Document No: STM_ID3.3.3
Test Report: Evaluation of STM Services through a Traffic Risk Assessment
## DOCUMENT STATUS

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Abbreviations

The following abbreviations are used in this document:

AIS        Automatic Identification System
COLREG     International Regulations for Preventing Collisions at Sea
CPA        Closest Point of Approach
ECDIS      Electronic Chart Display and Information System
EMSN       European Maritime Simulator Network
OS         Own Ship
PDU        Protocol Data Unit
SC         Shore Centre
STM        Sea Traffic Management
S2SREX     Ship to Ship Route Exchange
TCPA       Time to Closest Point of Approach
TG         Target Ship
1. Background

The primary purpose of the European Maritime Simulator Network (EMSN) is to gain experience with STM services and to understand how involved persons and institutions deal with its capabilities. This is done in a simulated environment, which saves large amounts of time, costs and environmental impact.

The scope and purpose of the various EMSN simulations are to reflect the STM concept and its services, to validate and evaluate the findings and to give input to various hypotheses and FSA developed by other activities within the project. The following services were implemented and available in the EMSN simulations:

**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
The objective of this analysis is to determine whether the available STM services improve maritime traffic safety through an objective numerical risk assessment.

3. Methodology
To determine whether the STM services have a measurable effect on maritime traffic safety, the following methodology was used:

1) Specify a set of maritime traffic scenarios.
2) Simulate the scenarios with and without the STM services (STM runs and Base Line runs).
3) Assess the traffic safety in each of the scenarios with and without the STM services using a numerical methodology further described in chapter 8.
4) Compare the safety assessments.

4. Delimitation
This study is not attempting to make a comparative analysis of the possible effects of each individual STM service on traffic safety separately. Rather, this study is an attempt to capture the possible effects of several STM services being available at the time of the simulation runs based on numerical data retrieved from the centralized data tracking server. The services may have been used individually by the test participants or in combination with other services. Other factors which may have an influence when analysing possible effects of introducing STM services such as usability of the services, familiarization and training in the use of the services, experience of the test participants, etc. have not been considered in this study.
5. Simulation scenarios

The English Channel and the Southern Baltic were selected as they are good examples of heavily trafficked areas. The Baltic scenario was created for the Fehmarn Belt representing one of the worlds' busy traffic corridors with numerous recommended routes, junction areas and crossing ferry routes. For the STM runs, a simulated Shore Centre “Baltic Shore Centre” was established. The English Channel scenario was created for the south coast of England with the port of Southampton playing the major port of interest and a fictitious “Shore Centre Southampton” on the Isle of Wight (IOW) was established for the STM runs.

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value A</th>
<th>Value B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>English Channel</td>
<td>Southern Baltic</td>
</tr>
<tr>
<td>Time of day</td>
<td>Day</td>
<td>Night</td>
</tr>
<tr>
<td>Visibility</td>
<td>Normal</td>
<td>Low (3 nm)</td>
</tr>
</tbody>
</table>

6. Participating simulator centres

The simulations were carried in the European Maritime Simulation Network (EMSN) consisting of up to 30 manned bridges during four sessions with the following centres participating:

<table>
<thead>
<tr>
<th>Centre</th>
<th>Bridges</th>
<th>Shore Centre/VTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aboa Mare</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Centro Jovellanos</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Chalmers University of Technology</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Flensburg University of Applied Sciences</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Frauenhofer CML</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Maritime Institute Willem Barentsz</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Sikkerhetssenteret Rörvik</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
7. Data collection

To enable a centralized data tracking and storing from all centres and bridges in the EMSN, a tracking application was set up at one network site which was able to send and receive PDUs using an own Application ID. The tracking tool itself is not further detailed in this document, but relies on the outlined PDU communication as described in STM_D3.2.1 EMSN Technical Description.

8. Assessing the maritime traffic safety with and without the STM services

The traffic safety (or risk) of the scenario simulations was assessed through a method based on the analysis of the “instant risk” of each of the ships throughout the simulation. The instant risk can be understood as follows:

Figure 1 presents the trajectories of three ships in one of the scenario simulations. The ships are labelled: Own Ship (OS) and Target Ships (TG). Throughout the simulation the distance, orientation, and speed of the target ships relative to the Own Ship change. At a given instant, the values of these variables, as well as previously observed ones, can be used to assess the risk of the instant situation in which the Own Ship finds itself. If the risk is high, the safety is low, and vice versa. Figure 2 presents the risk that each of the target ships pose to the OS throughout the simulation. (The method for calculating the instant risks is described at the end of this section). In the beginning, both target ships posed the same risk (0.6 in the figure). As the simulation advanced the risk posed by both targets ships increased (up to 1 at different times) and then decreased to zero. One can appreciate the reason for these changes in Figure 1. At the beginning, both target ships are travelling towards the OS (head-on or nearly head-on encounter). As the distance between the OS and the target ships decreases, the risk
increases. When each of the target ships passed the OS and keeps on sailing in an opposite
direction, the risk they pose to the OS drops to zero.

Figure 1. Example of three ship tracks during the Baltic scenario
(blue: own ship; purple: TG1; magenta: TG 2).

Figure 2. Instant risk posed by the target ships to the own ship in Figure 1
(purple: Target 1; magenta: Target 2).

The curves in Figure 2 consist of instant risk values in chronological order. The chronological
order is not strictly necessary to assess the traffic safety in the scenario. A convenient way to
do the assessment is through histograms (Svensson, 1998). Figure 3 presents three
histograms summarizing the instant risk values in Figure 2. The first and second histograms
correspond to each of the curves, while the third one is a combination of the other two. The
first histogram shows that the Target 1 ship posed a risk above 0.8 to the Own Ship for most
of the simulation time, while the second histogram shows the opposite for the Target 2 ship. The third histogram summarizes the risk posed by both targets. Overall the Own Ship was in considerable risk for most of the simulation. Presenting the instant risk calculations as histograms has two main advantages: First, it is a clear and straightforward way to combine the instant risks posed by and to all the ships in the simulation. Second, the histograms succinctly present the overall composition of all the encounters in the simulation.

![Histograms of the instant risk values in Figure 2.](image)

In the literature, many methods have been presented for calculating instant risk (e.g. Bukhari et al. 2013, Goerlandt et al. 2015, Zhang et al. 2017). The method used in this assessment is the one presented by Lopez-Santander and Lawry (2017). Lopez-Santander and Lawry’s method uses the following variables to assess the instant risk: closest point of approach, time to closest point of approach, type of COLREG encounter (head-on, crossing and overtaking), irregularity of the target ship’s trajectory, and the target ship’s sidelights visible to the ego ship (red and/or green). In the original publication, the instant risk may have the values 0, 1, 2, 3, 4, or 5. However, in this assessment, the instant risk is normalized so it may have the values 0, 0.2, 0.4, 0.6, 0.8, or 1. The calculation is performed every 60 seconds. Interested readers are referred to the reference for additional details about the method.
9. Comparing the safety assessments

Figure 4 presents four histograms. Each histogram summarizes all the instant risk values in the labelled scenario simulation. The best and worst-case scenarios that the histograms could show would be if all the instant risk values had values of 0 or 1 respectively. This is not the case in neither of the presented histograms. The instant risk values are unevenly distributed across the possible values that the instant risk may have. The goal of any measure to improve maritime traffic safety is to reduce the fraction of high risk instants. To determine in which of the scenario simulations was the traffic safer, one can look at the rightmost bars of the histograms, the ones that correspond to the high-risk instants (values of 0.8 and 1). If the fraction of the high-risk instants is smaller in one simulation than in other, one can conclude that the traffic was safer. Visually comparing histograms when presented as in Figure 4 is challenging. To ease the comparison, the histograms can be mixed into a single graph as done in Figure 5. In this figure, one can observe that both the first and second runs with STM tools gave a smaller fraction of high-risk instants (0.8 and 1) than either of the baseline runs. From this observation, one may conclude that the STM tools seem to improve maritime traffic safety.

Figure 4. Individual histograms of the instant risks in the four runs of the Southern Baltic – Daytime – Normal Visibility scenario.
In Figure 5, one can observe that both the first and second runs with STM tools gave a smaller fraction than either of the baseline runs, but this is not always the case. To facilitate even further the evaluation of the results a grading system is used for every mixed histogram. The grades are as follows:

- **Grade 0**: none of the runs with STM tools showed an improvement in safety compared to any of the baseline runs.
- **Grade 1**: only one of the runs with STM tools showed an improvement in safety when compared to one of the baseline runs.
- **Grade 2**: only one of the runs with STM tools showed an improvement in safety when compared to both of the baseline runs.
- **Grade 3**: one of the runs with STM tools showed an improvement in safety when compared to both of the baseline runs. The other run with STM tools showed an improvement only when compared to one of the baseline runs.
- **Grade 4**: Both of the runs with STM tools showed an improvement in safety when compared to both of the baseline runs.
10. Results and Discussion

The mixed histograms for all the scenarios are presented in the Appendix. Nearly all the scenario simulations had some sort of irregularity. Most of the regularities are ships freezing, disappearing, and re-appearing. The authors considered that these irregularities were unlikely to have a large effect on the results of the risk assessments.

From the overall shapes of the histograms, one can conclude that the Southern Baltic scenarios were riskier than the English Channel ones. Furthermore, for the English Channel scenarios, time of day and visibility seem to have a smaller effect on traffic safety.

The following table presents the results of analysing the mixed histograms to determine whether or not there was a decrease in high risk instances potentially due to the STM tools. Out of eight scenarios, the STM tools seem to improve traffic safety in five. Interestingly, the STM tools seem to have a negative effect on traffic safety for the Southern Baltic scenarios at night. The reason for this negative effect is unclear. However, in general the STM tools seem to improve traffic safety.

<table>
<thead>
<tr>
<th>Location</th>
<th>Time of day</th>
<th>Visibility</th>
<th>Grade</th>
<th>Improvement in Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>English Channel</td>
<td>Day</td>
<td>Normal</td>
<td>2</td>
<td>Inconclusive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced</td>
<td>4</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>Normal</td>
<td>4</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced</td>
<td>4</td>
<td>Yes</td>
</tr>
<tr>
<td>Southern Baltic</td>
<td>Day</td>
<td>Normal</td>
<td>4</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced</td>
<td>3</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>Normal</td>
<td>0</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced</td>
<td>0</td>
<td>No</td>
</tr>
</tbody>
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11. Conclusions

An analysis of the effect of available STM services combined on traffic safety based on instant risk calculations was performed. The results indicate that these combined STM services may improve maritime traffic safety. However, no separate analysis of the effect of individual services on maritime traffic safety has been made nor any analysis on usability and/or human
factors assessment. Therefore, the combined positive effect of the STM services reported here should be compared with the results of other evaluation methods to confirm it.
References


Southern Baltic - Daytime - Normal Visibility

1st run baseline
2nd run baseline
1st run with STM tools
2nd run with STM tools

Instant Risk

Southern Baltic - Daytime - Reduced Visibility

1st run baseline
2nd run baseline
1st run with STM tools
2nd run with STM tools

Instant Risk
Southern Baltic - Nighttime - Normal Visibility

- 1st run baseline
- 2nd run baseline
- 1st run with STM tools
- 2nd run with STM tools

Southern Baltic - Nighttime - Reduced Visibility

- 1st run baseline
- 2nd run baseline
- 1st run with STM tools
- 2nd run with STM tools