustments would impact the situation.
- The success of forbidden meetings predictions is very dependent on the ratio of STM to non-STM ships.

4.4.5 UC 5 Automatic route crosscheck

- Automatic route crosscheck was not evaluated. However, in interviews a common fear was that the automation of any service now performed by a master mariner, pilot or VTSO would lead to an inability to act accordingly when the system fails, or noticing when it does fail.

4.4.5.1 Manual route crosscheck

- The workload of the VTSO can increase too much if he or she must manually review routes.
  - By receiving the routes well in advance, the VTSO can go through routes during periods with low workload. Regulations should say how long in advance before reaching the VTS area the routes should be sent.
- Departing ships and ships with short trips may not be able to send routes in enough advance, which may increase the workload of the VTSO.
  - In regulations mentioned above it should also be included how and if route reviewing is possible for such voyages.

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Appendix A

Hazards matrix

No	STM USE CASE	POTENTIAL HAZARD
01	01 Ship-to-ship route exchange via AIS	VTS rendered out of the loop if ship-to-ship exchange is not transparent.
02	02 Route proposals	Pilot resistance towards route suggestions, e.g. rendezvous point pilot/ship or ship route when piloted
03	03 Close quarter situation predictor	VTSO confuses the situation at sea by interfering in an already stressed situation.
04	04 Cross-track error alarm	System latency - for how many legs will forbidden meetings be displayed and alarmed - problems with bridge "clicking away" alarms. Adding workload.
05	05 Forbidden meetings	System latency - for how many legs will forbidden meetings be displayed and alarmed - problems with bridge "clicking away" alarms. Adding workload.
06	07 BIMCO STM clause	Just-in-time arrival comes in conflict with the current pattern where there is money to be saved by arriving and anchoring as early as possible
07	07 BIMCO STM clause	Difficulties in predicting exact departure times make it more difficult to plan for arrivals, e.g. in harbours with limited space where ships have to leave room for each other
08	07 BIMCO STM clause	The ship's optimization towards its own goals (e.g. hurrying for departure) comes in conflict with the BIMCO service coordination
09	07 BIMCO STM clause	Time available for downtime shipboard activities (rest, maintenance) is lost because of just-in-time arrival
10	08 Estonian icebreaker service	Route sharing of IB and its way-points does not update fast enough and thus misinformation is relayed to escorted vessels.
11	08 Estonian icebreaker service	On the IB Bridge- the Ice-conditions (2 screens ICE-NAVS and ICE-charts) and ECDIS are on three different displays with different vessel categories on each. The captain did not view this as difficult to merge the images.
12	09 Automated ship reporting	VTSOs losing control of the covered area - leading to loss of situational awareness
13	10 Chat communication	If chat is closed (i.e. not forum-format) this cancels out the VTSOs VHF ability to over-hear ship-to-ship communication. Similar to S2SRX.
14	10 Chat communication	If chat is open (i.e., forum-format) for an entire VTS-area the flow of information could be to fast making both bridge crew and VTSOs miss information in the flow.
15	10 Chat communication	At which point does a VTSO escalate communication from text to VHF?
16	10 Chat communication	Misunderstanding is common with AIS-messages (difficult to control that information has been received and understood.)
17	10 Chat communication	Poor English skills is the most common source of miscommunication, second to poor VHF audio quality. How will language/typing issues translate to the use of a chat function?
18	10 Chat communication	As all can listen in on VHF radio channel 13, it is important to be sparse and concise about the information sent and received. What would be the same praxes for text messages?
19	All services	Workload increases as VTSO is forced to apply two sets of work practices for STM/non-STM ships (mixed traffic). Risk of confusion.
20	All services	STM is not used consistently by ships because of connectivity issues, resulting in workarounds/increased workload
21	All services	VTSO attention/memory of traffic information is inhibited by the move from written notes to automated alerts

22	All services	Pilot does not have an appropriate interface to STM route management, thus hindering VTS/pilot ship route negotiation (e.g. rendezvous point, time)
23	All services	A shift towards more VTSO double-checking, following up on the outcomes of automated functions, causes an erosion of VTSO competence. Trust as an issue. VTS does not trust the automated service to identify all hazardous situations, leading to additional work double-checking in information.
24	All services generating alarms	A bias develops towards control of certain parts of the control area, where more alerts are triggered
25	All services generating alarms	VTSO actions are driven by alerts prompting them to interact more with ships in situations where crew workload is high
26	All services generating alarms	Usability - A large bulk of alarm causes the VTSO to "drive to alarms" leaving less time for anticipatory/proactive work
27	All services generating alarms	Alarm trigger levels cause generation of false alarms / failure to generate appropriate alarms
28	All services generating alarms	Will an alert always demand an immediate action from the VTSO or may the action need to be delayed? In that case, how does the VTSO keep track of "alert/action pairs"?
29	All services generating alarms	Will there be a difference between the order of action imposed by the alert queue and the order in which operators deal with different ships today? Will the appearance of alerts disturb the timeliness of VTS/ship interactions?
30	All services generating alarms	Is there a risk of alerts being issued to early, i.e. for situations that will be resolved naturally as the situation progresses?
31	All services generating alarms	Have all cues to potential ship issues been mined to inform smart alarms? Some examples mentioned by VTSO are variations in speed, distorted reporting, false information, information that does not add up (e.g. around time of arrival)
32	All services with graphical representation	Difficult for the VTSO to tell STM and non-STM ships apart, resulting in increased workload.
33	All services with graphical representation	Representations of routes, meetings etc clutter the ECDIS display. No way to mentally offload the VTSO because all ships are represented in the same way graphically.
34	All services with graphical representation	Difficult to perceive non-STM craft in the ECDIS
35	Implementation	Implementations are made with poor usability
36	Implementation	Implementation does not take local VTS area characteristics into account, leading to inhibited use of STM services
37	Implementation	Local technical level of development (e.g. hardware, display technology) does not afford an effective implementation of STM services
38	Implementation	Local adaptations and corrections of the implementation are missed due to absence of V&V plan.
39	Implementation	A mismatch develops between technical VTS capabilities and their formal level of authority, i.e. the potential benefits of STM services do not materialize because of lack of authority.
40	Shipside	How does increased ECDIS use, textual communication etc affect bridge workload, e.g. when manning is low?
41	Shipside	Are there any risks involved when the ship is expected to substitute a long-planned route with one suggested by the VTSO? Could there be route considerations that are not transparent for the VTSO? Will this cause resistance from the ship?
42	Shipside	May increased reliance on the planned route and adherence to the "line" decrease the crew's contextual adaptation and situation awareness?

Appendix B

Evaluation survey 1

STM BALT SAFE SIMULATOR EVALUATION

Survey – First day impressions of STM services

Name:

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	I don't know
The new STM functions are easy to learn	☐	☐	☐	☐	☐	☐
Alerts and route handling tools use familiar VTS terminology	☐	☐	☐	☐	☐	☐
The new STM services are easy to integrate in my normal workflow	☐	☐	☐	☐	☐	☐
Using the STM services is straightforward and demands little effort	☐	☐	☐	☐	☐	☐
The services target the most important hazards in the traffic system	☐	☐	☐	☐	☐	☐

Do you foresee any issues or risks around the STM services after this first day?

What do you see as the main possible benefits of using the STM services?

Other comments:

Appendix C

Evaluation survey 2

STM BALT SAFE SIMULATOR EVALUATION

Survey – STM services evaluation

Name:

System Interaction

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	I don't know
Using the system is a pleasant experience	☐	☐	☐	☐	☐	☐
The system responds quickly to my actions	☐	☐	☐	☐	☐	☐
It is easy to manage the display of routes on screen	☐	☐	☐	☐	☐	☐
There is little risk of incorrect actions using the STM services	☐	☐	☐	☐	☐	☐
It is easy to identify individual objects (e.g. ship, beacons) on screen	☐	☐	☐	☐	☐	☐

Comments:

Alarm Management

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	I don't know
System alerts are clearly indicated	☐	☐	☐	☐	☐	☐
Alerts demands the right level of attention	☐	☐	☐	☐	☐	☐
It is clear what to do when an alert arrives	☐	☐	☐	☐	☐	☐
All alerts are relevant	☐	☐	☐	☐	☐	☐
Alerts appear at the right time for action	☐	☐	☐	☐	☐	☐

Comments:

System potential

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	I don't know
The new STM functions make communication with ships easier	☐	☐	☐	☐	☐	☐
I trust the information provided by the STM services	☐	☐	☐	☐	☐	☐
Using the STM services is straightforward and demands little effort	☐	☐	☐	☐	☐	☐
The STM services help to reduce my workload	☐	☐	☐	☐	☐	☐
The STM functions help to offload my memory	☐	☐	☐	☐	☐	☐
The STM services help me to be proactive	☐	☐	☐	☐	☐	☐
The STM functions help me maintain a good understanding of the traffic situation	☐	☐	☐	☐	☐	☐
The new STM functions are likely to reduce accident risks	☐	☐	☐	☐	☐	☐

Comments:

Appendix D

Evaluation survey 1 - results

	VTSO1	VTSO2 (W1)	VTSO3	VTSO4	VTSO5	VTSO6	VTSO7	VTSO8	VTSO9	VTSO10	VTSO11
The new STM functions are easy to learn	Neutral	Agree	Disagree	Agree	Agree	Agree	Disagree	Agree	Agree	Disagree	Agree
Alerts and route handling tools use familiar VTS terminology	Agree	Agree	Agree	Agree	Agree, I don't know	Agree	Neutral	Agree	Neutral	Disagree	I don't know
The new STM services are easy to integrate in my normal workflow	Disagree	Neutral	Strongly disagree	Agree		Neutral	Disagree	Neutral	Disagree	Agree	Neutral
Using the STM services is straightforward and demands little effort	Neutral	Neutral	Disagree	Agree	Neutral	Agree	Disagree	Disagree	Neutral	Disagree	Agree
The services target the most important hazards in the traffic system	Agree	Neutral	Disagree	Agree	Agree, Neutral, Disagree (These are not the only hazards)	Agree	Disagree	Agree	I don't know	Agree	Strongly agree

	VTSO1	VTSO2 (W1)	VTSO3	VTSO4	VTSO5	VTSO6	VTSO7	VTSO8	VTSO9	VTSO10	VTSO11
Do you foresee any issues or risks around the STM services after this first day?	That there is too much focus on sending routes, instead of giving the same information via VHF (for all vessels in the vicinity to hear).	Checking routes will be extra workload for VTS operators. The routes could five a “false safety” in situations. There could be too many alarms, for example if a vessel leaves a corridor at open sea, it shouldn’t be an alarm. The same if a pilot boat approach a vessel.	Too much workload using the features could cause the VTSO to lose focus. Usability is crucial.	The lack of standardized terminology during STM operations might cause trouble when brought to operative use (see standard marine communication phrases). Route sending should automatically involve closed loops comms. The relation of STM SOP:s is still unclear when reflecting VTS model course governed by IALA.	Comment to Q3: Depends on technical side of product - how it will be implemented. As now - not so good. If better integrated, then agree. It is about giving instructions. Fist impression is that it could be more user friendly.	Risks involved VTS route proposals.	The risk of changing route from VTS and overriding vessels route.	Sloppy route checking, trusting others.	Editing a route for another vessel without knowing its limitations is problematic. Chart is too bad for editing route.	Easy to loose overall view,	Should be more user friendly.
What do you see as the main possible benefits of using the STM services?	Increased VTS proactivity.	To see the vessels intended routes, to predict the traffic situations and close quarter situations.	There are possibilities for alarm functions in certain situations that could be useful, but they need to be very adapted to the VTS area and need of the VTSO! Allows for better overview of a ships intentional route.	Less speech via VHF, although might pose a risk as ships can’t “spy” route sending. Better situational info picture is always beneficial.	Have essential information earlier and more *lendy* (?) Information exchange can be more easy/better visible of *sereh* (?) -> avoiding confusions.	Traffic efficiency	It is good to see the intention of the vessel when monitoring.	Meeting points, hazard areas.	Less misunderstanding when explaining sailing route.	Shared intentions / knowledge.	To see forward possible conflicts.

	VTSO1	VTSO2 (W1)	VTSO3	VTSO4	VTSO5	VTSO6	VTSO7	VTSO8	VTSO9	VTSO10	VTSO11
Other comments:	It’s a bit hard to determine whether my feelings of inability to integrate STM into my normal workflow stems from the fact that I’m unused to the VTS system used in the simulator, and also to the fact that I’m not very familiar with the Gothenburg VTS area.	Interesting to be part of something new. Routes could be highlighted in different colors for easily separate the routes.	It must be intuitional and easy to follow and view several routes at once, and to use predictions.		Needs more development but at the end very useful.	Needs to be more user friendly.	Looking forward to the next days.		Speed in route?		

Appendix E

Evaluation survey 2 - results

	VTSO1	VTSO2 (W1)	VTSO2 (W2)	VTSO3	VTSO4	VTSO5	VTSO6	VTSO7	VTSO8	VTSO9	VTSO10	VTSO11
System interaction												
Q1: Using the system is a pleasant experience	Neutral	Agree	Agree	Neutral	Neutral	Agree	Agree	Neutral	Neutral	Strongly agree	Disagree	Strongly agree
Q2: The system responds quickly to my actions	Agree	Neutral	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Neutral	Agree	Strongly agree
Q3: It is easy to manage the display of routes on screen	Strongly disagree	Neutral	Neutral	Disagree	Neutral	Neutral	Neutral	Strongly disagree	Disagree	Disagree	Disagree	Disagree
Q4: There is little risk of incorrect actions using the STM services	I don't know	Neutral	Neutral	I don't know	Strongly agree	Neutral	Disagree	Disagree	Neutral	Neutral	Agree	Neutral
Q5: It is easy to identify individual objects (e.g. ship, beacons) on screen	Strongly disagree	Strongly disagree	Strongly disagree	Strongly disagree	Disagree	Disagree	Agree	Disagree	Disagree	Neutral	Strongly disagree	Neutral

	VTSO1	VTSO2 (W1)	VTSO2 (W2)	VTSO3	VTSO4	VTSO5	VTSO6	VTSO7	VTSO8	VTSO9	VTSO10	VTSO11
Comments:	There might be a risk of incorrect actions if the VTSO is to edit routes. This, however, has not been tested enough I think.	The vessel icon size should be in proportion to the dimension. I find it hard to get a good overview on the NaviHarbor, buys should be smaller when I zoom out, and vessels should be bigger.	Ships to small on screen to get good overview. Ships symbol would be easier to see if the view dimension on the screen were in proportion of their size.	It requires too many "clicks" on different screens in order to view routes. Chart symbols are hard to see and distinguish. It is hard to distinguish ship symbols and vectors from each other.	UI of the simulator is cluttered, proper training needed to adjust according to own preferences. Whether the system is pleasant to use, I find the question a bit odd. Another system again, not the easiest but offers the necessary info.	Q5: Too confusing.		I think VTS system needs more configurati on to be optimal		Q2: The web-solution is "lagging". Q5: Ships is too little info in icon.		Human machine interface needs developm ent.
Alarm management												
Q6: System alerts are clearly indicated	Strongly disagree	Disagree	Agree	Strongly disagree	Disagree	I don't know	Neutral	Strongly disagree	Neutral	Disagree	Agree	I don't know
Q7: Alerts demands the right level of attention	Disagree	Neutral	Disagree	Disagree	Neutral	I don't know	Agree	Strongly disagree	Neutral	Disagree	Agree	I don't know
Q8: It is clear what to do when an alert arrives	Neutral	Disagree	Disagree	Neutral	Agree	I don't know	Agree	Strongly disagree	Agree	Disagree	Agree	I don't know
Q9: All alerts are relevant	I don't know	Strongly disagree	Strongly disagree	Disagree	Disagree	I don't know	Agree	I don't know	Neutral	I don't know	Agree	I don't know
Q10: Alerts appear at the right time for action	I don't know	Neutral	Neutral	Agree	Agree	I don't know	Agree	Strongly disagree	Neutral	I don't know	Agree	I don't know

	VTSO1	VTSO2 (W1)	VTSO2 (W2)	VTSO3	VTSO4	VTSO5	VTSO6	VTSO7	VTSO8	VTSO9	VTSO10	VTSO11
Comments:	Haven't been using the alarm functionality that much, been focusing on other areas of functionality during the simulations.	The alarm list doesn't get my attention due to that many alarms are irrelevant, for example when a pilot boat approach a vessel. It should be better if the alarm pop ups on the screen to get my attention, but the most important thing regarding alarms is that the alarms showing is relevant for the operation, otherwise it is useless.	Alarm settings were better on VTS1 this time. It was less alarms such as when pilot boat is approaching for boarding.	There are too many irrelevant alarms. Alarms need to be audible.	More training needed for alarm types and when to they trigger. Should be examined in relation to IALA definitions (critical alarm etc).	I didn't notice any alerts for some reason. Perhaps not looking at particular window.	Alarms should be more visible.	I did not see the alarm table.		I did not see alarms on the VTS-screen. Only on the route screen.		
System potential												
Q11: The new STM functions make communication with ships easier	Neutral	Agree	Agree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	Strongly agree	Strongly agree
Q12: I trust the information provided by the STM services	Neutral	Agree	Agree	Agree	Strongly agree	Agree, Neutral	Agree	Agree	Agree	Neutral	Strongly agree	Strongly agree
Q13: Using the STM services is straightforward and demands little effort	Neutral	Neutral	Neutral	Disagree	Agree	Agree, Neutral	Neutral	Disagree	Neutral	Agree	Agree	Disagree
Q14: The STM services help to reduce my workload	Disagree	Disagree	Neutral	Disagree	Agree	Agree	Agree	Disagree	Disagree	Agree	Agree	Strongly agree

	VTSO1	VTSO2 (W1)	VTSO2 (W2)	VTSO3	VTSO4	VTSO5	VTSO6	VTSO7	VTSO8	VTSO9	VTSO10	VTSO11
Q15: The STM functions help to offload my memory	Agree	Agree	Agree	Disagree	Neutral	Agree	Neutral	Disagree	Agree	Agree	Neutral	Strongly agree
Q16: The STM services help me to be proactive	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Strongly agree	Strongly agree
Q17: The STM functions help me maintain a good understanding of the traffic situation	Agree	Agree	Agree	Neutral	Agree	Agree	Agree	Disagree	Agree	Agree	Strongly agree	Strongly agree
Q18: The new STM functions are likely to reduce accident risks	I don't know	Agree	Agree	I don't know	Strongly agree	Agree	Agree	Agree	Agree	I don't know	Strongly agree	Strongly agree
Comments:	To answer the last question, I would have to try STM functionality in a VTS system and in a VTS area that I am familiar with.	I think the system is good in general, the only concern I have is that the route monitoring might take the attention from the traffic of the operator		The ability to predict the vessels position along their routes can be a helpful tool that helps the VTSO to prepare for upcoming meetings etc. The route handling needs to be easier and faster to use in order to possibly reduce the workload of the VTSO. The VTSO need to be able to distinguish between several routes quickly.	Potential for STM is huge, but will be a long road ahead.	Q12: In general yes, but there may be errors, so you shouldn't relay on it 100% Q15: But there is risk.	System has great potential.	System needs more developm ent to be a good assitance.			Must be easier to show and hide routes.	As the main reason of accidents is uncertaint y, then STM is giving very precise prediction about vessels intention.

Using STM to increase BALTic Sea SAFEty

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