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nota ter informatie

Binnenschepen worden in hoog tempo uitgerust met trackpiloten. Een trackpilot (ook wel TrackControleAssistent genoemd) kan voor een binnenvaartschipper een vaarroute bepalen naar de bestemming. Bovendien kan het systeem het schip in belangrijke mate zelfstandig naar de bestemming laten varen, uiteraard onder toezicht van de schipper. Het aantal gebruikte trackpiloten in de binnenvaart groeit snel: naar schatting zullen er ultimo 2022 600 trackpilots zijn geïnstalleerd.

Als op de trackpilot wordt gevaren, zijn de verwachte posities van het schip in de komende minuten bekend. Die informatie zou kunnen worden gebruikt om de schepen in de omgeving te informeren door het delen en vervolgens zichtbaar maken van die informatie.

Of deze aanpak bij kan dragen aan de veiligheid en een efficiënte verkeersafwikkeling was onderwerp van een simulatorstudie van MARIN, uitgevoerd in opdracht van Rijkswaterstaat. In het experiment participeerden drie leveranciers van trackpilots: het Duitse Argonics, Shipping Technology uit Nederland en Tresco uit België. De gedeelde intenties werden getoond aan de schippers via een Inland ECDIS-systeem of een alternatief weergavesysteem op de brug van de simulator. Bijgevoegd vindt u het onderzoeksrapport waarin de onderzoeksmethode en de resultaten zijn beschreven.

MARIN concludeerde dat het delen van intenties bij kan dragen aan de verkeersveiligheid op het water en ook de verkeersafwikkeling efficiënter kan laten verlopen. Men zag onder meer dat schepen die intenties delen in de gelegenheid zijn eerder te anticiperen op manoeuvres van het verkeer en met als gevolg een reductie in het marifoongebruik. Om die extra veiligheid te kunnen borgen is het echter wel noodzakelijk om bij de doorontwikkeling en implementatie de juiste keuzes te maken.

In lijn met die conclusies is Rijkswaterstaat voornemens om de resultaten te gebruiken in twee vervolgprojecten:

1. De realisatie van 'best practices' voor trackpiloten. Hierin wordt aangegeven hoe een trackpilot het best kan worden vormgegeven en gebruikt om te voorkomen dat het gebruik van een trackpilot de verkeersveiligheid negatief beïnvloedt;
2. Een samen met andere stakeholders uit te voeren implementatie van het concept 'intenties delen.' Hierbij is aandacht voor de opmerkingen die MARIN in het rapport heeft gemaakt ten aanzien van een veilig gebruik van het delen en vervolgens weergeven van informatie over intenties.

Met vriendelijke groet,

Patrick Potgraven
Programma Smart Shipping van het Ministerie van Infrastructuur en Waterstaat

DIGITAL INTENTION SHARING

Simulation study on the benefits of intention sharing

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DIGITAL INTENTION SHARING

Simulation study on the benefits of intention sharing

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SUMMARY

How sharing intended sailing movements – the planned sailing route – among inland skippers works out on inland waters, had not been tested with real-time simulations yet. It has already been a research topic for coastal and high sea areas in which the results indicate that ship operators can anticipate earlier on the shared intended movements of other vessels and thus making their operations safer.

Rijkswaterstaat[1] commissioned MARIN to study the benefits of Intention Sharing (IS) between inland vessels on inland waters. Central to the investigation are the possible benefits of the concept for navigational safety and efficiency. The study was split in two main research activities: first, a literature study was conducted, and secondly, real-time simulations were performed at MARIN. This report describes the outcome of the simulator study.

Two days of real-time simulations were performed on three dedicated simulators with a trackpilot system installed − a system that can sail on a pre-defined track automatically. In this study, three trackpilot manufacturers partnered and developed a module to share and display the intended route or movements on or similar to an Electronic Navigational Chart (ENC). The simulations were used to make a comparison with and without IS, divided among two groups of skippers. Skippers sailed with simulated inland vessels in two different inland areas: on the river Waal and in Rotterdam. Multiple events across eight scenarios served as a test to scrutinize the skippers subjective experience, their anticipating sailing behaviour and their perceived value of IS in regard to navigational safety

Six inland skippers participated in the simulation study and were divided in two groups of three. In total 8 simulation scenarios were conducted of around 15 minutes each containing one or multiple events, such as crossing with traffic. Each group was exposed to the same scenarios; five scenarios were divided for each group into sailing with and without shared intentions. At the first day, participants received familiarisation on the simulator to get acquainted with the systems and set-up.

The simulator observations suggest the skippers' situational awareness is enhanced by the tested trackpilot systems and that IS is used to resolve traffic situations. Skippers used the IS information to anticipate earlier on the mutually shared routes of surrounding traffic with IS. This could advance navigational safety when the anticipation is used for resolving traffic situations ahead of time. Questionnaires and interviews reveal a general positive attitude towards IS: skippers agree on that IS can be beneficial to navigational safety, assuming that the system implementation and user-interface design would be improved.

However, limitations and critical issues were also observed which could undo the potential benefits of sailing on trackpilot equipped with IS and even reduce navigational safety. The most crucial issues observed were: (1) significant deviations from the predefined track by the trackpilot system, (2) lack of clear operational procedures for how to use IS, and (3) the usability of the tested systems being a cause for misunderstanding and incorrect use of the systems.

Based on study findings, the following actions are recommended to gain more insight into human performance effects involving IS in order to reap the full potential benefit to navigational safety and efficiency.

1. Conduct a safety study as a basis for setting up a certification process for trackpilots (focused on safety) to allow for market implementation.
2. Research and define an operational concept and establish procedures, concerning the best navigational task distribution between the skipper and trackpilot system, and if and how vessels can coordinate and settle their intended routes.

[1] Rijkswaterstaat is part of the Dutch Ministry of Infrastructure and Water Management and is responsible for the design, construction, management and maintenance of the waterways and the main infrastructure facilities in the Netherlands.

3. Set up guidelines tailored to the concept of Intention Sharing, which discusses the interaction between trackpilot system and human operator, information selection, integration and design of information. The guidelines should not prescribe the aforementioned topics, but should clearly signify indicate design rules in order to support the correct use these trackpilot systems equipped with IS.

1 INTRODUCTION

1.1 Introduction

In recent years, there has been a rapid increase of inland vessels using track control assistants, or called as ‘trackpilot systems’, which automatically features sailing on a pre-defined track. The degree of automation differs in functionalities, such as in following a waypoint based track automatically, compensating for wind and current, either with intelligent speed control that accounts for set arrival time, speed or based on fixed RPM settings. These systems create a new opportunity, known as ‘intention sharing’: sharing the planned route with the surrounding traffic. The concept of intention sharing has been cited in publicly available research with the use-case short sea and the on open sea, but has not been studied with a focus on confined inland waters yet. The inland water domain differs from other areas, such as in waterway characteristics and the way of sailing and manoeuvring: the sailing behaviour tends to be more responsive to the local circumstances. When vessels receive the intended sailing movements of the surrounding traffic, it is presumed this raises skippers’ situational awareness of future situations and paves the way to anticipate in advance the shared intended movements of other vessels. This is a conjecture supported by previous research on the concept of intention sharing, but does not define the skippers’ experience, nor how sailing behaviour is shaped in confined and more busy waters.

1.2 Aim of study

Rijkswaterstaat commissioned MARIN to study the benefits of sharing intended movements between inland vessels on inland waters. Central question to the investigation is what benefits the concept has for increasing the safety and efficiency, of inland maritime operations, with a focus on short-term ‘operational’ level. The study is split in two main activities: first, a literature study was conducted, and secondly real-time simulations were performed at MARIN.

Scope
The simulation study is performed with a small group of skippers and aims to explore the possible benefits of intention sharing in relation to navigational safety and efficiency. Due to the explorative nature of the study, no generalisations can be made on the effects on navigational safety based on the small group of inland skippers involved in the study. Instead, the study focuses on increasing understanding of sharing intentions with surrounding traffic on inland waters.

1.3 Phases in project

Research activity 1: Literature study
The first phase contains a literature study on ‘intention sharing’ or similar concept to ‘digital route exchange’ to grasp the current state-of-the-art knowledge and understanding of how the concept works. The results of the literature study can be found in Appendix 1.

Research activity 2: Simulator study
The research activity of the simulator study consists of two main phases: the development phase and execution of the simulator program.

Development
The development phase consists of creating the required functionalities to conduct a simulator study to explore the benefit of IS. Each participating trackpilot manufacturer developed an ‘intention sharing module’ to send out and receive data for the identification and position of vessels. In addition, MARIN configured an interface between the own simulator software Dolphin and the external trackpilot systems to allow the systems to receive the required generated simulator data – such as AIS data – and provide a bridge to share the IS data.

Each participating trackpilot manufacturer designed a module to their design for displaying intentions on the depicted interfaces. MARIN developed a simulator experiment, with several simulation scenarios on simulated inland waters to be sailed by inland skippers.

Conducting study
As a result of the developments, real-time simulations were performed with inland skippers and the trackpilot system equipped with IS, which were installed at MARIN simulators. The results of the simulations provide the main content of this study and report; the literature study can be found in appendix 1.

1.4 Content report

Chapter two describes the method section of the performed simulator study, containing information on the set-up and involved trackpilot systems. Chapter three describes the direct results of the acquired data and observation of the simulator study. The results are discussed in chapter four. As last, the conclusions and recommendations can be found in chapter five.

2 METHOD

This chapter describes the simulator study set up, the involved simulators and trackpilot systems.

2.1 Goal simulator study

The main goal of the simulator study is to gain insight into the benefits of intention sharing for inland shipping, in terms of safety and efficiency of traffic handling. The focus is on inland waters with a short time window – ranging from roughly 5 minutes to 11 minutes – before meeting or crossing other vessels.

Main research question: *What are the benefits of intention sharing for traffic handling by inland skippers on inland waters?*

The following sub-research questions are formulated to further specify how the understanding into the possible benefits of IS is increased:

1. How does IS influence resolving traffic situations, such as crossing and passages, for inland ships?

2. How does IS influence communication, situational awareness and decision-making?

3. Are there operational boundaries, such as in time and distance between vessels, traffic density or traffic complexity, to utilise any found advantages of IS?

2.2 Set-up simulation study

Overview
To answer the research questions and gain insight into the possible benefits of intention sharing, two days of real-time simulations with participating inland skippers were organised, simulating different inland shipping scenarios combined with trackpilot systems equipped with IS. Each trackpilot could sail on a pre-defined track, with automatic steering; the speed was regulated manually by the skipper. The simulations were used to compare with and without IS, divided among two groups of skippers. Skippers sailed with simulated inland vessels in two different inland areas on the river Waal and Rotterdam. Multiple events across eight scenarios served as a test to investigate the skippers' subjective experience, anticipating sailing behaviour and perceived value of IS concerning navigational safety. VTS was left out in the simulations and part of the operational concept to focus on the added value of IS for inland skippers.

The simulator program consist of:

- Two days simulations: 0.5 day training + 1.5 day experiment

- In total 6 participants: 3 participants sail and 3 participants rest at each time

- Three trackpilot systems with IS, each one installed on a simulator (two multi-purpose simulator and one full-mission bridge)

To scrutinize the effects of intention sharing, a comparison is made between two groups of skippers receiving the same scenario with or without intention sharing.

1. IS versus non-IS
    a. Comparable situations with IS and without IS

Furthermore, a few scenarios with intention sharing are simulated with both groups of skippers, varying in traffic complexity and type of events to investigate the effects of navigating with IS in different conditions

2. IS in different complexity levels
    a. Traffic density
    b. Complexity of traffic situations (directions, speed, type vessels, relative position, …)
    c. Day, fog

Participants
Six inland skippers participated in the simulator study, with an average age of 54, a minimum of 43 and a maximum age of 70 years. All skippers had more than 15 years of experience as inland skipper. In addition, half of the group was familiar with one of the trackpilot systems used in the study.

Simulator
To sail with three inland skippers at the same time, three dedicated simulators were used: two multi-purpose simulators (MPS) and one Full-mission bridge simulator, a more elaborated description of the depicted simulators can be found in Appendix 3.

Each simulator was equipped with an ENC, tiller, thruster, and intercom for VHF and the simulated world was displayed on large screens or projected. Skippers could only sail manually with the provided controls – or track following with the installed trackpilot system – no Rate of Turn pilot or automatic course pilot was available. The simulator software was configured to send out AIS and position data to all trackpilots. In addition, MARIN simulated vessels, which were used as traffic vessels, send out their intended routes as well. This resulted in that all vessels within the simulated world could send and receive intended routes of surrounding vessels.

Figure 1 Multi-purpose simulator with a trackpilot installed

Trackpilot system
Three trackpilot manufactures (Argonics, Tresco and Shipping Technology) partnered in this study, and developed a module to share and display the intended route or movements on or similar to an Electronic Navigational Chart (ENC). The manufacturer had the freedom to choose the display design of the intended routes, resulting in three different designs. Each trackpilot is capable of sailing a pre-selected track with automated steering and displaying the intended routes of surrounding traffic; entailing the other skippers participating in the simulation study and configured traffic in the simulation software of MARIN.

Total system

The total system covers at least one main ECDIS – or comparable – display which the intentions of other vessels are visualised. Next is a radar display, a screen for the trackpilot itself (when required), and larger screens for displaying the simulated world: the sailing environment.

Furthermore, the control is switched from manual steering to the trackpilot by pressing the red button at each simulator position desk and indicated by a red button light. In sum:

- Each trackpilot uses its own ENC to displays the intentions based on route waypoints forming a track, received from each trackpilot
- Each ENC displays vessels intentions or other nautical information in their own chosen design
- The intended route is only sent out when the trackpilot is on; once skippers switch to manual steering, the intended route is no longer shared
- The trackpilot only automates the steering, skippers had to change speed manually with the dedicated thruster at each simulator
- Each trackpilot sends out a minimal amount of distance, ranging from 2 to 5 kilometres

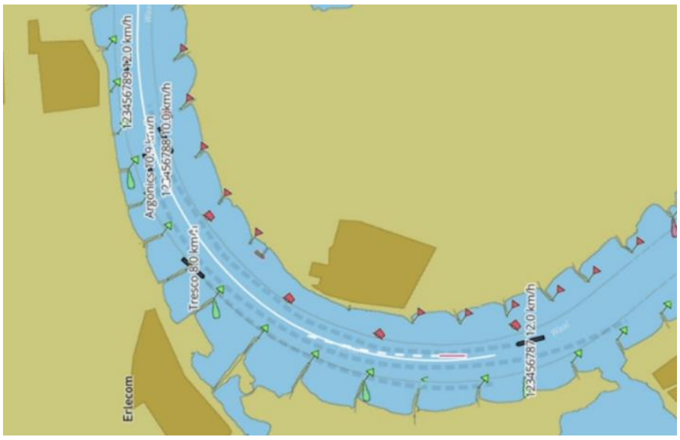

Figure 2 Example of displayed shared intentions from a trackpilot

Scenarios

Table 1 contains the simulator scheme for which scenario is simulated with and without IS, and which group (A or B) received each condition.

Table 1 scenario scheme

	Scenarios							
Variables	1	2	3	4	5	6	7	8
IS	Bridge	Pannerdensch	Maas-waal	Busy traffic	Emergency	Crossing	Fog	Short
NON-IS	A/B	A/B	A	B	A	B	A	A/B
Time to conflict	11	5	8	8	7	6	6	4
Fog/ night							X	

Several events were configured in the simulations scenarios, reflecting normal navigational events on inland waters, consisting:

- Taking over other ships
- Blue sign situation
- Crossing other ships (90 degrees)
- Meeting multiple vessels at same point in time & location
- Bridge passage and planning with other vessels

The two teams (3 per team) serve as each other control group: each group will perform the same scenarios. The results per scenario will be compared within the group A (participant 1-2-3) and between the second group B (participant 4-5-6).

Example of a scenario

Figure 3 displays an example of one of the scenarios used for the simulations. It displays the set-up of vessels positions and stage for creating a crossing with multiple vessels that needs to be resolved. In this scenario, skippers have a relatively short time to get acquainted with the situation and resolve the problem as much as possible with the trackpilot equipped with IS.

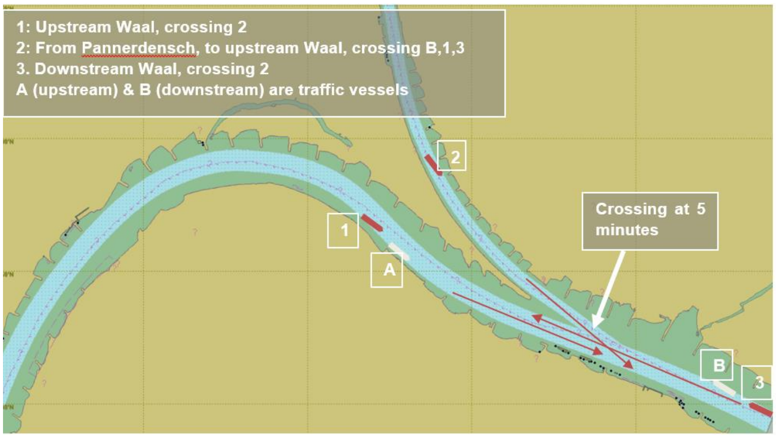

Figure 3 Example of a simulator scenario

Area

Two sailing inland areas were configured for the simulations: the river Waal and in Rotterdam at the turn de Esch. The red marks in the displayed figures point out the sailing area.

Figure 4 Sailing area river Waal

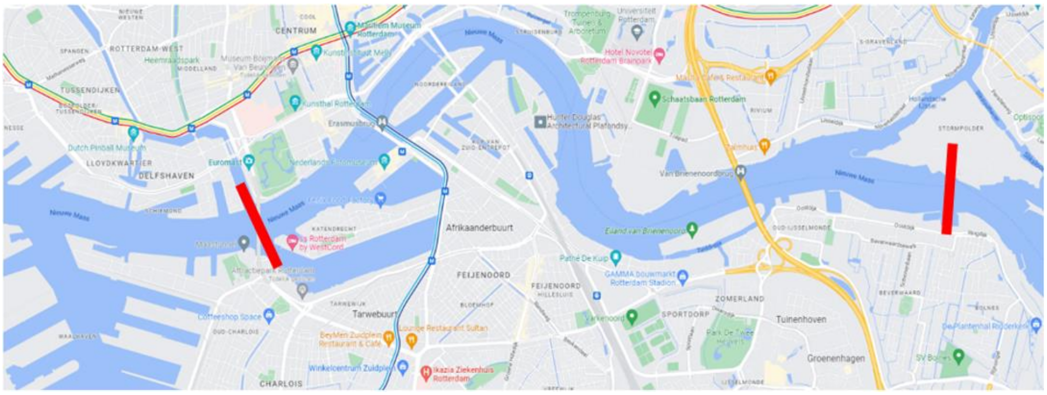

Figure 5 Rotterdam de Esch

2.3 Procedure

On the first day of the simulations, all skippers received a briefing about the experiment and the trackpilot systems. Part of the briefing went into the premises of the concept intend sharing and clearly stating the sailing instructions: ‘primarily sail with the trackpilot, turn to manual mode when the situation demands it according to your judgement, and use voice-communication if you feel this is needed. In the sailing areas, there was no VTS to regulate traffic, intending to let the skippers coordinate their sailing intentions alone. All skippers were asked to sign a consent form to acknowledge the information about the experiment and use the recorded data for research purposes.
After the briefing, the skippers were divided into couples and trained on the dedicated simulators to get familiar with the simulator environment and trackpilot systems. All skippers received training on each simulator and the installed trackpilot for three hours by rouletting between the simulators. To familiarise with the area, a training scenario was used to let skippers sail in the simulated environment.

After the training sessions, the skippers conducted the experimental scenarios, each lasting around 15 to 20 minutes. Each group (A & B) received the same scenario, which contained one or multiple events, such as a crossing. For three scenarios, both groups simulated with shared intentions of the surrounding traffic; in five scenarios each group received either the scenario with or without shared intentions to compare group A and B with each other. Before the start of a new scenario, each skipper was repeatedly instructed to keep the starting speed that each vessel was given – as long the situation would allow – to ensure the similarity of the planned events between the simulations of both groups. At the start of the scenario, skippers were enabled to activate the trackpilot with a pre-selected track. During the simulation, skippers could change the track via each trackpilot interface; the speed was always manually adjusted with a thruster within hand reach.

3 RESULTS

This chapter contains the results of the performed activities, starting with a task analysis and thereafter the outcomes of conducted questionnaires, acquired observations of the simulations, and interviews with the participants.

3.1 Task of the skippers

A basic task analysis has been conducted to depict and understand the task changes for the skipper when sailing with IS compared with no IS. The default situation as base for the comparison entails manual steering with no help of automation for navigation tasks. Two main tasks are compared for sailing with and without IS: voyage planning and monitoring the environment for navigational purposes. To structure how the navigation task is performed, four main human information process stages are distinguished: 1) Detect, 2) Analyse, 3) Decision making, 4) Executing. Figure 6 depicts the main tasks for sailing without IS, and figure 7 the tasks with IS. The depicted tasks are simplified to illustrate the information processing stages and how this changes when using IS.

3.1.1 Navigation tasks without IS

For 'voyage planning' the four stages are briefly explained: the first stage involves detecting (1) relevant information, such as the current vessel position and speed. Then, information is analyzed (2) to understand the current state of the situation, for example, if the vessel is at the correct position in the river or too far to one side or if the speed is too high or low. In the third phase, the understanding is used for decision-making (3), or plan-making, course and speed. Once a plan is made, it is executed (4), in the case of manual operation with manual inputs to the tiller and thruster.

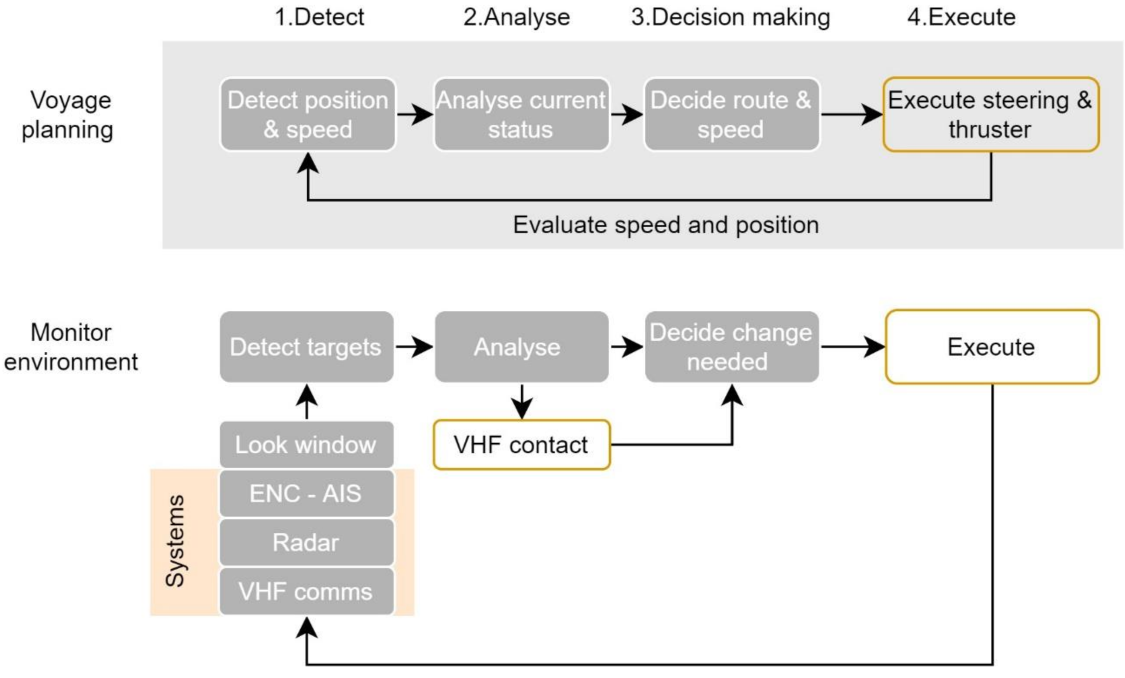

Figure 6 Task analysis navigation tasks

3.1.2 Navigation tasks with IS

Figure 7 displays the same navigation tasks as in figure 6, but the changes are marked in red. Each sub-task is altered when navigating with a trackpilot system equipped with IS. There are several changes:

1. The five information process stages are now mainly taken over by the trackpilot system: it is no longer a necessity to go through each stage because the route is already defined and sailed automatically. Furthermore, the level of automation and task distribution between automation and the human operator will shape the five information processes. For example, when the speed is not regulated by the trackpilot, this still needs to be done by the skipper which impacts the information processing stages.

2. However, the five stages are still subject to be performed by the skipper but will likely occur in a slower recurrence with the goal to assess if the predefined track and speed are still preferred. Stage 3, 'predicting the future situation' is supported with the predefined track displayed on the ENC; the skipper can visually inspect the intended route.

3. A new task arises: monitoring the trackpilot performance – how accurately the TP is sailing the predefined track. The skippers need to know the performance and whether the system is correctly sailing the intended track.

4. The control interface to steer/control the vessel is changed: a skipper has a new opportunity to change the vessels' position on the water by adjusting the track via the controls of the dedicated trackpilot.

5. The detection of new targets (vessels) is enhanced with an additional information source provided by the intended track of surrounding traffic; additional information is added to the existing information sources. With the added IS information, VHF contact to acquire information about sailing intentions is less required and could result in reduced VHF contact.

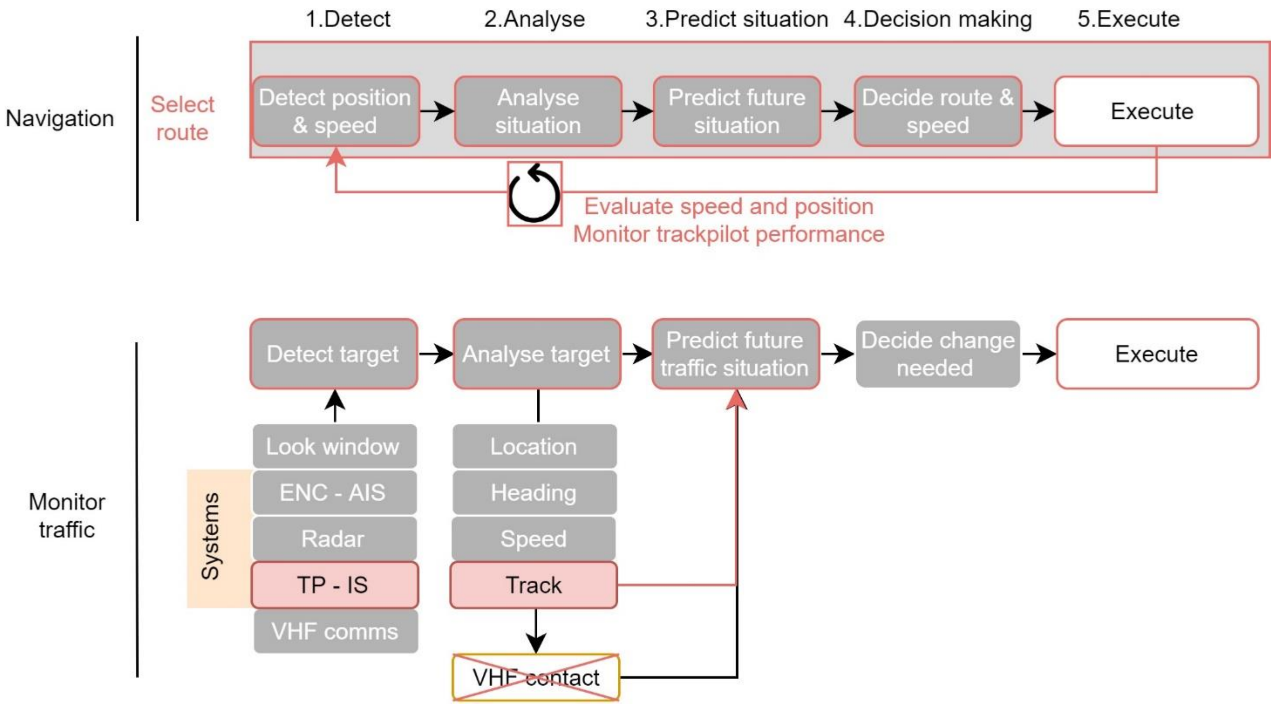

Figure 7 Changes to navigation tasks with IS

3.2 Questionnaire outcomes

After each simulated scenario, skippers filled in a questionnaire before the interview about the experience of sailing with or without intention sharing. The results of the questionnaire are presented in this section; interpretation of the results with regard to the study objective can be found in chapter 5 Discussion.

1. How realistic was the scenario?
All six skippers answered this question 8 times for each scenario. The y-axis displays the Likert scale, from 'very unrealistic' (1) up to 'very realistic' (7); the x-axis numbers the scenarios. The average score of all the scenarios is 6 out of 7. Scenario one (bridge crossing) has the lowest score, with 4.2 and is also most divided between the groups: group A scored a 2.3 and group B a 6. Group A explained that the participants retained their speed to an unrealistic extent, which resulted in an unsafe traffic situation. In addition, the scenario contained a stranded vessel at a bridge pillar, which was found unrealistic by group A; group B did not made the same notion. The highest score is given to scenario 4 (much traffic in the river and blue sign).

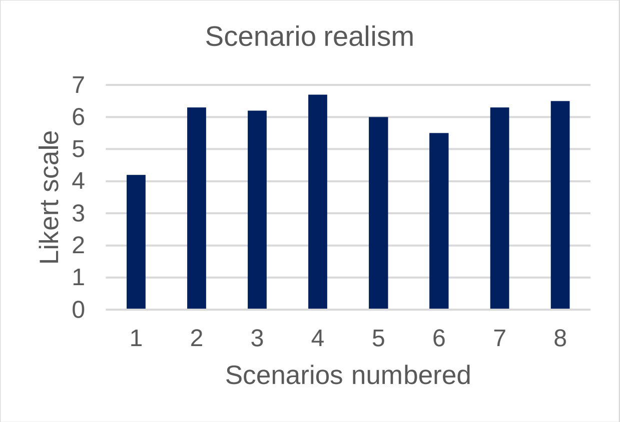

Figure 8 Experienced realism of scenarios

2. How useful was the information about intentions?
Only the group whom received a scenario with IS were provided with the question, at scenario two to seven. In scenario one, two and eight both groups simulated with IS. The y-axis displays the Likert scale, from 'very un-useful' (1) up to 'very useful' (7); the x-axis numbers the scenarios. The average score of all the scenarios is 5.7 out of 7. Scenario four is scored lowest with a 4 and scenario seven (Fog) is scored highest with 7 out of 7. The lower score on scenario four has to do with visual cluttering: the scenario contained a high density traffic situation, which resulted in numerous overlapping lines (intended routes) on the screens – the visibility of the lines became an issue.

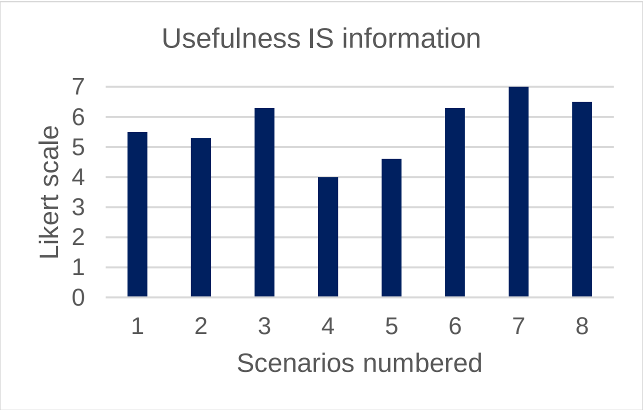

Figure 9 Reported usefulness IS information

3. Does showing intentions benefit the navigational safety in this scenario?
For this question, only the group whom simulated the scenario with shared intentions, group A or B, were given the question, with the exception of scenario 1, 2 and 8 in which both group simulated with shared intentions. The y-axis displays the Likert scale, from ‘not beneficial (1) up to ‘very beneficial’ (7); the x-axis numbers the scenarios. The average score of all the scenarios is 5.6 out of 7. Scenario two (traffic from Pannerdensch kanaal) is scored lowest with 4.3 and scenario three, six and seven (Fog) share the highest score with 6.7 out of 7. The reason for the lower score on scenario two is not very clear; one of the skippers scored a 2 with the argument that there was no navigational safety problem, hence there was no safety benefit for IS. This is in contrast with the arguments of other skippers concluding that IS did help to identify unsafe crossings with surrounding traffic.

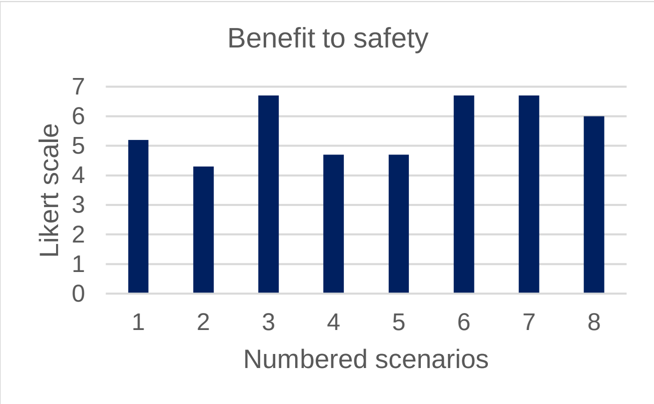

Figure 10 Reported benefit to safety

4. What can be improved with the system?
Several things were mentioned by the skippers on what can be improved on the trackpilot systems. The comments relate to trackpilots and in specific IS.

1. Develop and improve a play-forward functionality to detect and determine where vessels will be in relation to the own vessel in time, based on the current speed and intended track.
2. Improve the trackpilot performance: sometimes the heading of the vessel was not in line with the intended track or the trackpilot did not always closely follow the intended route.
3. It would be helpful to display a ‘blue sign’ in the system.
4. When IS is stopped, display the heading line to keep an indication of where the vessel is going.
5. Improve the design of IS information, for example the chosen color schemes of the displayed lines on the interface
6. Allow for more distance to the selected track in order to activate the trackpilot.

3.3 Observations of simulations

Each group of three inland skippers conducted 8 scenarios, therefore, in total 16 simulations runs were performed. This section contains the summarized observations of the simulations.

- Skippers become more familiar with the trackpilot systems over time, the concept of IS and how to use it for navigational purposes. This is a learning effect that resulted in more anticipation of emerging events in scenarios by skippers over time. Due to missing clear operational procedures, there was not an adequate practice in using IS alongside with VHF.

- Observations from simulator scenarios with a short timeframe (5 minutes) to react for skippers on an emerging traffic conflict revealed that the trackpilot systems with IS provides the means to anticipate the intended tracks of surrounding traffic. For example, in scenario 2, located on the River Waal near the Pannerdensch kanaal, skippers were reacting to changes to the intended routes – and resolving a possibly unsafe situation – within less than a minute before encountering each other without any VHF contact.

- Some skippers needed help understanding and correctly using the trackpilot system equipped with IS. The difficulties are associated with the complexity of the design of control and information presentation; some controls and information presentations are difficult to understand.

- The trackpilot systems did not always follow the intended route correctly, resulting in hazardous situations – the skippers realized too late that the trackpilot system was not following the route properly and it took time to understand and to make the decision to switch to manual steering.

- Observations from scenario 4, which contains a high traffic density navigational situation, show that with multiple intended routes displayed on the screen, the visual display is cluttered, as can be seen in figure 11. It burdens the skippers' workload in identifying and understanding the shared intended routes.

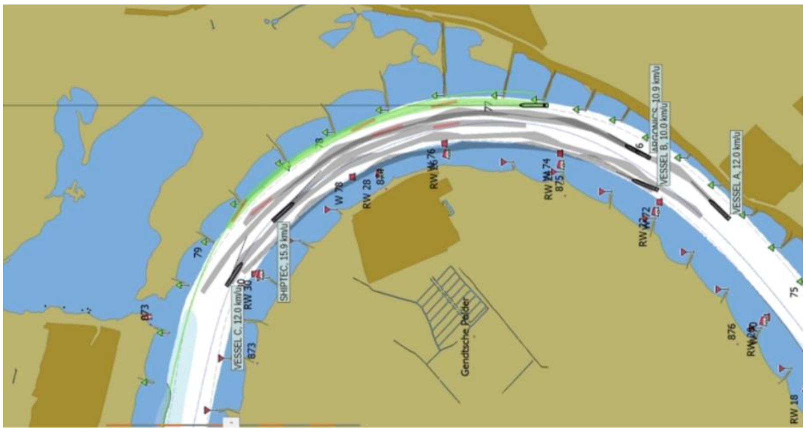

Figure 11 A still from scenario 4 of one of the trackpilot systems with IS

- Crossings and traffic situations that are clearly presented on the screen – which are easy to understand with a minimal amount of time such as within several seconds – are most beneficial in supporting the situational awareness and decision-making.

- In situations with bad visibility, such as with heavy fog, the additional information of IS was highly supportive in building up situational awareness on what surrounding traffic is doing.

- Observations of the simulations suggest that sailing with IS could increase the chance on breaking navigation priority rules, would may be explained by a higher perceived safety level. With IS, skippers may feel safer and therefore backslide to more risky sailing behaviour.

- It was observed that skippers could assume that surrounding traffic will detect and respond on their shared intended route. This brings about a new risk that both skippers do not change route to avoid an unsafe situation.

- The shared intended information provides only information on current status on what other vessels plan to do. It does not provide information whether the intended routes will be changed and in what direction. It was observed multiple times during the simulations that skippers changed the intended route only a very short time or distance before encountering traffic. This behaviour lead to unsafe navigational situations.

3.4 Interviews

After filling in the questionnaires upon each simulation, a researcher interviewed the group to elaborate on the provided answers, with the goal to deepen the understanding of possible benefits, limitations and requirements of intention sharing. The comments made during the interviews are in this section summarized; in chapter 4 Discussion, the results are discussed before drawing conclusions in chapter 5.

Benefit of intention sharing
In the interviews, skippers made several comments about the added value or benefit of having intention shared, which are summarized here below:

1. IS provides information on the intended movements and therefore helps with detecting and judging future traffic situations
2. The information of IS can be used for the own decision-making on speed and sailing track, to increase the space with the surrounding traffic when this seems required
3. IS has particular benefits for crossings and certain manoeuvres in which other traffic is encountered
4. The play-forward functionality featured on one of the trackpilot is seen by skippers as very helpful. One of the participants suggested improving this feature to control the play-forward movement with a rotary knob; this provides the skipper more control in the speed of playing forward and inspecting the moment of interest
5. IS reduces (the need for) VHF communication, as the displayed tracks can see the intended movements
6. IS is helpful, also in busy waters, by getting a more accurate future prediction on how surrounding traffic will be sailing, as long the displayed lines on the screen are adequately presented with clarity
7. In bad visibility, IS provides extra guard of where other vessels are heading
8. Any adjustments made to the track – setting an offset to starboard or port side – were immediately visible on the interface, which allowed for the settlement of intended routes with the surrounding traffic

Critical findings
Upon the seen benefits, there are several critical comments made in the interviews about intention sharing. Here below they are summarised:

1. There is a risk of relying too much on the displayed intended movement of surrounding traffic
    a. the intentions displayed gives the impression that vessels will sail that track, however, it does not tell if surrounding traffic will keep to the intended route or change it later
    b. It does not provide information on the performance of the trackpilot; how well the trackpilot will keep its intended track, influenced by hydrodynamics effects and local conditions
2. In situations with a short timeframe, less than 5 minutes, IS can be confusing and not reliable due to any last-moment-changes made to the intended track by surrounding traffic

3. Risking misunderstanding the trackpilot status; having a thorough understanding of what the trackpilot is currently doing
4. Risking misunderstanding the displayed information, such as confusion about which track belongs to which vessel due to display clutter – for example, by having overlapping lines presented
5. Confusion about or unfamiliar with the presented information due to the different display designs of each trackpilot system
6. There is a risk of new assumptions: skippers may expect that surrounding traffic will respond on their shared intended route. Sending out intentions does not imply it will be correctly notified by surrounding traffic; if both parties expect the other will respond, it could lead to both parties being non-responsive, until it is too late
7. Displaying intentions of traffic while the surrounding traffic is switched to manual mode would wrongly represent the actual situation and should not be made possible
8. Sailing in a nautical environment with mixed traffic of IS and no IS, can lead to confusion, when seeing vessels in the real world that are not displayed by the system. That can induce a time-consuming verification matching process, which could burden situational awareness instead of improving it
9. Intention sharing could lead to an increase in breaking priority rules on inland waters, because skippers can reason that their intended route can be detected upfront by the surrounding traffic, creating a feeling of safety

4 DISCUSSION

Overall impression intention sharing
The overall results indicate that IS holds the potential to improve navigational safety; however, it's potential leans on critical aspects related to trackpilot system performance, operational procedures, user-interaction and information design of the involved systems.

Part of the picture is told by the answers of the questionnaires; on the 7-points Likert scale, the average score for the question 'does showing intentions benefit the navigation safety' holds a 5.6 out of 7. The simulations and logged data support the positive view: skippers tend to anticipate further in time future situations, using the displayed intended routes of surrounding traffic, and make less use of voice communication. However, any conclusions drawn based on simulator data should be taken highly cautiously due to the explorative nature of the simulator study. In some cases, skippers did indeed anticipate faster on an emerging traffic situation compared to sailing without IS. Still, the opposite could also be found: waiting on other skippers to respond on the shared intended route. If the information on the intended route is detected and understood well, it can highly support the mental calculation of predicting the future traffic situation.

Regarding the potential to benefit the (navigational) safety and efficiency, a basic model with three main influencing factors is used to discuss the possible benefits and new risks with IS. The three factors that influence each other and impact safety are the human factor, the (operational) procedures, and the systems that the skippers use.

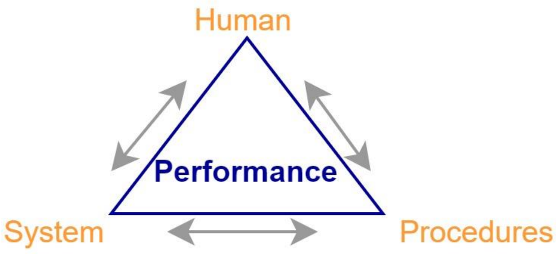

Figure 12 Basic performance model

4.1 Human factor

The human factor is briefly discussed, concerning the effects for human performance when using a trackpilot system equipped with IS.

4.1.1 Situational awareness support

The results from the simulations suggest IS supports situational awareness, especially in predicting future situations. This relates to the three mental processes of situational awareness (Endsley), presented in figure 4, and are here applied to intention sharing: 1) at first the surrounding traffic must be detected, which is made easier when the tracks of other vessels are displayed on the ENC – when designed well. 2) secondly, the information of the detected information is interpreted or analysed in terms of what it means – for example what kind of vessel is it and how does the position relate to the own vessel. 3) Thirdly, projections are made about how the situation will develop, which is the most complex cognitive task and most prone to wrong estimations. The additional information on intention sharing accurately indicates where traffic will be sailing, relieving the cognitive effort in making this prediction and guarding against wrong expectations. The tested interfaces of the trackpilot succeeded in supporting situational awareness.

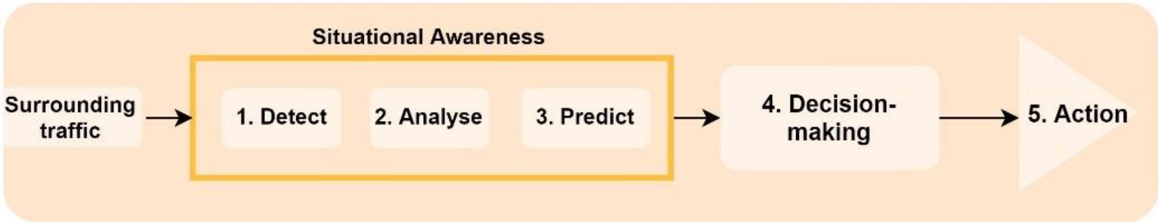

Figure 13 Model of situational awareness

Although the shared routes indicate where traffic will be sailing, it does not always consider the dimension 'time': where traffic will be at a specific time. This is still a complex cognitive task to complete. However, the exchanged information coming from trackpilots contains dimensions 'location and time'; one trackpilot manufacturer took advantage of this and built a play-forward functionality. Skippers were highly optimistic about this feature.
In addition, IS also enables to show future track conflicts with surrounding traffic, which was highlighted on screens of some of the trackpilot systems. The type of information is highly supportive in the situational awareness of identifying and predicting potential navigational conflicts.
Although the results indicate that the tested trackpilot systems equipped with IS were good enough to enhance and extend situational awareness, several usability issues need further development to be used (further explained at 5.3). Enhancing situational awareness may result in higher safety in inland waters. However, there are different short and long terms effects to be taken into account related to building up and retaining situational awareness and human performance. Some of these effects are discussed in the next section, concerning the task changes for the skipper when using a trackpilot equipped with IS.

Workload
The workload is altered due to the task changes; whether the workload is higher or lower depends highly on the design of trackpilot systems equipped with IS, the operational procedures for using it and how to coordinate with surrounding traffic. Suppose the concept of IS is applied to the current situation on the river. In that case, it may result in a higher workload due to having an additional system on board in a mixed traffic situation: some vessels have IS, and some do not. Sailing in a nautical environment with mixed traffic of IS and no IS, can lead to confusion when seeing vessels in the real world that are not displayed by the system. That can induce a time-consuming verification matching process, which could burden the situational awareness instead of improving it. The simulation observation suggests a higher workload; however, skippers were sailing with an immature design of displaying intended routes and were exposed to (only) a few hours of training with the trackpilot, which needed to be more to understand the system fully.

4.1.2 Task changes

With the trackpilot equipped with IS, the navigation or sailing tasks are significantly changed. A considerable shift in operation comprises that the task of manoeuvring is taken over by the trackpilot following automatically a predefined track, which changes the role of the skipper from an active operator to a more passive observer. Basic information processing stages are therefore altered. For example, it is no longer required to decide on and execute the required rudder inputs to follow a certain desired path. Both information-processing stages are replaced: the decision-making process for the necessary rudder input and the execution of steering. Instead, the skipper only needs to decide whether the current track is still preferred or needs adjustment to avoid traffic. Furthermore, the task execution process of changing course is replaced with the interface of the trackpilot system: a touchscreen, mouse and keyboard or physical buttons to provide input.
The implications of these tasks changes are manifold; it alters the skippers' attention strategy for updating situational awareness because this was primed or induced by their steering actions, such as continuously assessing whether the given input resulted in the correct vessel movements. The need for updating the situational awareness is therefore lowered and more leftover to new criteria to answer the question: when is attention required to assess the current situation and predict if the predefined track is

still preferred? How and when the situational awareness will be updated, here summarised as the ‘attention strategy’, matters to the likelihood that any relevant changes in the surroundings or essential information on the screens are detected and interpreted correctly on time by the skipper. The likelihood of detecting and interpreting relevant changes directly impacts navigational safety and efficiency.

Control interface
Another implication of the task change relates that skippers will use a different system to adjust their course and speed: not by use of the tiller or thruster, but by utilising available controls and displayed information of the trackpilot. This implies a dependency on a correct understanding and usage of the trackpilot system – which is the replacement of the interface to control the vessel. Observations of the conducted simulations revealed that, despite training with the trackpilot systems, skippers struggled with understanding or controlling the system correctly at several moments. The level of understanding skippers have of the tiller and thruster on their vessel, may be equal required of the new trackpilot control interface to minimise the chance of misunderstanding or erroneous input to the system.

VHF
Another observed effect due to the task changes is the reduced use of VHF to coordinate navigational actions with the surrounding traffic. In several cases during the simulations, skippers used the IS information to establish a new route or track. One observation during the simulations signals a possible adverse effect that may to be taken into account. In some situations, skippers were expecting the other (participant with IS in the simulation) would react on their shared intentions. The ground for that expectation lays in the fact that the skipper in question is aware of that the other can detect the intended route and will anticipate; however, if both parties at the same time have the same expectation, it could lead to dangerous situations – as was observed during the situations. Although not observed during the observations, some arguments can be found in favour of a different way of coordinating via shared intentions, for example, to reduce miscommunication.

4.2 Procedures

The different way of coordinating actions with surrounding traffic relates to operational procedures and practices. During the simulations, skippers had the assignment to use the trackpilot and IS to their advantage in navigating, and when it was deemed required VHF could be used. There were no procedures defined a priori of the simulations. As a result, skippers used the trackpilot systems to coordinate with other vessels to a dangerous end; in some scenarios, skippers changed their intended track only shortly before encountering oncoming traffic. It stresses a need for clear operational procedures for using IS, especially concerning coordinating with surrounding vessels that sail with or without IS systems.

4.3 System design

System performance – trackpilot
With a digital system supporting situational awareness and yielding a higher degree of accuracy than individual mental calculation – because the intended tracks can be seen – the dependency on the shared intended route will be higher. If the system provides incorrect information, for whatever reason, this could lead to critical misunderstandings of the nautical situation. Furthermore, there will be a significant dependency on detecting and understanding the additional information correctly. The better the system will be – displaying accurately traffic intended routes – the higher the trust given to the systems. As mentioned in the results section, there is a risk of relying too much on the displayed intended routes, because the actual route can differ from the intended route due to numerous reasons, for example, strong hydrodynamic effects, weather circumstances or other local conditions. High placed trust in systems relates to the well-known problem of the ‘automation conundrum’ (Endsley, 2017): as the system reliability improves, the lower the situational awareness of the human operator and the likelihood of taking over manual control when required.

In addition, a track can be changed by a skipper at any point in time, which is currently not extra notified in the system. Any changes made to the intended route of surrounding traffic by surrounding traffic when a skipper is not attending to the display, bear a risk of missing out on those changes. This is relevant to adequately updating situational awareness: detecting any (relevant) differences in the traffic situation on time. The same risk exists for displaying intentions of traffic while the surrounding traffic is switched to manual mode would wrongly represent the actual situation and should not be made possible.

One of the encountered problems was that skippers turned off the trackpilot because the status of the trackpilot was misunderstood. It did not always concord with the skippers expectations and mental model of navigation.

Interface design
As part of the situational awareness is based on digital information, the presentation should be crystal clear, as several issues were observed during the simulations. The current tested trackpilot systems, the first designs of displaying, did provide the intended routes, however, it is yet an immature design and needs further improvement. One of the difficulties concerned relating routes with the corresponding vessel; this became more difficult with more vessels. Another example involves the correlation between colour use and characteristics of displayed lines and their meaning; these features differ among the tested trackpilot systems, which brings about confusion and sets the stage for human error when skippers give input to the system. Any uniformity and standardisation in the design will reduce this risk of applying the wrong learned practised of one particular trackpilot to another. A possible design solution for visual cluttering of multiple traffic routes displayed may be providing control to the skippers on which routes should be shown; provide the skipper freedom to decide which routes are of interest.

4.4 Limitations of the study

Several limitations in conducting the simulator study were present, which are briefly discussed in this section. Aside from the limitations found during the simulations, the answers to the main research question are bound to the set-up and explorative nature of the study – to investigate the possible benefits of intention sharing to navigational safety and efficiency. The simulator study has been conducted with six inland skippers, which is a low number of participants to draw any significant conclusions, based on the acquired data and simulation observations, whether the concept of IS benefits navigational safety and efficiency. The experimental set-up of the simulator study aimed to compare two groups with each other, each group receiving the same scenario but with or without IS, to scrutinize the differences and potential related benefits of IS. Due to the low number of participants, any finding should be taken with caution and reviewed against contrary results.

Limitations during simulations
Not all participants were familiarised enough with the trackpilot systems equipped with IS, as became apparent during the simulations. Skippers were exposed to the complexity that each of the three trackpilot systems differed in set-up, layout and control interface. Some participants needed help with understanding the trackpilot systems and correctly using them during the simulations. This hindered an effective study at some points, as some skippers had troubles using the systems, which caused delays in providing input to the system or resulted in a misunderstanding of the presented information. During the day, skippers become more familiarised with the system, which positively affected the envelope of the simulations.

One of the trackpilots did not receive the position of the other vessels in the simulated world when no intentions were shared; this was however, displayed on the ENC of the build-in display of the simulator. In the case of simulating a scenario without IS, the skipper had to attend to two interfaces: one trackpilot interface displaying the own predefined route, and the other screen where the surrounding traffic was displayed. This setup was different from the two other trackpilot; both sets of information (own route and positions of other vessels) was presented in one interface that represented an ENC.

Technical issues
At several points during the simulations, there were technical issues with the trackpilot systems, for example, instead of vessel names there were only numbers displayed on the ENC. During scenario 6, group B endured several technical problems with the trackpilot systems, which distracted them from the sailing tasks.

Performance trackpilot
The performance among the trackpilots differed. To some extent, skippers complained about the reliability of some of the trackpilots. This resulted in different sailing behaviour impacting the envelope of the simulated scenarios.

Concluding remarks limitations
In sum, there are several limitations of this study, however this study does provide insights into the operational effects of IS, described in the potentials to support situational awareness and navigational decision-making.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This section contains the conclusions, which are structured to the stated research questions in this study.

Main research question: What are the benefits of intention sharing for traffic handling by inland skippers on inland waters?

The study results indicate a potential benefit for IS to be used for resolving traffic situations earlier in time, providing more time and options for safe and efficient navigational solutions. Therefore, the IS could potentially benefit navigational safety and efficiency; however, this conclusion is subject to several limitations and critical issues.

A. Observations from the simulations reveal that skippers anticipate earlier on enfolding traffic situations, due to the extra information provided on intended routes. With early anticipation, efficiency can be improved by having more time and options to solve a potential conflict with small changes in course and/or speed. On its turn a potential conflict is resolved early and no last minute actions are required which has a positive safety effect. Furthermore, the overall attitude of skippers towards the concept of intention sharing is positive, concluding that the participants see potential in using IS to their benefit – related to navigational safety and efficiency.

B. However, the current tested operational concept and tested systems demand further development to permit any further usage. Several critical issues were observed that could limit or frustrate the potential benefits of sailing on trackpilot equipped with IS or even reduce navigational safety. Observed critical issues involve the following:

   a. significant deviations from the predefined track by the trackpilot system,

   b. missing clear operational procedures for how to use IS

   c. the usability of the tested systems being a cause for misunderstanding and incorrect use of the systems and guidelines for implementation might be required;

Sub-research question: How does IS influence resolving traffic situations, such as crossing and passages, for inland ships?

C. The simulation observations reveal that IS is used to anticipate earlier on the shared routes of surrounding traffic with IS, which could advance navigational safety when the anticipation is used for resolving traffic situations ahead of time. IS seemed most useful when the presented information is clear on the location and related traffic that will be encountered. Scenarios with higher traffic density resulted in multiple overlapping lines and visual cluttering (the intended routes) on the dedicated screens of the trackpilot systems, which made it problematic to adequately detect and use the IS information.

Sub-research question: How does IS influence communication, situational awareness and decision making?

D. The results indicate that IS supports situational awareness in projecting future positions and tracks, which can be used to benefit the own navigation efficiency and safety in moving away from reacting on surround traffic to more planning-based sailing behaviour.

E. Simulations results reveal that the required amount of VHF communication is reduced and replaced by information exchange of intended routes via the trackpilot systems.

F. The concept of intention sharing brings on new human performance challenges due to the task transfer of sailing from the skipper to a (track control) system. These challenges come with new risks, such as risk-compensation behaviour, situational awareness out-of-the-loop problems and overreliance on automation.

G. User-system interaction for proper control of the trackpilot is crucial for a good overall human-system performance. A less optimal system design is prone to human error; the interface design related to intention sharing imposes easily visual cluttering and hinders effective support of building and retaining situational awareness in more dense and busy waters.

H. There is a tendency – also observed during the simulations – that skippers may feel safer with intent sharing, lowering the threshold to break navigational (priority) rules.

I. Matching vessels with intention sharing with vessels seen in the real world bear a risk of identifying the wrong vessels, especially with a mixed traffic with different systems on board, with and without trackpilots and shared intentions.

Are there operational boundaries, such as in time and distance between vessels, traffic density or traffic complexity, to utilise the advantages of IS?

J. Results of the simulations suggest that with a shorter timeframe, it becomes more difficult to fully rely on IS as only means to resolve a traffic situation. It highly depends on the usability of the involved system, such as the visual clarity of displayed intended routes and performance of trackpilot in sailing the intended route.

5.2 Recommendations

The following section contains the recommendations for trackpilot usage and on the concept of intent sharing.

Trackpilot – activities and further research

A. Conduct a safety study as a basis for setting up a certification process for trackpilots (focused on safety) to allow for market implementation. Take into account a human performance risk-assessment to attest the safety of a trackpilot system covering topics such as the workplace environment (wheelhouse), user-system interaction, interface design and procedures.

B. Create an industry certification process for trackpilots based on a safety case to verify a certain safety level and display operation ability in different circumstances and sailing areas, and interaction with other (trackpilot) systems.

C. Investigate how to overcome situational awareness of out-of-the-loop problems when sailing with a trackpilot that takes over the navigational tasks.

D. Define best practises on operational procedures and concrete design guidelines of the human machine interface.

E. Define a training guideline, describing the competencies (knowledge, skills and attitude), operational procedure, best practises and behaviour, for how to use a trackpilot (with intent sharing). Define the training requirements and estimations of training hours and training context.

Trackpilot – directions for solutions on observed issues

F. Ensure the trackpilot system provide adequately transparency in the current and planned actions, and current active mode.

G. Ensure trackpilot system adequately issue the operator when the system mode is changed – for example when switching between the modes of sailing on trackpilot and manual steering.

H. Ensure trackpilots follow the track with a clearly defined accuracy and if a defined threshold is exceeded the trackpilot should clearly reach the skipper to take action.

I. Ergonomically integrate track information in a single screen to group relevant navigational information. This will help skippers to correlate nautical information with geographic information more easily.

J. To guard against situational awareness of out-of-the-loop problems, investigate strategies to actively involve the operator with checking the system. For example, set up a mandatory manual action as function to keep the operator involved. Other directions to investigate are establishing new engaging tasks to involve the operator such as route optimisation or with goals of reducing fuel consumption.

Intent sharing – activities and further research

A. Research and define an operational concept and establish procedures, concerning the best navigational task distribution between the skipper and trackpilot system and how vessels can coordinate and settle their intended routes. For example, this links to the risk of non-response when skippers assume the other will respond on their shared intended route.

    1. The role of digital coordination and VHF in coordinating or acknowledging arrangements for solving traffic situations
    2. How to use the system in busy and confined water with a short timeframe in encountering traffic
    3. How IS should be used alongside existing systems on board and how to use for coordinating with other vessels
    4. Switching control procedure
    5. Fall-back procedure when to reset or disengage the system
    6. Dealing with non-IS vessels
    7. How to apply IS in a VTS sector

B. Research how to cue the skipper when the intended track of surrounding traffic is changing or changed, or changed to manual control, to increase the change of detection any alterations that may affect navigational safety. In addition, take into account how trackpilot performance following the intended route should be presented to the skipper, to detect anomalies in an early stage.

C. Set up guidelines tailored to the concept of Intention Sharing, which discusses the interaction between trackpilot system and human operator, information selection, integration and design of information. The guidelines should not prescribe the aforementioned topics, but should clearly signify indicate design rules in order to support the correct use these trackpilot systems equipped with IS. .

    1. Minimising complexity
    2. Minimise visual cluttering and ensure visual clarity – prevent confusion of detected routes
    3. Ensure consistency and logic order

Intent sharing - directions for solutions on observed issues

D. Support the situational awareness as much as possible – foremost situational awareness in projecting future situations – with the location and time where vessels will meet, and ensure the support is in line with the skippers' mental model of the nautical traffic environment. Provide the extra IS information only when it is relevant for the operator and locate the information in conjunction with other relevant nautical information. An example of a feature to support the situational awareness is to play forward the future positions of vessels, based on the shared intended tracks and current speed, to visually detect on the electronic chart where vessels will be in time. A possible direction to further investigate is providing the user control with a turning knob as a means to playforward time.

E. Provide user control in the trackpilot system for displaying shared intended routes of interest of surrounding vessels. In this way visual cluttering by multiple lines on the display can be prevented and it acknowledge the nautical expertise of the skipper to select only the relevant shared routes. However, the control and user-interaction should be designed with A and B in mind to prevent missing relevant route information and changes.

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ABBREVIATIONS

Intent sharing: Sharing the intended route with the surrounding traffic

Trackpilot: Track control system that is able to sail on a predefined track.

APPENDICES

APPENDIX 1 LITERATURE STUDY

INTRODUCTION

An essential aspect of safe ship navigation is to understand the intention of vessels around your own ship. Over the last years, automated navigation support systems are more and more used onboard ship. It is expected that these systems will be able to calculate/predict the route of its own ship more accurately e.g. 30 min head. It is likely that if the predicted route, or intention, will be shared with other vessels, the safety of shipping will increase. In order to investigate the benefit sharing of intent, Rijkswaterstaat requested MARIN to explore the benefits of intent sharing. The first step of the study consist of an literature study.

The idea of sharing of intent is not new. Several EU research projects have addressed the topic as it is recognised that communication problems are one of the most prominent causes of collision accidents at sea; most frequently lack of communication and misinterpreting information, particularly information about ships intentions [Ref 1.] For this study the following EU-projects are relevant:

- EFFICIENSEA (2009 – 2012)
- MONALISA 1 (2010 – 2013)
- ACCSEAS (2012 – 2015)
- MONALISA 2 (2013 – 2015)
- EFFICIENSEA2 (2015 – 2018)
- STM Validation (2015 – 2019)
- STM Balt Safe (2019 – 2021)

Appendix 1 includes a brief description of these projects.

The reports of the EU-projects are public and available on the internet by the following links: https://www.seatrafficmanagement.info/documents/ and https://www.iala-aism.org/technical/e-nav-testbeds/completed-testbeds/. These sites contains a lot of information about sea traffic management and e-navigation. The reports related to intent sharing have been selected from these sites and reviewed. The relevant documents which are used for this study are listed in the reference list.

This document describes the main finding of the literature study and the conclusions regarding the tested route exchange tools. It will also propose further steps to study the benefits of intent sharing.

MONALISA 1 & 2

MONALISA (2010 – 2015) projects have developed, explored and tested route exchange functionality using the *e-Navigation Prototype Display* (EPD), a test bed ECDIS platform . This involved concepts such as:

- Intended route exchange whereby a ships currently active route is broadcast via AIS or the Marine Cloud to other ships and shore centres in range. In such tests a ship sent eight waypoints ahead of its present position which could be seen on other ships electronic chart systems. The waypoints have to be entered and broadcasted manually.

- Route suggestion service: A shore-based VTS centre may send a suggested route to a vessel via AIS. The vessel can see the suggested route and reject or accept the proposal.

- Strategic route exchange: A vessel can send a proposed voyage plan to a nearby shore-based VTS centre. Subsequently, the involved VTS centre and vessel can send amended route proposals back and forth; 'negotiate', until both parties have accepted or rejected the voyage plan.

Figure 1 e-Navigation Prototype Display (EPD) [Ref 16.]

The concept has been tested on several simulators. Six simulator centres, four navigational schools, three simulator manufacturers, three research institutes and 18 manned virtual vessels were connected in these tests. The main finding of these test are [Ref 3.][Ref 4.]:

- Using intended routes to negotiate a meeting situation between two ships could serve just the same purpose, only with less risk of misunderstanding because the route intentions of both ships are displayed graphically, not only for the upcoming manoeuvre but also for the following. Possibly this behaviour could lead to avoiding entering into a close quarter's situation.

In the ACCSEAS project (2012 – 2015), the concepts of MONALISA were further tested and improved.

Also in ACCSES the route exchange functionality was embedded in an ECDIS platform. In the tests a ship sent eight waypoints ahead of its present position which could be seen on other ships electronic chart systems. The waypoints have to be entered and broadcasted manually.

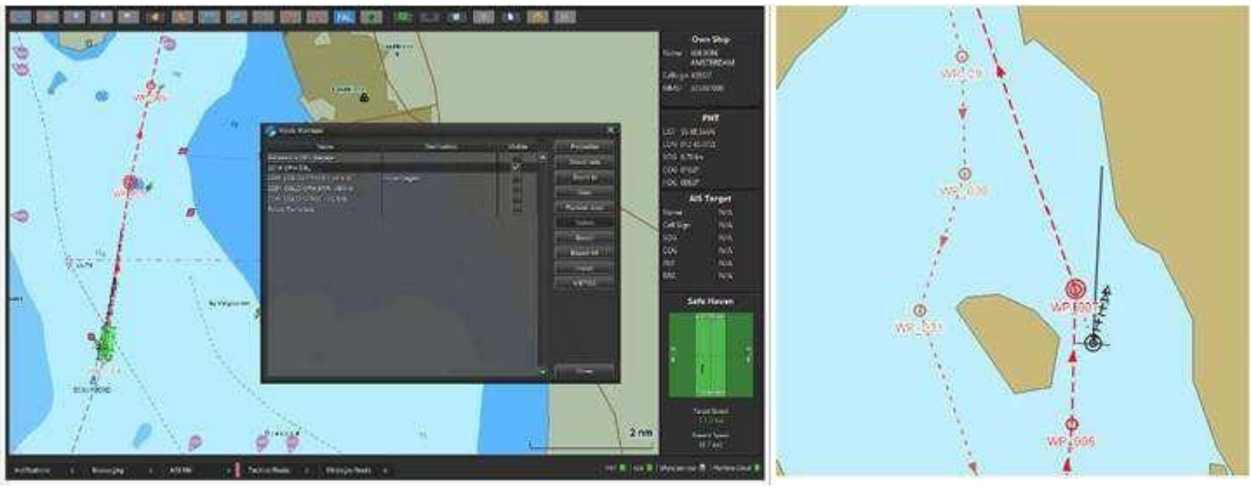
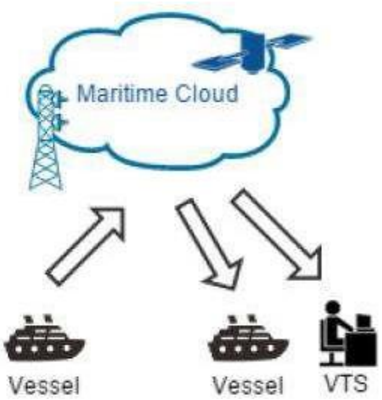


Figure 2

The feasibility was investigated including human factors issues and scenarios for possible unintended consequences. The means of route exchange by using AIS turned out to be too fragile in practice, due to the limitations in the protocol and poor robustness of delivery. In the ACCSEAS and MONALISA 2.0 projects, these services were migrated to use of the Maritime Cloud Maritime Messaging Service (MMS).

Figure 3 Maritime Cloud [Ref 5.]



In ACCSEAS, the effectiveness or efficiency of the intent sharing principle and sea traffic management system were evaluated based on qualitative data from simulations. A group of 9 operators/captains/VTS specialists performed multiple case studies to conclude on usability, professional acceptance and unintended consequences of change. The tests cover both simulator tests and tests in a real environment onboard a ship. The main finding of these test are [Ref 5.][Ref 6.][Ref 7.]:

- The concept is very good, provided the data that is displayed is correct (e.g. no deviation from intended, broadcasted route). No data is better than wrong data.

- Tool is found to be more important I open seas then in approaches.

- It was the generally envisaged by the bridge team that once the usability of the concept had been improved to a more mature and implementation ready level, the workload of the navigator would in fact remain the same as in today's navigational situation. However, as one of the participants put forward, "the workload re-mains the same, but the system will increase the quality of decision making".

- From a pilot point of view it was deemed the Intended route service may in fact reduce workload as cooperation with the bridge team would become easier, knowing that both the bridge team and the pilot will have the same information available to them with regard to other vessels intentions.

- From a VTS perspective, it was envisaged that the Intended route service would increase the quality of service, yet also increase the workload.

- The Intended route service was considered a valuable concept.

- Intended routes should be displayed on a need to know basis, being able to customize and not to clutter the screen.

- The results indicate that the "route suggestion" functionality served as a graphical means of supporting voice communication between navigator and VTS Operator. It was also indicated that this is considered valuable by both navigators and VTSOs and that both groups expect to see this kind of feture in future operational use.

- The results further indicate that the use of the “route suggestion” functionality could reduce the risk of miscommunication between VTSOs and navigators and that the functionality could assist in increasing the shared situational awareness between VTOs and navigators sailing in a VTS-area.

- It was found that negotiating by clicking and dragging waypoints in the intended route might be a way of avoiding to enter into a close quarter situation. Provided it was done in good time.

EFFICIENSEA 1 & 2
In the EfficienSea 1 project also an exchange functionality using the *e-Navigation Prototype Display* (EPD) has been tested.

EfficienSea 2 develops, prototypes and tests concepts for cost effective and seamless roaming between communication channels. The candidate technologies for digital communication considered in Efficiensea 2 are [Ref 2.]:

- NAVDAT:
- VHF Data Exchange System: VDES
- Digital Selective Calling: DSC
- Digital VHF and HF:
- Wi-Fi:
- 4G
- 5G:
- Satellite communication systems

The conclusion regarding route exchange communication [Ref 2.]:
Route Exchange relies on the transfer of waypoints with some possible additional text data and was found to be a low data application. This meant that a number of systems had the capabilities to support the applications. Even at peak demand, the majority of communication systems would take less than a second to service this demand.
The application does necessitate the need for ship-ship, as well as ship- shore and shore-ship, communication. As the VDES AIS channels are designed for ship-ship, ship- shore and shore-ship communication and the position reporting style of the data file that the application transmits, VDES is best suited to supporting the application.

STM Validation

As an outcome from MONALISA, Sea Traffic Management (STM) was founded. This project aimed to facilitate the navigation on board and enhance the communication. STM offers a variety of tools to help ships and shore units with e.g. optimizing routes, route sharing with other ships, port call synchronization and winter navigation. The STM VALIDATION project (2015 – 2018) was aimed to validate the Sea traffic management (STM) concept, the infrastructure and the services introduced in MONALISA by showing the benefits in practice on 300 ships, in 13 ports, 5 shore centres and 12 connected simulator centres.

As part of the STM Validation project a ship to ship route exchange (S2SREX) tool has been tested. The tool also comprise a rendez vous tool (RDV). S2SREX can be considered an embedded function in the electronic chart display and information system (ECDIS), and RDV is an additional calculated layer predicting the meeting point between two vessels. Also in this tool the ship sent eight waypoints ahead of its present position which could be seen on other ships electronic chart systems. The waypoints have to be entered and broadcasted manually.

Ship to Ship Route Exchange (S2SREX) is a technical solution for broadcasting a ship’s route to other ships in its vicinity through AIS; direct communication between ships and not via the maritime cloud (called SeaSWIM network) (Figure 4).

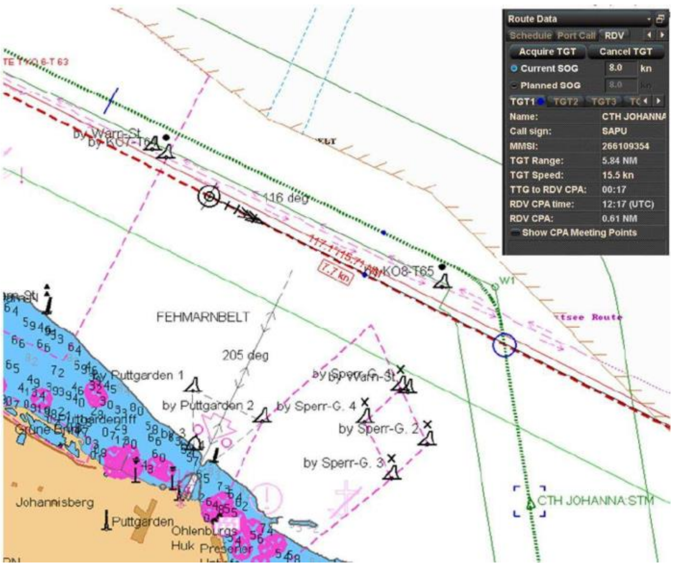


Figure 4

The purpose of this study was to evaluate S2SREX/RDV in a controlled simulator setting to assess how it may affect the decisions and actions taken by navigators in various traffic situations. The following research questions were addressed:

- Does S2SREX/RDV influence decision making?
- Do the participants trust S2SREX/RDV information?
- Does S2SREX/RDV make navigation safer?

Qualitative data were collected using post-test questionnaires and group debriefs to evaluate the participants' perceptions of S2SREX/RDV in the various traffic scenarios, and quantitative data were collected to assess the ship distances and behaviour in relation to the International Regulations for Preventing Collisions at Sea (COLREGs).

The results of the study confirm the findings of previous studies [Ref 11.]:

- The results from various quantitative analyses indicate that the STM services are valuable in areas in which strategic navigation is applicable, i.e. where there are fewer temporal and spatial constraints. However, in areas with dense and regulated traffic and less room for strategic navigation, the value of the available STM services in improving traffic safety could not be directly demonstrated.
- As part of the project, monitored route exchange formats for use via AIS and VDES (VHF Data Exchange System, the next level of AIS) have been developed as Binary Broadcast Messages (BBM) to facilitate safe navigation. These are denoted as AIS/VDES route messages and allow ships to exchange a fixed part of the monitored route with other ships in the same geographical area in a standardized format. Only AIS broadcasts have been used in the voyage management test-bed.
- Ship-to-ship exchange of route messages, containing up to seven route legs, was a "test within the test" as it did not use the digital infrastructure for exchange but, instead, deployed the on board AIS equipment. The feedback on its usefulness and effect on situational awareness and safety was positive from the voyage management test-bed ships. However, refinement is necessary in terms of human-to-machine interface HMI-related aspects and how/when routes are to be presented to the OOW (Officer of the Watch).
- The study supports that S2SREX may enhance the officer's situational awareness and shows a tendency to improve navigational safety in traffic situations when used as a tool for supporting decision-making and situational awareness at a longer range, i.e. during strategic navigation.

The study also indicates that there are several risks involved in using S2SREX, notably over-reliance/misinterpretation of the data and potential confusion/uncertainty when the "route" and "intention" are implicitly assumed to be same thing, especially when using S2SREX in tactical navigation.

The STM BALTSAFE (2019-2021) is a further continuation of the STM Validation projects, with a focus on further increasing the capacity and situational awareness of bridge officers and VTS operators. As part of the STM Validation project, a group of vessels were equipped with S2SREX and its functionality tested in the project's testbed. The STM BALT SAFE continues the testing of the S2SREX functionality.

The project's testbed spans the entire Baltic Sea region (i.e. from the waters east of Denmark to the Gulf of Finland and the bay of Bothnia) and increases the number of S2SREX-equipped vessels. The STM BALT SAFE project focus specially on tankers and their traffic between Finland and Estonia.

This quantitative evaluation consists of an analysis of the adoption and usage of the S2SREX solution. The data for the analysis will be ship tracks and broadcasted routes of a random sample of STM ships within a period of 3 months. From the data, the following indicators will be calculated:

- Ship usage: the percentage of the total sailing time in which an STM ship broadcasts its route.
- Ship congruence: the percentage of an STM ship's tracks that are within an area defined by its broadcasted routes and a cross-track error.
- Total usage: the percentage of the total sailing time of all STM ships in which they broadcast their routes.
- Total congruence: the percentage of the sum of all the STM ship tracks that are within areas defined by the ships' broadcasted routes and a cross-track error.

The results of the analysis are not yet available.

CONCLUSIONS & RECOMMENDATIONS

In the EU-projects the route exchange functionality was embedded in an ECDIS platform. The tool allows the ship to sent eight waypoints ahead of its present position which could be seen on other ships electronic chart systems. The waypoints have to be entered and broadcasted manually. The tool has been tested both on simulators and in a real environment onboard a ship. The use cases covered short sea shipping routes in a coastal areas.

Since the route have to be entered / updated manually, the tool appeared to be not applicable in congested waters with many ships present; in very tight and time constrained collision situations the crew will not have time to click intentions into the ECDIS.

Nevertheless, the conclusion was that the tested tools will increase the safety level by avoiding close quarter situations. The tool was used to negotiated between ships about the intended route so ending up in a close quarter situation could be avoided. It was noted that there was no significant VHF communication reduction.

The main identified risk in using route exchange functionality tool was over-reliance/misinterpretation of the shared route and deviation from intended, broadcasted route; no data is better than wrong data.

Another common feedback from the tests is that refinement is necessary in terms of human-to-machine interface HMI-related aspects and how/when routes are to be presented. A poor interface design will not only increase the workload of crew but will also affect the acceptance of these systems.

As the VDES AIS channels are designed for ship-ship, ship-shore and shore-ship communication and the position reporting style of the data file that the application transmits, it was concluded that VDES is best suited to supporting the application.

Based on the findings of the literature study, it is recommended to investigate the possibility to automate the creation broadcasting of the intended route. If the intended route is generated automatically, the route exchange functionality could be applied in more confined areas with many ships present, such as a port area and inland waterways. It is expected that this will enhance the safety of shipping, in analogy to flashing lights of a car.

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APPENDIX 2 SIMULATION PROTOCOL & SCENARIOS

Appendix 2 contains the simulation protocol and a brief explanation of each simulated scenario.

Simulation program

MARIN
BETTER SHIPS, BLUE OCEANS

Colin Guiking
Heike Diepeveen
Martijn Schipper

Intention sharing

Introduction experiment & systems

Study: Intent sharing

MARIN

Goal of simulator-experiment: study the benefits of intent sharing

Intent sharing: displaying the route on the ENC

2

Program

Overview
- 2 days of simulations
- 6 skippers, two groups A & B
- 3 trackpilots – 3 simulators
- 7 to 8 scenarios of 15 min

Measures
- Questionnaires after each session
- Eye-tracking

- This morning: training
- Afternoon: scenarios
- Tomorrow: scenarios

Day schedule

Time	Day 1	Group
8:00	60m: Introduction & theory	
9:00	90m: Practise	A&B
10:30	20m: Break	
10:50	70m: Practise	A&B
12:00	60m: Lunch break	
13:00	30m: S1	A
13:30	30m: S1	B
14:00	30m: S2	A
14:30	20m: Break	
14:50	30m: S2	B
15:20	30m: S3	A
15:50	30m: S3	B
16:00	Break and evaluation	

Time	Day 2	Group
8:30	15m: Introduction	
8:45	30m: S4	A
9:15	30m: S4	B
9:45	30m: S5	A
10:15	20m: Break	
10:35	30m: S5	B
11:05	30m: S6	A
11:35	30m: S6	B
12:05	55m: Lunch break	
13:00	30m: S6	B
13:30	30m: S7	A
14:00	30m: S7	B
14:30	20m break	
14:50	30m: S8	A&B
15:20	30m: S8	A&B
15:50	General evaluation & closure	Everyone

Area & vessels

- Area: River Waal & Rotterdam (Esch)
- Current: 0.4 – 1.8 km/u

- Inland vessels: 110 x 11,4

Figure 1 River Waal

Figure 2 Rotterdam

Tasks & instructions

Tasks for skippers

1. Sail with the trackpilot and retain the speed – as long as the situation allows
2. Try to resolve the situation with the trackpilot as first option, not via VHF

- Roulette on the 3 simulators
- Each group gets the same scenario (with or without intentions)
- No VTS

Simulatorsetting

- 3D world view
- Radar
- ENC + intentions
- Trackpilot interface

- Rudder (manual)
- Thruster
- Intercom for VHF
- Button to take over manual control
- Button to take over with trackpilot

7

Tresco trackpilot: overview

Trackpilot

A. Trackpilot follows track automatic
B. Steering: offset BB of SB
C. Displaying intentions of vessels & and critical CPA

Intentions

- Black vessel: own vessel
- Thin black line: Heading
- Blue dashed line: automatic track
- Thin green line: follows the blue line
- Wide green line: 8 minutes intentions
- Wide gray line: intentions other vessel
- Red vessels: critical CPA

8

Tresco trackpilot: control

Mode trackpilot

Tresco TrackPilot is actief!	Tresco TrackPilot klaar om in te schakelen!	Tresco TrackPilot kan nog niet inschakelen te ver of te langzaam!	Tresco TrackPilot geen data alarm!

Track (offset)

Track afstandsmeter

9

Argonics: overview

- Blue: Referenceline
- Red: current setline – reference blue
- Green: offset to red line

Shipping technology: overview

- ROT
  SET
- RUDDER
- PILOT ON/OFF
- SPEED KN/KM/u

- Red: own vessel
- White dashed line: intention based on ROT
- Solid white line: intented route
- Other colors: other vessels

Shipping Technology: on/off

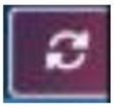
1. Press button “start autonomous”
2. Trackpilot navigation is **on**

Press again to pauze

Shipping technology: creating offset

1. Shift track button
2. Press ◀ or ▶

Each press is 5 meter offset

X Reset? Press 

SIMULATOR SCENARIOS

Scenario 1: Bridge passing Nijmegen

The main purpose is to create a conflict situation for crossing the bridge, due to multiple vessels planned at the same time for crossing. Therefore, the vessels need to plan the bridge crossing. Ship 1 and 3 are put in position (location and speed) to take over vessel A and vessel 2, to increase the task load. Vessel A (simulated vessel) will stay on the North side of the river (blue sign), creating a possible second conflict situation with vessel 2 and/ or 3, at the same for the bridge crossing conflict.

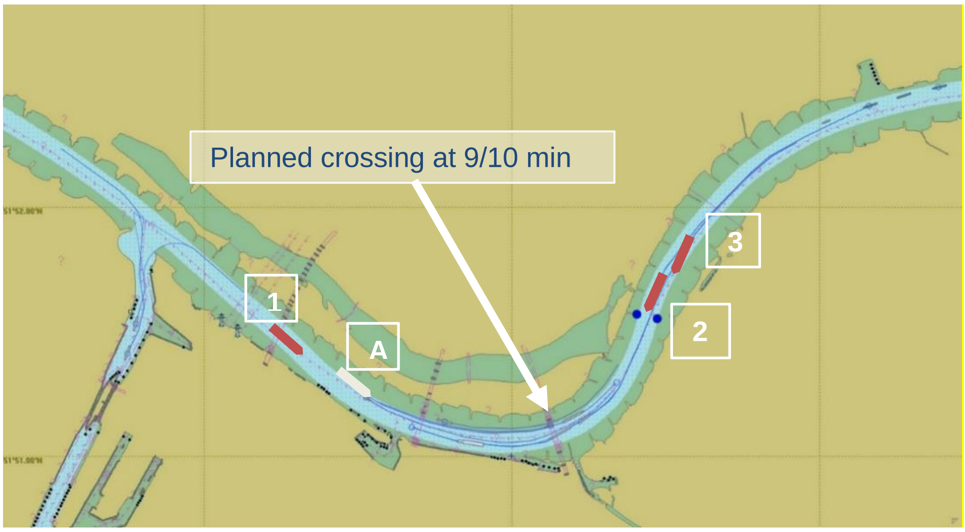


Figure 14 Scenario 1 Bridge passing Nijmegen

Scenario 2: Pannerdensch kanaal
Planned event: crossing river traffic at 5 minutes

The main purpose of scenario two is to create a crossing conflict between multiple vessels. In this scenario, the participants have less time to prepare for the upcoming conflict which is around 5 minutes from their starting point and speed. Vessel 1, 2 and A are sailing downstream; vessel 3 and B are going upstream. All vessels are given a starting speed to ensure they will meet at the crossing point. Vessel 2 needs to blend in with vessel 1 and A, while encountering vessel B and 3.

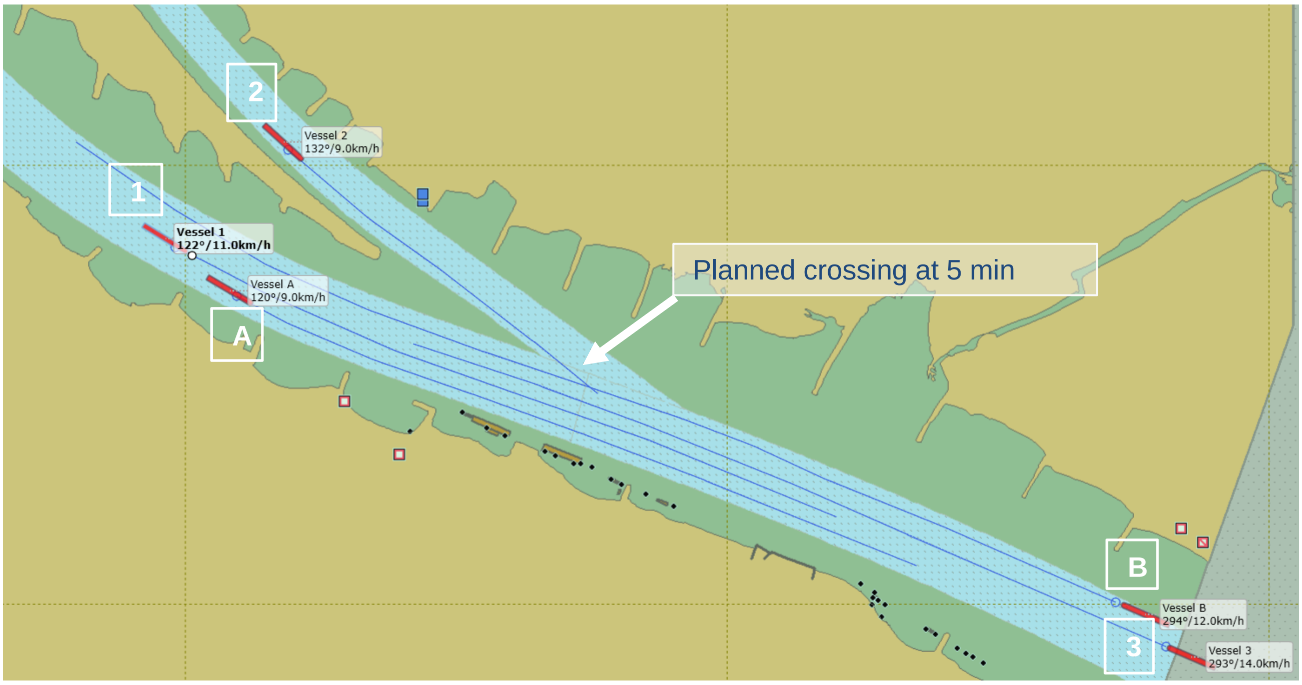


Figure 15 Scenario 2: Pannerdensch kanaal

Scenario 3: Maas-Waal kanaal
Planned event: crossing with outgoing vessel from lock to the river at 8 minutes.

The purpose is to create a conflict situation with crossing vessels: Vessel B – which is controlled by the instructor during the simulations – coming from the Maas-Waal kanaal and going to the river will cross with Vessel 2, 3 and 1.

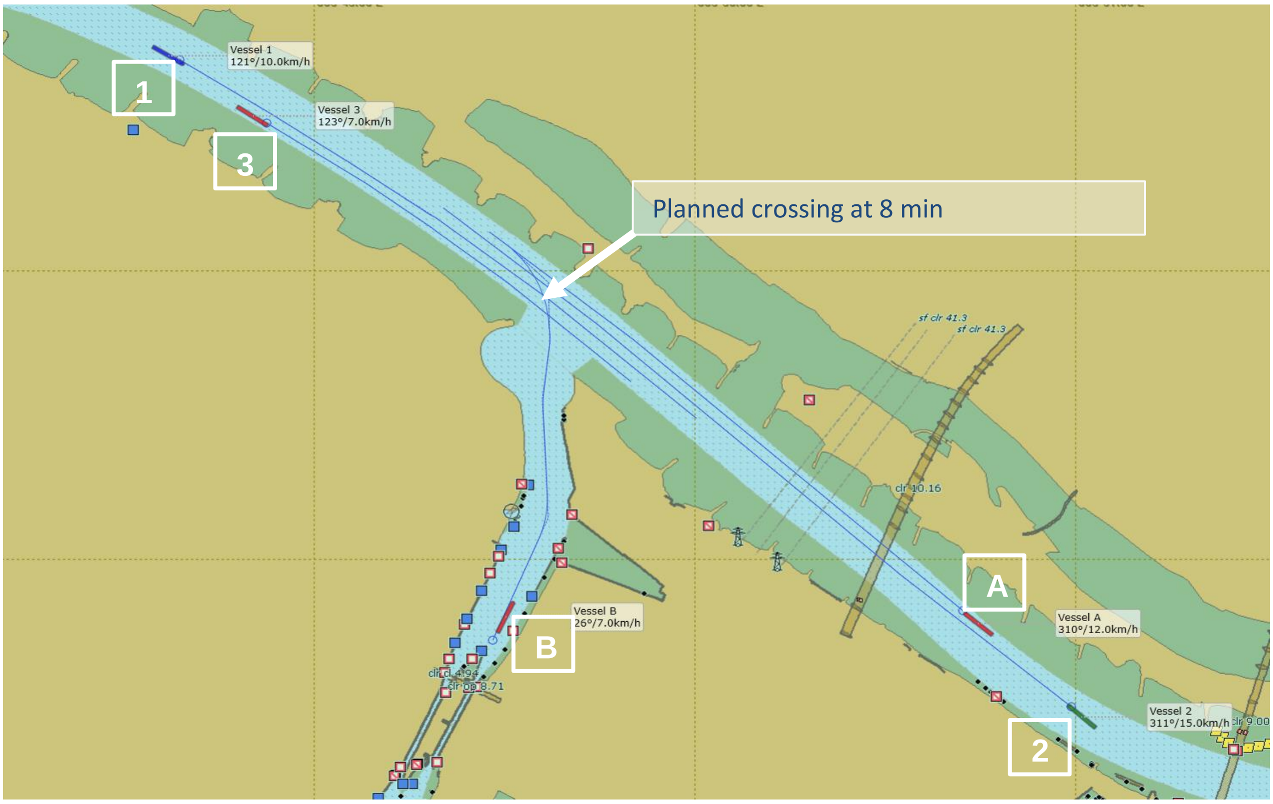


Figure 16 Scenario 3: Maas-Waal Kanaal

Scenario 4: Zandberg
Planned event: meeting all vessels at the midst of the corner at around 8 minutes.

In scenario 4 the purpose to attest the ability to use the shared intended routes with a more dense traffic picture. There are three simulated vessels added to this scenario, which are controlled by the simulator instructor. All vessels are planned to meet at the midst of the corner to create a planning conflict: the participants need to response on each other either by changing their track or their speed over time.

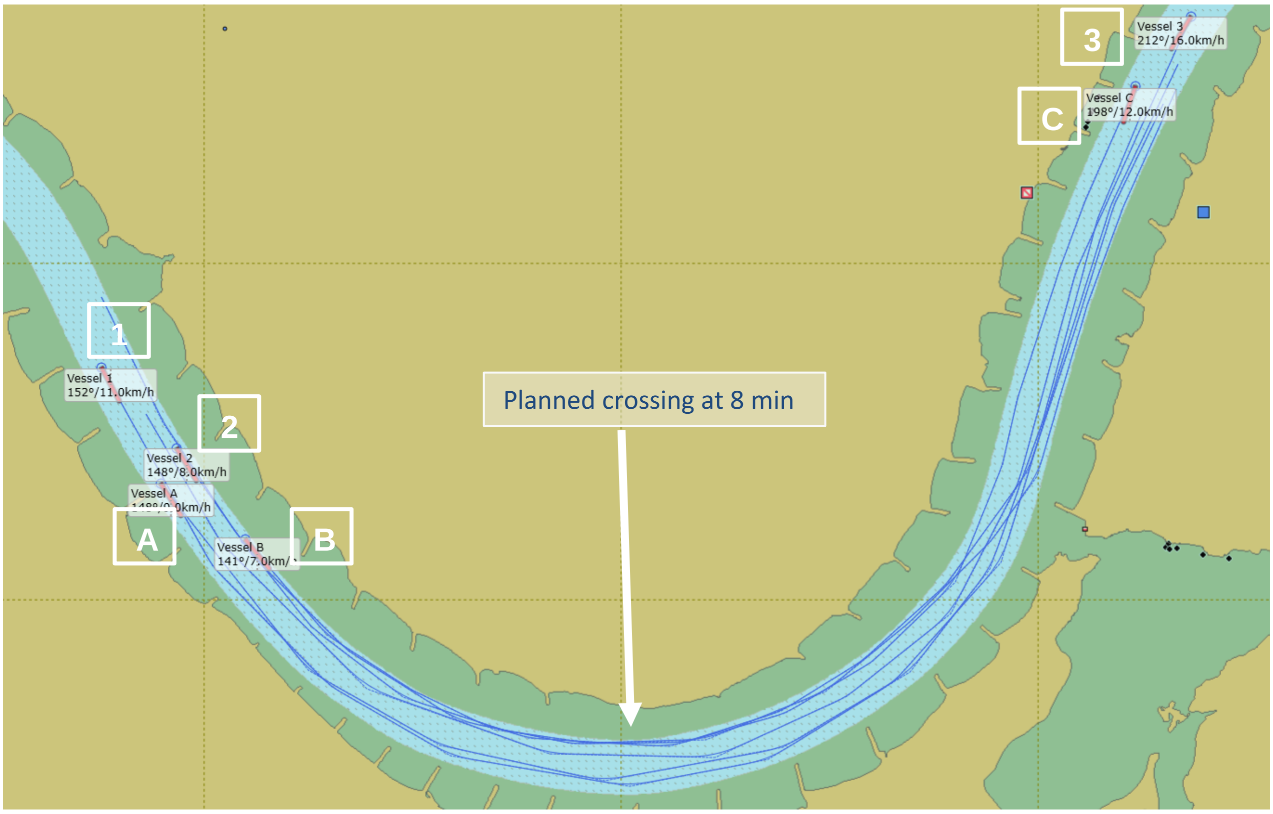


Figure 17 Scenario 4: Zandberg

Scenario 5: Rotterdam emergency

Planned events: a track conflict with a vessel coming from the Koningshaven and an emergency situation due to a drifting vessel located mid-fairway.

The purpose of scenario 5 is to test the usability of intent sharing in an (sudden) emergency situation consisting of a traffic (simulated) vessels having an engine failure and which start drifting. In this event, the participants have less time to plan their manoeuvres; they need to switch from planning the route to quickly response on sudden events. Another event consist of a planned crossing between vessel 2 coming from the Koningshaven with vessels sailing to the West following the main river. Due to the current, it may be more difficult to take a predefined turn for vessel 2 (the track of the trackpilot) with no significant offset.

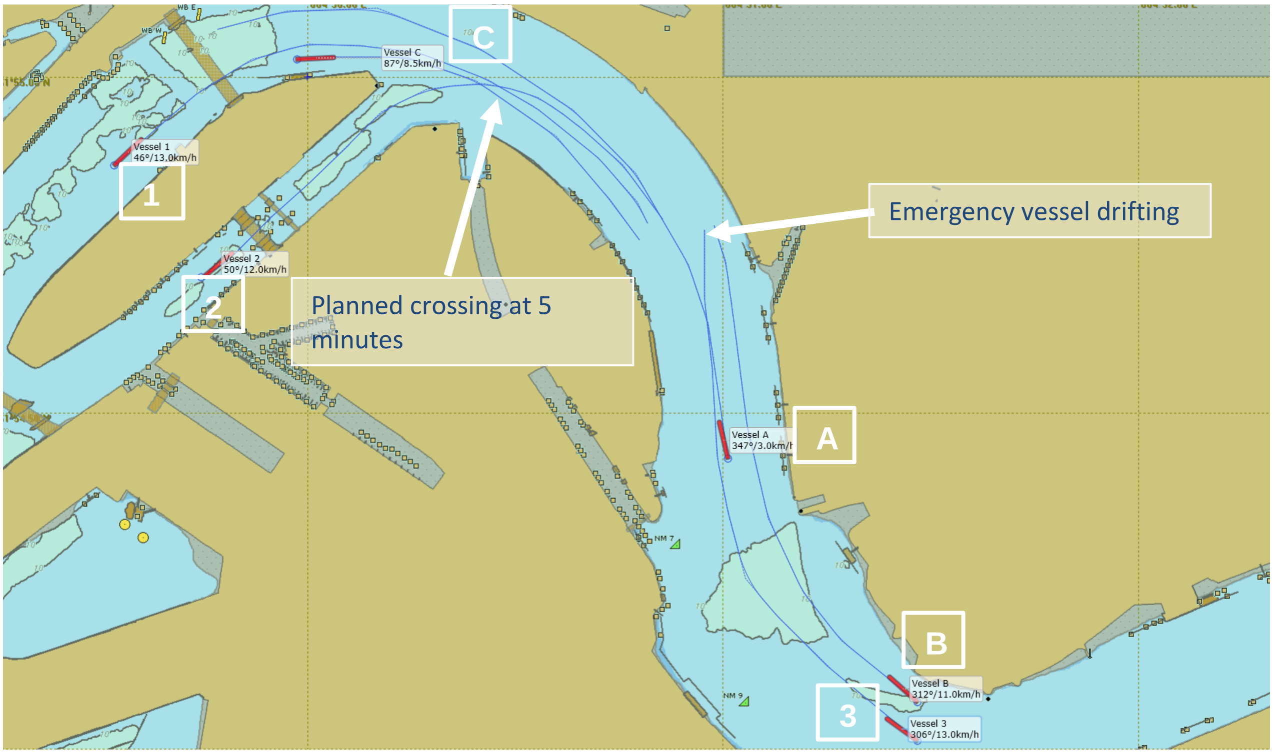


Figure 18 Scenario: Rotterdam emergency

Scenario 6: Rotterdam crossing
Planned event: two planned crossing at two locations at 5 and 9 minutes.

All participants are closely located to each other and will meet several simulated vessels controlled by the simulated instructor. The close position will likely make it more difficult to anticipate: close attention and monitoring of the shared intended track may be needed to detect track changes of other participating vessel who anticipate on upcoming simulated vessels. The first crossing: vessel 1, 2, and 3 are sailing to the West and will meet vessel C and B which will cross the river, and therefore crossing the routes of participants. The second crossing takes place a few minutes later: vessel A and D which are sailing to the East will enter the Koningshaven and crossing the routes of vessel 1, 2, and 3.

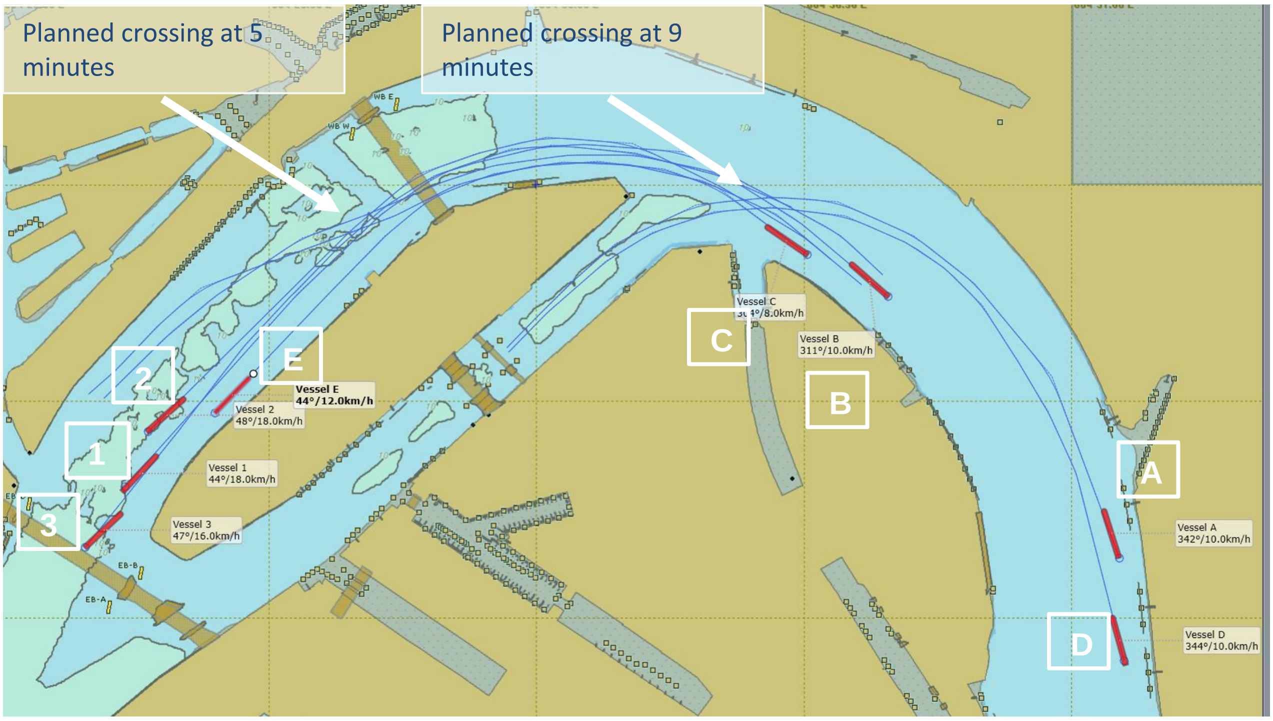
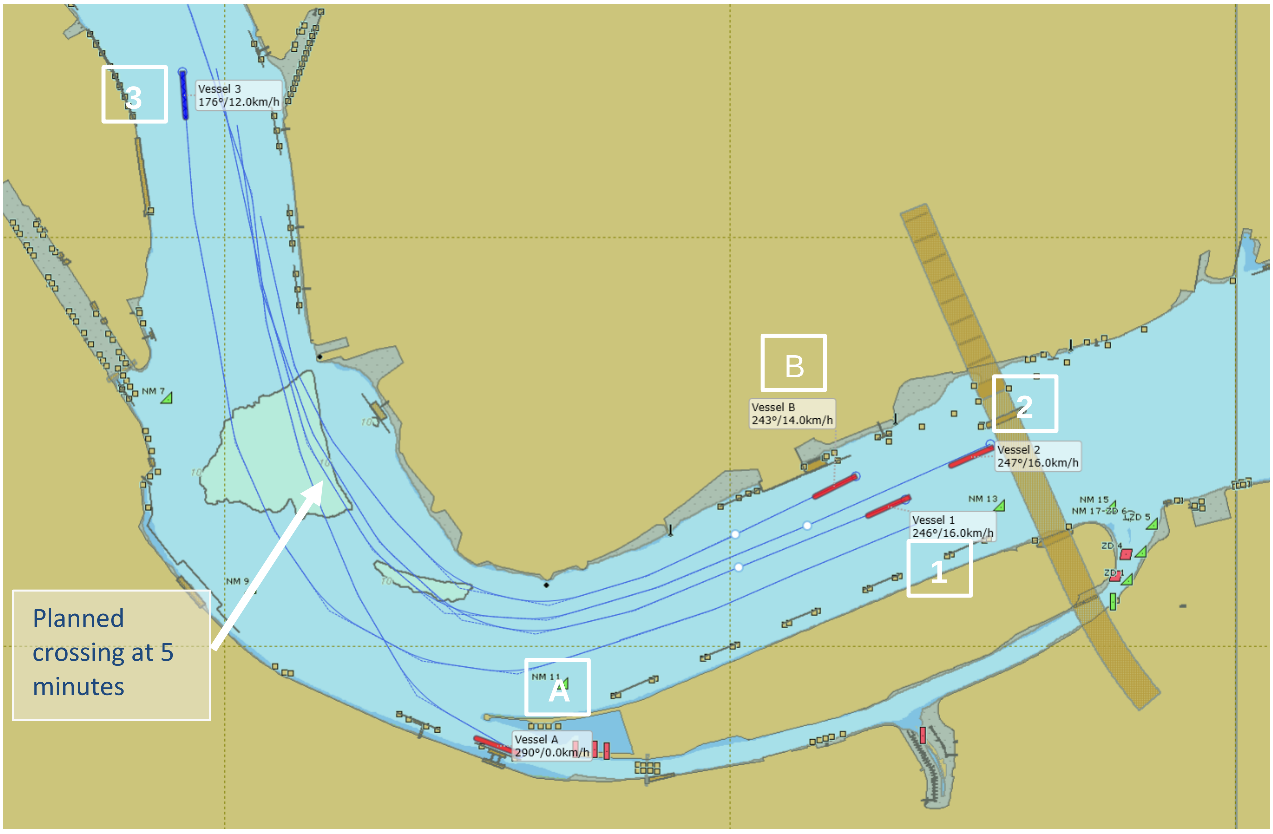


Figure 19 Scenario: Rotterdam crossing

Scenario 7: Rotterdam Fog
Planned event: Crossing with the routes of participating vessels at around 5 minutes with dense fog.

The purpose of scenario 7 is to test the added value of intent sharing in fog conditions. Vessel A will depart from the south side of the river at a certain moment will go to West. Vessel 2 and 1 are going West as well and will meet Vessel A at a certain point. Vessel 3 is going East and will cross the route of vessel A. All participants need to anticipate on vessel A in order to keep a minimal safe distance.



Scenario 8: Pannerdensch kanaal second

Scenario 8 is similar to scenario 2, with the main difference being the higher traffic density due to the presence of additional simulated vessels controlled by the simulator instructor. The purpose of this scenario is for the skippers to use the trackpilot system and information about the intentions of nearby vessels to resolve a preplanned crossing conflict involving multiple vessels.

Figure 20 Scenario 8 Pannerdensch Kanaal second

APPENDIX 3 SIMULATION RESULTS

Appendix 2 contains a short description of the envelop of the performed simulations.

Scenario 1 Bridge passing Nijmegen

At the beginning of the scenario, vessel 2 experiences difficulties activating the trackpilot system and moves to the south side of the river in the first two minutes. During this time, the simulator instructor communicates to all vessels that there is a stranded vessel at one of the bridge pillars. After four minutes, vessel 2 successfully activates the trackpilot system and shares its intended track with the other vessels. In order to anticipate the emergency situation at the bridge, vessel 2 slows down to a speed of 11 km/h.
At around the 5-minute mark, vessel 1 loses track of the trackpilot system and makes an unintended maneuver towards the south side of the river. It almost hits the ground, but is able to recover with manual steering and maintains a low speed for the rest of the scenario. At around 6.5 minutes, vessel 1 requests a starboard side passing with vessel 2 via VHF. At the same time, vessel 3, following behind vessel 2 and traveling downstream, is closing in at a speed of 17-18 km/h. Just before reaching the bridge, vessel 3 overtakes vessel 2 on the port side and manages to fit itself between the space left between vessel 2 and the approaching vessel A - a simulated vessel.

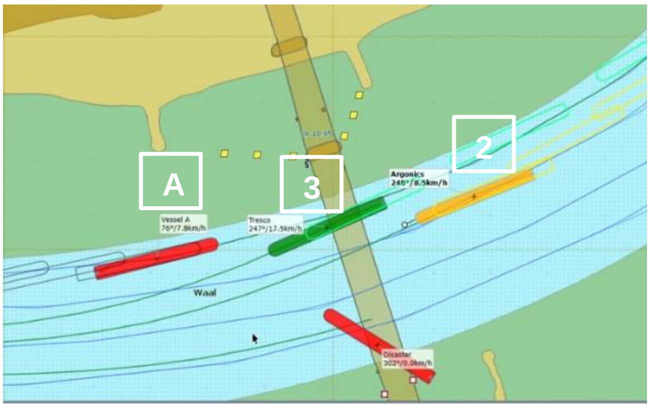


Figure 21 Still from simulation: vessel 3 (green) squeezes between vessel 2 (yellow) and vessel A (red).

At the beginning of the simulation, vessels 2 and 3 were following instructions closely and maintaining a consistent speed. As a result, vessel 3 did not adjust its speed in response to the developing situation, which led to a near-miss at the bridge. The shared intended tracks were not used effectively to anticipate each other's movements, as the tracks were changed but not the speed in order to create a larger safety margin between the vessels.

Scenario 1: Bridge passing Nijmegen – Shared intentions

In the first minutes of the simulation, all vessels maintained their original tracks and speeds. Vessel 2 communicated via VHF that it would stay in the mid-fairway due to a stranded vessel at the bridge pillar. In response, vessel 1 reduced its speed to give vessel 2 more space to pass the bridge. Vessel 3 had already reduced its speed earlier to provide sufficient space to safely pass the bridge as well.
In conclusion, after a few minutes, vessel 3 created a larger distance between itself and vessel 2. At this point, it became clear that the upstream vessels and the downstream vessel would cross each other at roughly the same time and location. The intended lines provided information on where the routes overlapped or came close to each other. Vessel 1 also provided more space by reducing its speed, but this was in response to VHF communication.

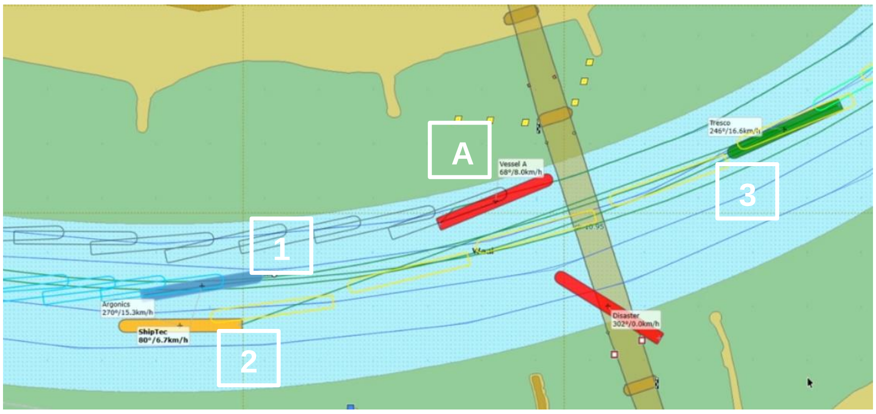


Figure 22 Still from simulation scenario 1

Scenario 2: Bridge passing Nijmegen – Shared intentions

At the start of the simulation, approximately 30 seconds in, the participants used VHF radio to communicate with vessel 1 and inquire about its plans. In the first minute, vessel 2 changed its course to avoid vessels B and 1. Shortly thereafter, vessel 3 began moving towards the port side to clear a path with vessel B. At four minutes into the simulation, vessel 3 contacted vessel 1 via VHF to arrange a passing agreement (starboard to starboard). At this point, it was unclear what vessel 1 would do due to overlapping lines. Vessel 1 slowed down and stayed behind vessel B, both heading upstream. A few minutes later, the simulation ended and the crossing conflict had been resolved.
Vessel 2 was able to anticipate the course of vessel 1 after making contact via VHF radio. However, the intended line of vessel 1 was not visible for a long enough period to determine its direction or approach, so VHF communication was necessary to gather information and inform the decision-making process on how to alter the course of vessel 2. If the shared track of vessel 1 had been visible for a longer time, it may have helped in this situation.

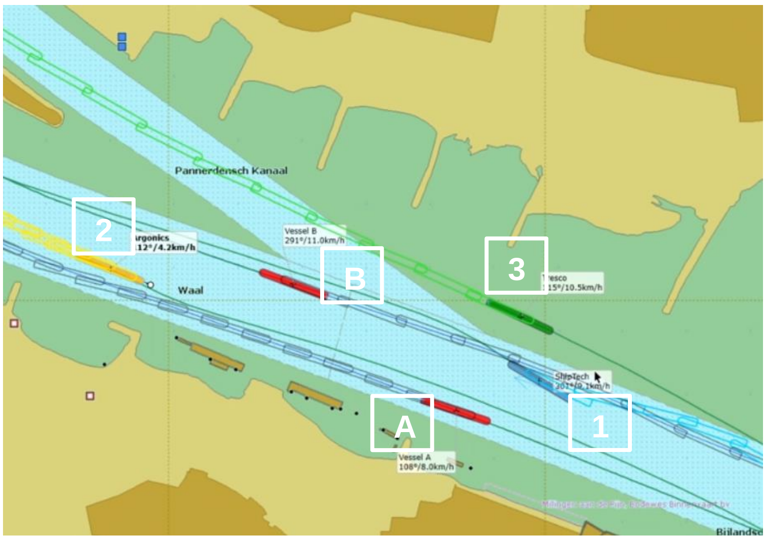


Figure 23 Pannerdensch Kanaal

Scenario 3: Maas-Waal kanaal – Shared intentions

Within the first 100 seconds, vessel 2 altered its course to keep clear from the track of vessel 3. It moved to the port side (north side of the river) in response to the multiple lines in the middle of the river and in response to the outgoing vessel from Maas-Waalkanaal. Vessel 1 moved to the starboard side (south side of the river) and reduced its speed. However, because most of the vessels did not reduce their speed, the planned conflict event - as designed in the scenario - occurred, as shown in figure 12. Although vessels 2 and 3 attempted to avoid each other by changing their intended tracks multiple times, they were unable to prevent the unsafe situation without reducing speed, as shown in figure 12. During the simulation, there was no VHF communication; the intentions of the outgoing vessel were clear to all skippers based on the shown route on the ENC.

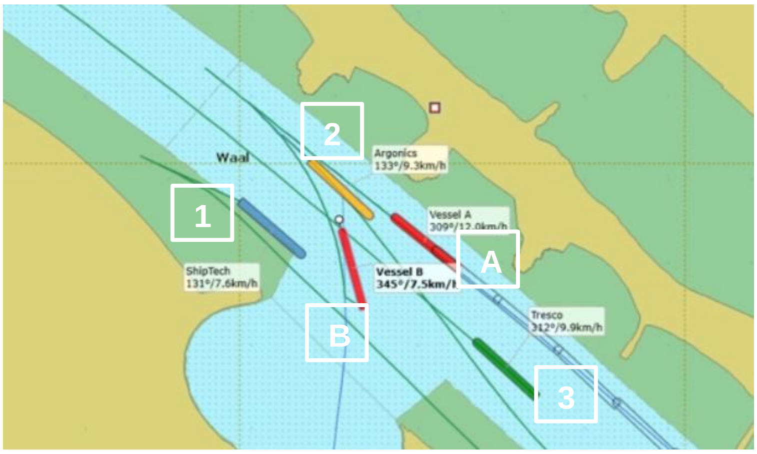
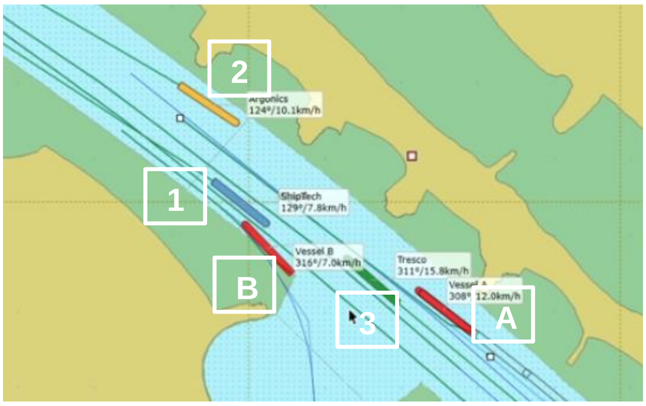


Figure 24 Still from simulation scenario 3

Scenario 3: Maas-Waal kanaal – no shared intentions

Compared with the first simulation group simulating scenario 3, this time all skippers communicated intensively via VHF to inform each other and arrange a safe crossing. This took place for a few minutes long to communicate all intentions and confirm all agreements that were made. As a result, vessel B passed vessel 1 starboard – starboard, so all other vessels could safely continue their original track.



Scenario 4: Zandberg – with intentions

Within the first two minutes, vessel 3 maneuvers to the "normal" side (south side) of the river. Vessel 2 contacts vessel 3 to arrange a crossing, but overlooks vessel 3's higher speed and therefore no arrangement is needed. During the simulation, vessel 1 (downstream) changes its course to maintain a distance from the path of vessel 2 (upstream) based on shared intentions.
Around 13 minutes in, vessel 2 contacts vessel 1 via VHF to gather information about vessel 1's reduced speed and to request permission to pass. Additionally, vessel 2 communicates that no intentions are being shared (due to problems with the trackpilot at that moment).

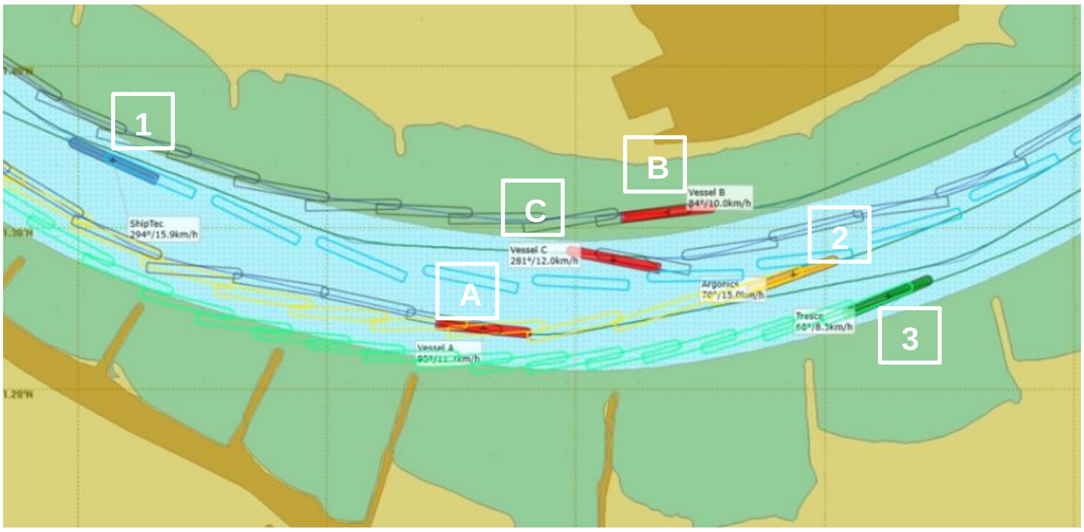


Figure 25 Still from simulation scenario 4

Scenario 4: Zandberg – Without intentions

The group without intentions communicated more frequently via VHF. Vessel 3 stayed in front of vessel 2, both heading upstream, similar to the group with intentions. However, they both sailed on the north side of the river instead of the south side (the normal side when going upstream). Additionally, vessel 3 chose to pass vessel B at the beginning of the corner. Vessel 2 also passed vessel 3, but on the south side of the river. While this was happening, vessels that were heading downstream, such as vessel 1, were approaching and communicating via VHF about how to pass each other. Due to the downstream traffic, vessels 2 and 3 had to significantly increase their speed to stay safe from the vessels heading downstream.

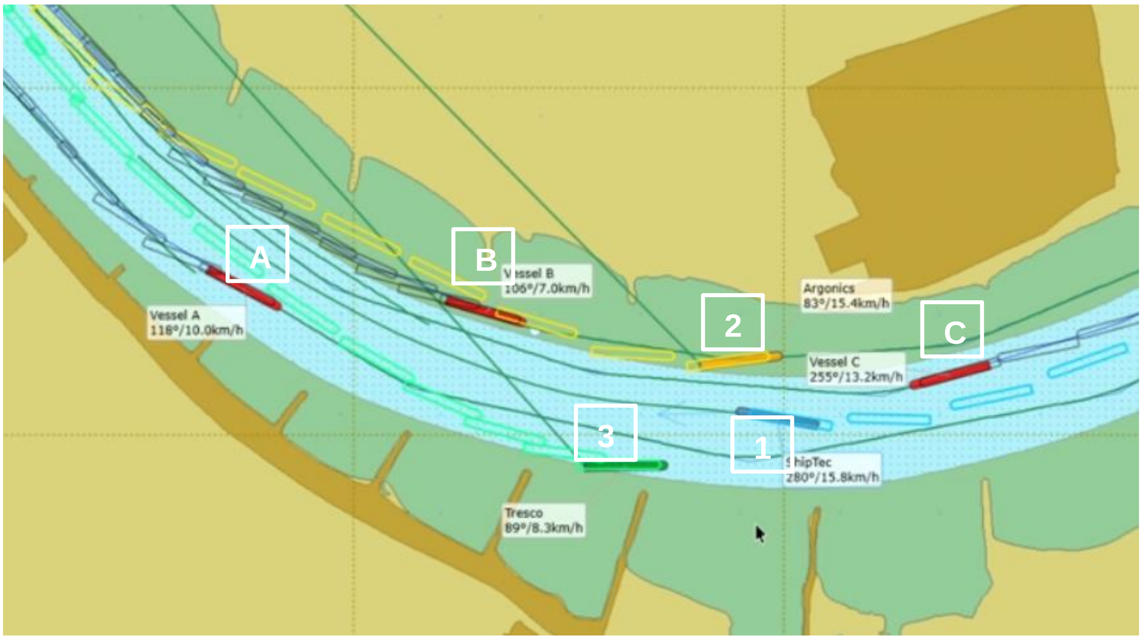


Figure 26 Still from simulation scenario 4

Scenario 5: Rotterdam emergency – Non-intentions

During simulation scenario 5 without intentions, similar observations were made compared with previous scenarios with no shared intentions: all skippers used VHF frequently to coordinate their navigational behaviour, and also to resolve the emergency situation in this scenario.

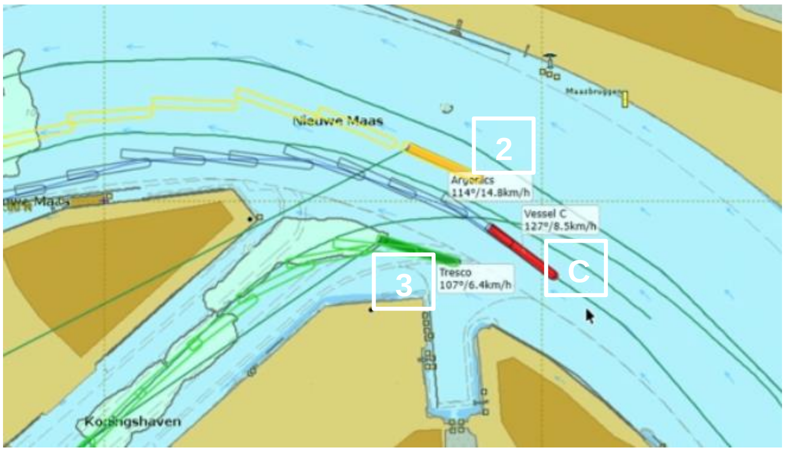


Figure 27 Still from scenario 5 without intentions

In the first minutes, vessel 2 calls vessel 3 to coordinate their actions. As a result, vessel 3 lowers speed and vessel 2 takes a wider turn to overtake vessel C and to create space for vessel 3. In the minutes hereafter, for one of the simulated vessel an engine failure was induced and starts drifting.

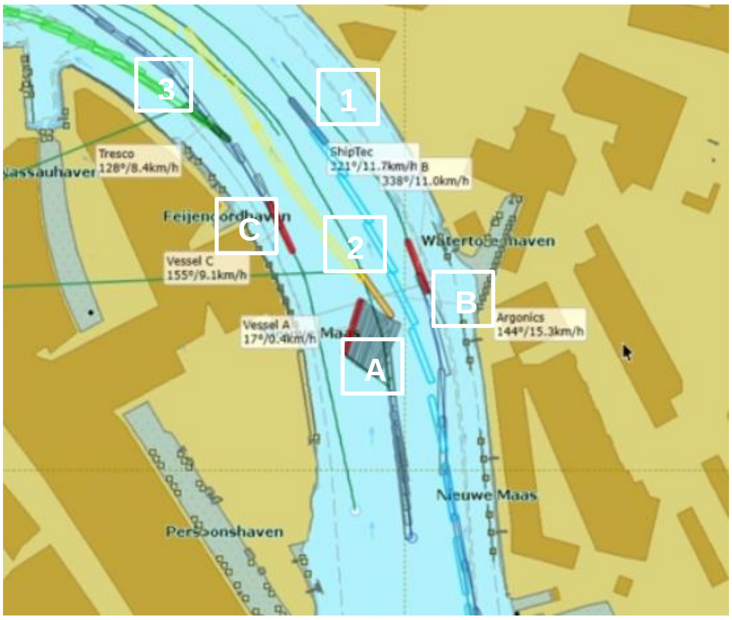


Figure 28 Still from scenario 5 without intentions

Scenario 5: Rotterdam emergency – Intentions

During the simulation there is almost no VHF communication, aside the notification of the simulator instructor about the engine failure of vessel A. At 7 minutes, vessel 3 (green vessel) significantly deviates from the intended track when taking the turn, due to the current. In response to that, vessel 2 moves his own track to port side to create space for vessel 3.

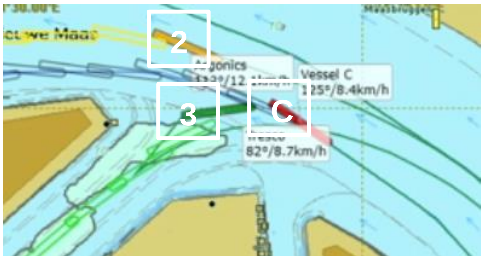


Figure 29 Still from scenario 5 with intentions

At 10 minutes, vessel 2 is moving the intended lines multiple times to find the best way to pass the drifting vessel (A). In the end, vessel 2 and 3 pass the emergency vessel at starboard side; all coordination between vessels takes place via the interface on which the intentions are shown. No VHF is used to coordinate the intended routes.

Scenario 6: Rotterdam crossing – Intentions

The first planned crossing was easily solved by the particpants with moving the track to middle of the fairway, in response to the two vessels (Vessel B & C) that were sailing at the south side of the river and going West.

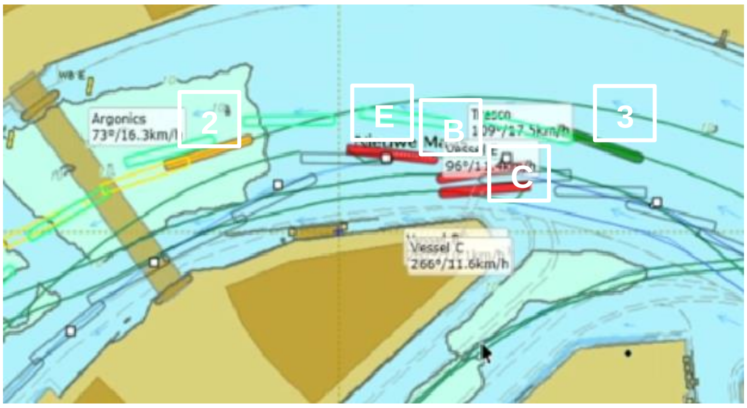


Figure 30 Still from scenario 6 with intentions

Vessel 2 contacted vessels A and D to inquire about their plans. This communication was also displayed on one of the interfaces in the simulator. In response, vessel 2 slowed down to allow vessels A and D to pass, as they were headed towards Koningshaven. At 11:20, vessel 3 encountered issues with its trackpilot system, which stopped sending and receiving intentions and unexpectedly altered the vessel's course. The participant took control from the trackpilot to correct the vessel's course.

Scenario 7: Rotterdam Fog – without intentions

As vessel A began to cross the river, it was contacted by vessel 3 (downstream) via VHF radio to inquire about its intentions. A few minutes later, vessel 2 also reached out to vessel A via VHF to ask about its intentions, to which vessel A responded that it would be staying on the starboard side of the river. Vessel 2 then contacted vessel 3 to discuss how to pass each other safely. During the simulation, the skippers made use of VHF radio to communicate and plan their actions.

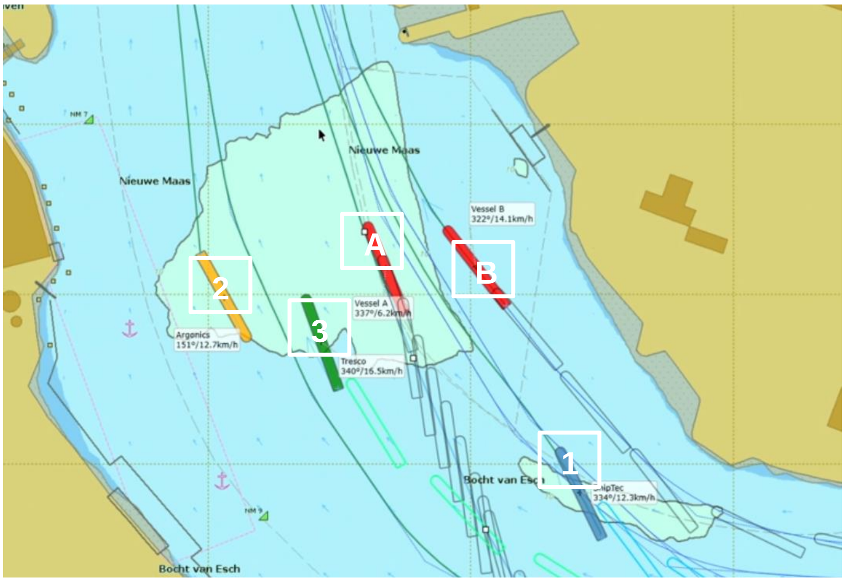


Figure 31 Still from simulation scenario 7

Scenario 7: Rotterdam Fog – intentions

In scenario 7, two vessels collided due to a misunderstanding of intentions. Approximately three minutes into the collision, vessel 2 contacted vessel A via VHF radio to inquire about its intentions, even though the positions of all vessels were shared and visible on their interfaces. A few minutes later, vessels 2 and 3 approached vessel A which was crossing the river. While vessel 3 passed vessel A on the right side, vessel 2 collided with it. It was later revealed that the skipper of vessel 2 thought vessel A would remain in the middle of the fairway to allow vessels 3 and 1 to pass. In an attempt to avoid a collision, vessel 1 had turned off the trackpilot system and switched to manual steering just before the collision – but it was too late.

Figure 32 still from simulation scenario 7

Scenario 8 Pannerdensch Kanaal second – with intentions

The simulation was troubled with a malfunction of the connection between the trackpilots and the simulation software, as a result the radar and trackpilot system on one of the participant did not work correctly. So one of the skippers was sailing almost ‘blind’. It resulted in a collision with one of the simulated (controlled by the simulator instructor) vessels.

Scenario 8 Pannerdensch Kanaal second – without intentions

With constant use of VHF, all vessel were able to make agreements for how to pass each other safely. However, it was a challenge to keep sailing with the trackpilot in a very dense traffic situation. Again the simulation was troubled with radar failure and missing AIS information.

APPENDIX 4 MARIN SIMULATORS

Set- up simulations

Three MARIN simulators were used for the study: two compact manoeuvring simulators and one full-mission-bridge simulator.

The Compact Manoeuvring Simulators (CMS) have a 270° visual image and an additional monitor providing view astern. The CMS is equipped with controls for the main propulsion (two controllable pitch propellers), and joysticks to operate the winches (to pay out or heave in). The CMS has three displays:

1. Electronic chart, which shows the vessels in the area
2. ARPA Radar display
3. Conning display featuring:
    a. engine power and rudder angle (or direction and rpm),
    b. use of bow thruster (azimuthing and tunnel) as well as stern thruster;
    c. forward speed, the lateral speed fore and aft, the rate of turn,
    d. length of and force in the tow line,
    e. wind speed and direction, etc.

Furthermore, the CMS simulators were equipped with displays of the trackpilot systems. Figure 33 shows the extra screen on the left on which the shared intended routes of surrounding traffic was presented.

Figure 33 CMS Simulator with the trackpilot system from Shipping Technology

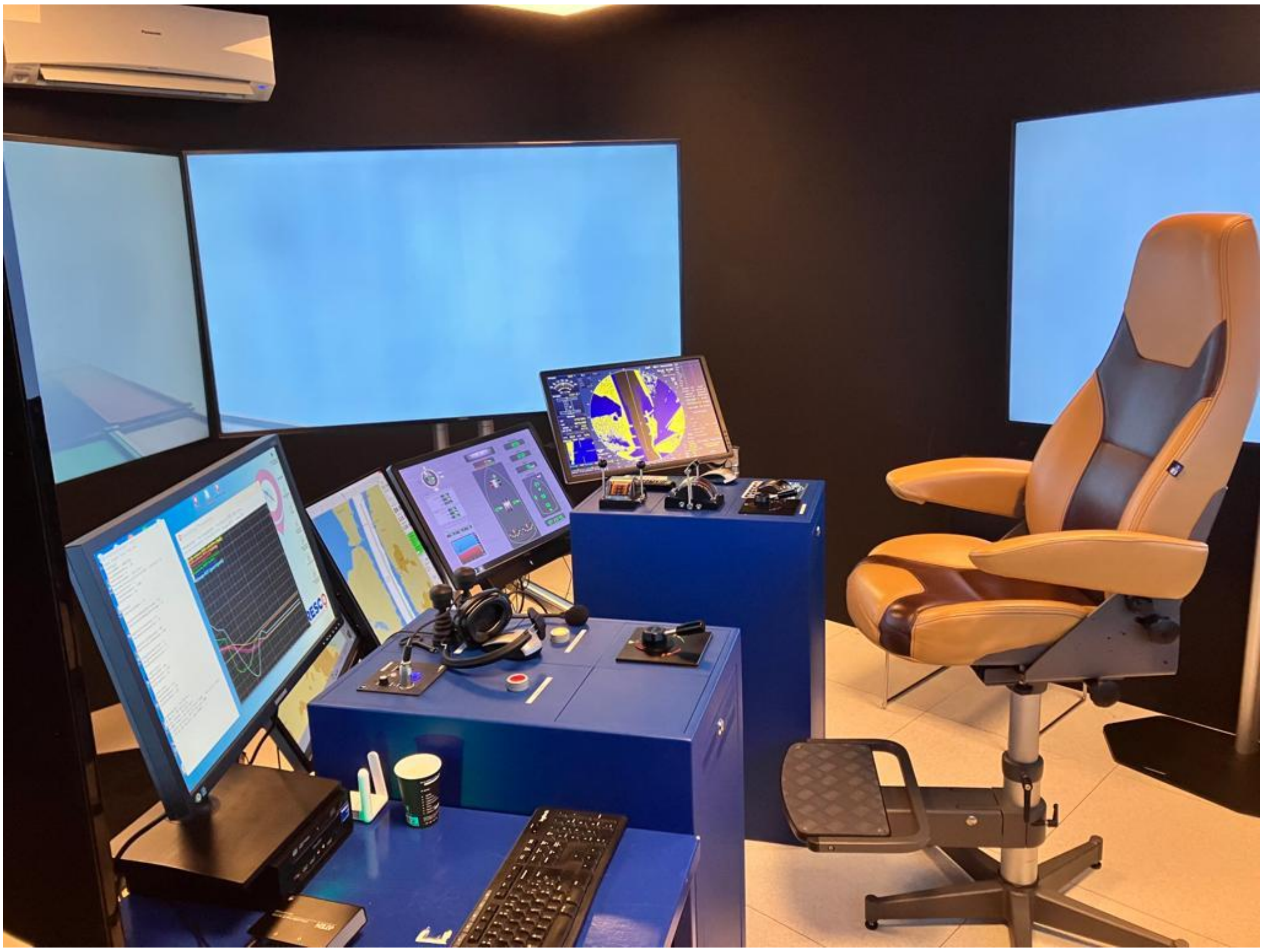


Figure 34 Simulator with the trackpilot system from Tresco

MARIN’s Full-Mission Bridge 2 (FMB2) has a 200 degrees projected outside view. A monitor provides an additional astern view. Furthermore, the FMB2 contains multiple screen:

1. Electronic chart, which shows the vessels in the area
2. ARPA Radar display
3. Conning display featuring:
    a. engine power and rudder angle (or direction and rpm),
    b. use of bow thruster (azimuthing and tunnel) as well as stern thruster;
    c. forward speed, the lateral speed fore and aft, the rate of turn,
    d. length of and force in the tow line,
    e. wind speed and direction, etc.

Figure 35 Simulator FMB2 with the trackpilot from Argonics

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