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EMSN Test Report - Evaluation of STM services:
Human Factors
## DOCUMENT STATUS

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Disclaimer:

A peer-reviewed paper has been presented and published at the Royal Institute of Naval Architects (RINA) Human Factors Conference in London, UK on 26 September, 2018. This report provides a summary of this paper and further details can be found through the following reference:

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### Abbreviations
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<table>
<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CPA</td>
<td>Closest Point of Approach</td>
</tr>
<tr>
<td>ECDIS</td>
<td>Electronic Chart Display and Information System</td>
</tr>
<tr>
<td>EMSN</td>
<td>European Maritime Simulator Network</td>
</tr>
<tr>
<td>ETA</td>
<td>Estimated Time of Arrival</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>IALA</td>
<td>International Association of Marine Aids to Navigation and Lighthouse Authorities</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization</td>
</tr>
<tr>
<td>LOA</td>
<td>Levels of Automation</td>
</tr>
<tr>
<td>TCPA</td>
<td>Time to Closest Point of Approach</td>
</tr>
<tr>
<td>OOW</td>
<td>Officer of the Watch</td>
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<td>RDV</td>
<td>Rendezvous Service</td>
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<tr>
<td>S2SREX</td>
<td>Ship to ship Route Exchange</td>
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<tr>
<td>STM</td>
<td>Sea Traffic Management</td>
</tr>
<tr>
<td>VHF</td>
<td>Very High Frequency</td>
</tr>
<tr>
<td>VTS</td>
<td>Vessel Traffic Services</td>
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</table>
1. Background

The STM Project (2014-EU-TM-0206-S), examines many aspects of digitalization within the shipping sector. The goals of the STM project are to create a safer, more efficient and environmentally friendly maritime sector. STM connects and updates the maritime world (ships, ports, vessel traffic services, service providers, shipping companies) in real time through information exchange and sharing to offer a digital infrastructure for shipping.

As conceptualized in MONALISA2.0 and advanced in the STM Validation Project, the European Maritime Simulator Network (EMSN) was developed. The EMSN consists presently of 13 connected ship handling simulators based in seven EU countries with the possibility to run scenarios with over 30 manned simulated vessels. The EMSN is a unique testbed that enables the introduction and testing of new technologies in complex and large-scale traffic situations, without exposing seafarers to any risks.

The technologies that have been developed in the STM Project are called the “STM-Services”. These services include: Route Cross-check, Route Optimisation, Ship to Ship Route Exchange (S2SREX), Rendezvous (RDV) Navigational Warnings, Chat Service, Enhanced Monitoring, Port Call Synchronisation, Port Call Optimisation, Winter Navigation, Importing Pilot Routes and SAR-Search and Rescue (see http://stmvalidation.eu/stm-services/ for detailed information about all services). The proposed benefits of these services include reduced administrative burden, increased safety/situational awareness, and operational efficiency. Although all of these services are available, they were not all tested in the EMSN trials.

For the purpose of this report, the services evaluated in this study are hereby referred to as the STM Services and are limited to: Receiving Navigational Warnings, S2SREX and RDV, Chat Service, Route Cross Check and Enhanced Monitoring. These services are described below in sub-section 1.1. The goal was to evaluate how these STM services may affect navigational safety and efficiency.

1.1 The STM Services

**Ship-to-ship route exchange:**

This service provides the navigator with a route segment consisting of the next 7 waypoints of the monitored route of another vessel. Route segments are broadcasted through Automatic Identification System (AIS) and give additional information to the presently available data obtained by radar/ARPA and AIS. Nothing in the S2SREX information exonerates the navigator from applying the International Regulations for Preventing Collisions at Sea.
(COLREG) and rather than being used in a close quarters situation, the S2SREX may be used as a tactical tool for supporting decision-making and situational awareness at a longer range.

**Rendezvous Function:**

As an integral part of the S2SREX, this function allows the navigator to view where own ship will meet a target ship if both vessels continue along their monitored broadcasted route with the present speed over ground. This function provides route-based Closest Point of Arrival (CPA) and Time to Closest Point of Arrival (TCPA) based on AIS information.

**Shore-to-Ship Route Exchange (Receiving route suggestions from shore):**

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

**Receiving Navigational Warnings:**

This service provides a notification which overlays a Navigational Warning Message directly on the ECDIS. If the Navigational Warning involves a geographical area to avoid or be aware of, this will be automatically plotted onto the ECDIS so it is visible to the bridge team.

**Chat Function:**

A standalone software like other programs (e.g. Skype) which was integrated on the same station as the ECDIS. Text communications with other stations with enabled STM tools such as Shore Centres and ships.

**Enhanced Monitoring and Route Cross Check:**

After having received a ship's monitored route and schedule, shore centres will be able to detect if planned schedule is not kept or if ship deviates from monitored route. A shore centre can receive any planned route and cross check such route against any navigational dangers and if necessary send a route suggestion back to the ship.

## 2. Objective

As the ability to connect and share information has become more available it is important to understand how this will impact the entire maritime logistics chain, and not just individual components of this complex sociotechnical system. The objective of the human factors analysis was to use the EMSN as a test bed to determine whether the available STM services improve safety and/or efficiency of navigation from the end user (i.e. Master and OOW) perspective.
3. Methodology

The experimental set up and methodology of the EMSN STM trials are provided in detail in STM Report ID3.1.1 EMSN Test Plan and General Exercise Specification. The following section will solely describe the human factors data collection methodology for the two weeks of simulations which tested the STM services.

3.1 PARTICIPANT RECRUITMENT
Professional mariners (active or recently active masters, mates, officers and maritime pilots) were recruited as test participants. Participants were recruited through various social media platforms, professional maritime organizations, and convenience sampling.

3.2 PARTICIPANT DEMOGRAPHICS
An electronic demographic survey was completed prior to arrival at the simulation centres. A total of 227 professional mariners, 33 (15%) women and 194 (85%) men participated in this study. The participants were between 20 and 69 years of age. In terms of navigational experience, 1 participant had less than 1 year of experience, the rest of the participants had between 3 to 31 years, and the majority of participants had between 11-20 years of sea-going experience. The current role of participants varied, 68 participants were captains, 18 Pilots, 29 Chief Officers, 57 Deck Officers, 7 VTS Operators, 16 working in educational services, 14 working in the maritime field, and 18 who did not report in the demographic survey. The test participants were of various nationalities and a breakdown of each simulation centre and the number of participants from each respective centre is provided in Table 1.

<table>
<thead>
<tr>
<th>Simulator Center</th>
<th>Number of Participants</th>
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<tbody>
<tr>
<td>Swedish Maritime Administration (SMA)/ Chalmers University of Technology (CTH)</td>
<td>21</td>
</tr>
<tr>
<td>Aboa Mare (AM)</td>
<td>8</td>
</tr>
<tr>
<td>Centro Jovellanos (CJ)</td>
<td>19</td>
</tr>
<tr>
<td>UPC Barcelona (UPC)</td>
<td>5</td>
</tr>
<tr>
<td>Rörvik (SSR)</td>
<td>78</td>
</tr>
<tr>
<td>Fraunhofer CML</td>
<td>28</td>
</tr>
</tbody>
</table>
### Table 1: Simulator Centers and Number of Participants at each Centre

<table>
<thead>
<tr>
<th>Simulator Center</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flensburg University of Applied Sciences (FUAS)</td>
<td>24</td>
</tr>
<tr>
<td>Southampton University (WMA)</td>
<td>32</td>
</tr>
<tr>
<td>HS Emden-Leer (EL)</td>
<td>12</td>
</tr>
</tbody>
</table>

#### 3.3 RESEARCH ETHICS

Participants were fully informed of the procedures and risks of the experiment and signed electronic and written Informed Consent prior to the start of the simulations. The experiment complies with the requirements of article 28 of the EU General Data Protection Regulation (2016/679) regarding protection for physical persons in the processing of personal data. Each participant was assigned a unique identification number (ID) prior to arrival, which was used for all the questionnaires throughout the study to maintain confidentiality. Additional information related to research ethics is provided in STM Report ID3.3.2 EMSN-Test Person and Data Collection Management.

#### 3.4 SIMULATED SCENARIOS

In order to test the services, subject matter experts developed two simulator scenarios, one in the South Western Baltic and another in the English Channel/Southampton. The scenarios were strategically designed to test the different functionalities of the STM Services. The Baltic Scenario tested the participants in dense, close quarters traffic situations whereas the English Channel scenario was generally less busy. Each geographical area also had a respective shore center, one located in Southampton, UK and the other in Gothenburg, Sweden. The shore center functioned as a typical VTS center with additional access to the STM services.

#### 3.5 EXPERIMENTAL DESIGN

Data were collected over eight days during two non-consecutive weeks in 2018. Nine simulation centres and up to 30 ship bridges in the EMSN were used for data collection. Each simulation centre held a standardized briefing session at the beginning of the day for the participants. The briefing consisted of information about the STM/EMSN, the STM Services used (including step-by-step instructional videos on how to use the services), schedule for the day, and an opportunity to ask questions. The participants were assigned to a two-person bridge team, one Master and one Officer of the Watch (OOW).
After the briefing, a 1.5-hour familiarization session was held on the simulator bridges. Once familiarization was complete, the first exercise began and lasted for 1.5 hours. The first exercise was always the English Channel Scenario as it was designed to be less busy and provided the participants time to explore the usage of the STM services.

Once the simulation was concluded, the participants completed a “post-scenario questionnaire” which asked questions specific to the STM services. The same process was completed in the afternoon for the Southern Baltic Scenario. The test day concluded with a common de-brief with all participants in attendance.

3.6 DATA COLLECTION AND ANALYSES METHODOLOGIES
There was a significant human factors data collection effort throughout the EMSN simulations which consisted of both qualitative and quantitative data. This data collection included situational awareness questionnaires, post-scenario questionnaires, human factors observation questionnaires, and several Vessel Traffic Services (VTS) assessments (see Appendix I). However, for the purposes of this report the only data analysed is the qualitative data from the structured open-ended group debrief sessions, as this contained the richest information about the participants experience with the STM services. The quantitative data from the survey responses will be analysed and presented at a later date.

3.6.1 Daily De-Briefs: Qualitative Data
The purpose of the group debriefs was for the test participants to provide an account of their experiences with the STM services, both positive and negative in a non-bias environment. The structure for the debriefs was consistent for all simulation centers. At the end of each test day, the participants from each simulator centre gathered in a de-briefing room and discussed the simulations. The questions were standardized and the participants were also encouraged to explain the motivation of their response. The list of questions included:

**Standardized STM Service Specific Questions:**

1. In general, do you think the STM services affect SAFETY in Navigation?
   a. If YES… how do they improve SAFETY
   b. If NO… how do they decrease SAFETY?

2. In general, do you think the STM services affect EFFICIENCY in Navigation?
   a. If YES… how do they improve EFFICIENCY?
   b. If NO… how do they decrease EFFICIENCY?

3. Do you think that the new STM services will change today's way of working/navigation/management procedures? If YES, how:
4. What training (technical/pedagogical) would be necessary in order to use the new STM services?

5. Do you think Shipping Companies will adopt these services for their fleet?
   a. If YES, then why?
   b. If NO, then why not?

3.7 DATA ANALYSIS

A grounded theory approach [1, 2] was used to collect and analyse the qualitative data from the debrief sessions. Software program MAXQDA12 (Release 12.3.5, distribution by VERBI Software GmbH, Berlin Germany) a qualitative and mixed methods software program was used to organize, visualize and analyse the open-ended debrief responses. The coding process was continuous as new themes and relationships emerged between data, this is also known as axial coding [1].

Once it was established that the data were saturated [1], memos explaining the phenomena were recorded. The memos were written to help understand and support the observed findings which are discussed in Section 4.

4. Results and Discussion

The analysis of the debriefs revealed two common categories which were generally applicable to all STM services. The first common theme was that the STM Services provided seafarers with additional time to plan and respond to emerging navigational situations. This category materialised based on the positive comments of each service and coded segments including: planning ahead, situational awareness, trust, automated systems, workload, cost, decision making, and communication. This category encompasses both safety and efficiency, which will be explored in relation to each STM Service in the section below.

The second common category emerged from the negative comments regarding the STM services. Participants generally agreed that the usability of the services caused frustration, which negatively impacted their overall opinion of the services. This category emerged within the coded negative comments of each service, and the recommendations for improvement from the participants. The results are described and discussed below.

4.1 PARTICIPANT FEEDBACK ON STM SERVICES

A summary of the positive and negative comments of each STM service is provided in Figure 1, followed by a detailed analysis of each STM service.
4.1.1 SAFETY, EFFICIENCY AND INCREASED TIME TO PLAN, RESPOND AND ACT

Understanding the impact of safety and efficiency that the STM services have on navigation practices was the aim of this research. Generally, the participants agreed that the STM services will increase safety and efficiency by providing the operators additional time to plan, act, and respond to events through the automated aspects of the STM systems. Each of the STM services has the potential to reduce the workload for the bridge team, allowing additional time to perform other tasks, and maintain watch of surrounding traffic. Based on the analysis of the participants comments, approximately 60-70% of participants thought that one or all of the STM Services would increase safety and efficiency in some way, approximately 20% said they were not sure/hard to tell because the services were still novel, and 10-15% of participants though that the services could decrease efficiency. A detailed analysis of each STM service is provided below.

Navigational Warning: The navigational warning service was the most highly ranked in terms of general positive feedback with regards to safety and efficiency. A direct quote from a participant was that the service was, “fantastic, and brilliant”.

Positives Comments:

- The automatic plotting of the navigational warning could reduce workload and allow the bridge team to maintain situational awareness without the distraction of having to listen,
record, and plot coordinates. Participants were able to use that time to perform other navigational tasks.

- The message notification which appeared directly on the ECDIS will alert the bridge team much sooner than a printed Navtex message, which participants said could remain unseen for hours. The instant notification could provide additional time for the bridge team to react to the message if necessary.

- Participants think that this service could reduce human errors

- They believe that this service will reduce “noise in communications” on the Very High Frequency Radio (VHF), as navigational warnings promulgated by VHF could be superseded by the Navigational Warning service and graphically depicted on the ECDIS.

Negative Comments:

- The usability of this service was the only weakness identified, because it was difficult to see the message notification on the ECDIS screen as it was the same color as the menu tab.

**S2SREX:** Approximately two thirds of participants believe that this service will have a positive effect on navigation, and was coined as a “nice to have” service. However, S2SREX was also controversial because participants are not convinced it will be used properly.

Positive Comments:

- Informative tool that can help with planning and decision making
- This tool allowed ships to identify others intentions and act accordingly.
- It reduced unnecessary communication over the VHF and will reduce misunderstandings. This service replaces the common “what are your intentions?” inquiry over the VHF.

Negative Comments:

- Participants were concerned that ships were not following their broadcasted route which could be a risk if a navigational decision is made based on false information.
- The usability of the tool was a common complaint among participants. The screen became very cluttered when several ships routes were shown which made it difficult to see which route belonged to which ship.
- This service was not considered to be usable in dense traffic conditions with many close quarters’ situations (e.g. Southern Baltic).
- Over reliability on this service could be dangerous
**RDV:** This service and the S2SREX service had many overlapping comments. Participants in general liked the RDV service, although there were many issues with the user interface.

Positive Comments:
- This service could increase situational awareness and allow navigators to identify actions of vessels around them and act accordingly.
- This tool offered a helpful visualization of CPA.

Negative Comments:
- Operators must ensure not to over rely on the RDV service. It is a service and it must be used as such.
- Usability was a major issue with the RDV service and many participants agreed that the screen was cluttered which was distracting when the RDV service was being used for several ships at a time.

**Chat:** This service had the most negative comments related to safety, efficiency, and usability. There may have been a generational gap in the responses to this question. Although this has yet to be analyzed, it appeared that the younger seafarers saw more potential benefit from the chat service than the older seafarers. However, in general the results still showed a negative trend in opinion, and the service was even referred to as “miserable to use”.

Positive Comments:
- Potentially useful for ship to shore, and could render less miss-understandings and a clearer information exchange.
- Group chat would be desirable
- This service could increase efficiency if the usability was improved.
- The chat service could help with the issue of English as a second language for many mariners.

Negative Comments:
- Chat messages will distract the operator and draw too much attention to the ECDIS screen, which is a problem already present with ships officers and this should not be encouraged. This service will decrease safety.
- Poor user interface
- It is faster to call a ship on VHF than write a chat message
- Usable for long term situations, but not close quarters
There is a risk that because the information exchange will only involve two parties (ship-to-ship or shore-to-ship), the rest of the vessels in the area will be unaware of ongoing traffic situations and agreements made through the chat service instead of the VHF.

**Suggested Route from Shore Centre:** This service wasn’t used as much as anticipated throughout the simulations. However, based on the feedback received, participants generally had more positive comments about the service than negative. This tool was used mostly to test the STM services and not because the participants needed a new route.

Positive Comments:
- Participants were pleased to receive a route when the oil spill was announced in the Baltic Scenario. Many participants were sent a new route, they checked it, and used it.
- Local knowledge at the shore center will improve route quality and thus also operational efficiency

Negative Comments:
- Workload could increase for the VTS Operator, also qualifications / skill set of the VTS Operator could change.
- The captain has to check and approve the new route, which could potentially decrease efficiency and increase workload.
- Liability concerns in case of an incident.

**4.1.2 USABILITY OF THE STM SERVICES**

There were many negative comments about the usability difficulties of the ECDIS/STM client interface. This is likely expected because of the limitations in design specifications for these types of interfaces and could, in some circumstance, be due to a lack of familiarisation with the experimental equipment. This is one of the most challenging aspects of introducing new technologies in any work environment [15]. The participants in this study are the end user group, which is the focus of IMO’s e-Navigation strategy [1], thus it is critical that these informants be included in product development from the initial design stages[3, 4]. However, despite previous research on Human Centred Design in shipping which clearly show the benefits of early user involvement in design and the importance of usability testing [5-7], the results of this study confirm that this is still an unresolved issue. The crew did however feel, despite a need for better user interfaces, that the services freed up time, which could have a positive effect on the identified stressful situation on the bridge due to high workload [8-12].
4.1.3 TRAINING, COSTS, COMMUNICATION AND WORKLOAD

In addition to the overarching categories within this analysis - training, costs, communication and workload emerged as sub-categories within the data. The key concepts highlighted by participants are discussed below.

4.1.3.1 Training
A core aspect of the e-Navigation implementation plan is the educational and training aspect of new services or technologies [13]. Almost all participants agreed that training for the STM Services could be built into an ECDIS model course or an 8-hour training, and would not require an additional stand-alone course. Generally, participants also agreed that a simulation/practical aspect to the training should be required where they can practice using the services in an operational environment. These results align with previous research on maritime training and the importance of a performance-based tasks and the practical component of learning [3, 6, 9].

4.1.3.2 Cost and Implementation of Services
Participants believe that shipping companies will only adopt the STM Services if they generate an economical improvement, decrease operational costs, or are forced to adopt the services due to regulatory requirements. The general consensus was that shipping companies have little interest in spending money unless it is required by legislation.

4.1.3.3 Communication
Communication was commonly coded within the data, both within a positive and negative context of STM service integration. The STM services provide an alternative means of communication which is safety critical since decision-making is based on communication between ship-to-ship and ship-to-shore operators and local information integration for preparation and prediction [17, 18].

Communication was most commonly coded within discussions related to the chat function. Some participants believed that agreements made through chat messages between two vessels could lead to reduced situational awareness and increased risk. For example, if a ship made an agreement through chat messages, which would traditionally be made over the VHF, then no other vessel in the vicinity would be aware of this agreement. Participants thought this could negatively impact navigation practices and awareness of ongoing traffic situations and agreements.

On the contrary, miss-communication over the VHF was discussed since English is a second or even third language for many seafarers. A considerable amount of information was mis-
understood over the VHF throughout the study and some participants thought that the chat function could improve this mis-communication because the message is written and able to be reviewed whenever necessary. In this case, if communication could become clearer and mis-communications could be decreased then safety would be increased.

4.1.3.4. Workload

As defined by the IMO, “the VTS are shore-side systems which range from the provision of simple information messages to ships, such as position of other traffic or meteorological hazard warnings, to extensive management of traffic within a port or waterway”. The results from the de-brief indicated a potential shift of workload from the bridge crew to the VTS/ shore center which aligns with previous research on e-Navigation [8, 17, 19, 20]. Moreover, manning of shore centers, training requirements for VTS operators, skill sets, and liability issues [17, 20] were also discussed.

The IMO has clear legislation for traditional navigation, which states that while the VTS Operators and pilots may provide navigational assistance, the Master of the vessel is responsible for the safety of navigation [19]. However, the introduction of e-Navigation services challenges the traditional hierarchal structure of shipping. E-Navigation is high priority for the IMO and therefore the uncertainty surrounding liability and regulatory implications will hopefully be resolved in the near future. There is still much validation testing of the available services yet to be completed to ensure the technology is matched with the user’s abilities and needs.

5. Limitations

There are several limitations to consider in this research:

- The bridges were not always manned with two crew members.
- Senior students were used as subjects in cases when there were not enough certified/qualified participants.
- These services were being used for the very first time, and therefore the learning curve was steep for participants.
- This report offers only one aspect of the human factor’s considerations within the STM EMSN. This data should be further analysed in conjunction with the participant survey responses and the numerical data of ships behaviour to provide a more holistic view of the potential impact of the STM services in navigational safety and efficiency.
- This was the first time the EMSN has been tested to such a large scale, which means there were technological challenges with equipment, internet connections, etc.
6. Conclusions

This project highlighted the many benefits, challenges and risks associated with the implementation of the STM services from the point of view of experienced seafarers. The research presented in this paper suggests that in general the STM Services promote navigational safety and efficiency.

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

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

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


Appendix I: Additional Human Factors Data Collected within EMSN Simulations

The following data was collected from the bridge teams (OOW and Master) using the program Qualtrics, a qualitative and quantitative survey software. A preliminary basic analysis has been completed by Activity 5, and this data will be further investigated at a later date.

**Background Questionnaire:** Demographic information was collected for all participants in a detailed background questionnaire completed prior to arrival at the simulations.

**Workload Diaries:** Participants were asked to complete a situational awareness/workload assessment every 15 minutes during the scenarios. The assessments altered between the Master and the OOW to ensure the watch was always covered. Participants were advised not to complete the workload diary if the workload was too significant and both participants needed to keep their attention on the traffic situation.

**Post-Scenario Questionnaire:** After each scenario (Baltic and English Channel) the participants completed a “Post-scenario questionnaire” which asked questions specific to the STM Services and their functionalities.

**Human Factors Observation Questionnaire:** Each simulation centre assigned one or two persons to observe participants on selected bridges. The Human Factors Observation questionnaire was developed to assess the behaviours of the bridge team, including; communication, situational awareness, errors/violations, and collision avoidance.

**Vessel Traffic Services (VTS) Data:**

The VTS data that was collected is considered above and beyond the required deliverables for Activity 3. However, the data is currently being analysed and will be presented in an academic paper in 2019.

**Background Questionnaire:** Demographic information was collected for all VTS Operators in a detailed background questionnaire completed prior to arrival at the simulations.

**Post-Scenario Questionnaire:** After each testing day the VTSO completed a “Post-scenario questionnaire” which asked questions specific to the STM Services and their functionalities.
VTS Operator Observations: Throughout the scenarios there was a VTS Manager assigned to each VTS station (One located at Chalmers, Gothenburg and one located at Warsash, Southampton) to observe and record the interactions between ship and shore with and without the STM services. This information was manually logged in an Excel sheet and every time an interaction occurred this information was recorded.