

MOSWOZ simulator study 2025

Final report

INTERGO
International Centre for Safety Ergonomics & Human Factors

SIMWAVE
MARITIME CENTRES OF EXCELLENCE



Colophon

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1. Introduction

1.1 Background

The North Sea, one of the busiest maritime areas in the world, is not only used for shipping but also for various other activities, including energy production. With the ambition to significantly increase offshore wind energy production in the coming decades to meet climate goals, important questions arise regarding maritime safety. To ensure continuous safety, Rijkswaterstaat (RWS) is investigating the impact of offshore wind farms (OWFs) and has initiated the Monitoring and Research Program Maritime Safety Wind at Sea (MOSWOZ). In the complex and sometimes stressful environment of the North Sea, human factors are crucial in preventing collisions. Ship crews can regularly encounter critical situations that require quick decision-making. At the same time, RWS introduces mitigating measures to overcome the possible effects of the OWFs.

In collaboration with RWS, Intergo and Simwave have conducted a simulator study on this subject in 2024. The main research questions of the study were:

1) What is the effect of the OWFs and increasing traffic intensity in the North Sea on the behaviour of ship crews?
2) How effective are the mitigating measures?

The study provided insight in the crew behaviour during different circumstances and the mitigating effect of Vessel Traffic Monitoring (VTMon), an Emergency Response Towing Vessel (ERTV) and a deep-sea pilot. However, some questions remained unanswered. First, it was not possible to make a clear comparison between experienced and inexperienced crews. Second, during the study modern supporting tools were not available in the simulation. Additionally, RWS wanted more insight in the ability and preference to make a round turn manoeuvre during specific emergency situations. Finally, RWS wanted to explore the potential use of a Shore Based Pilot to guide ships in the vicinity of OWFs.

1.2 Research question

The following research questions are considered the main questions for this additional research and are addressed in the conclusion:

1) What is the crew sailing behaviour during high demand situations, in which a round turn manoeuvre might be considered?
2) What is the difference in performance of the sailing task between experienced and inexperienced crew?
3) What is the VTMon operator task performance with smart support tooling?
4) What is the Shore Based Pilot (SBP) task performance with advanced tooling?

Additional research questions are presented in the results sections and are considered sub-questions that support the answers to these main questions.

Two scenarios were developed, one of which included two variants, resulting in a total of five simulation runs conducted to address the research questions. Research question 1 was explored in scenario 1. Research question 2 reflects findings from both scenarios, each performed by an experienced and an inexperienced crew. Research questions 3 and 4 were addressed in scenario 2.

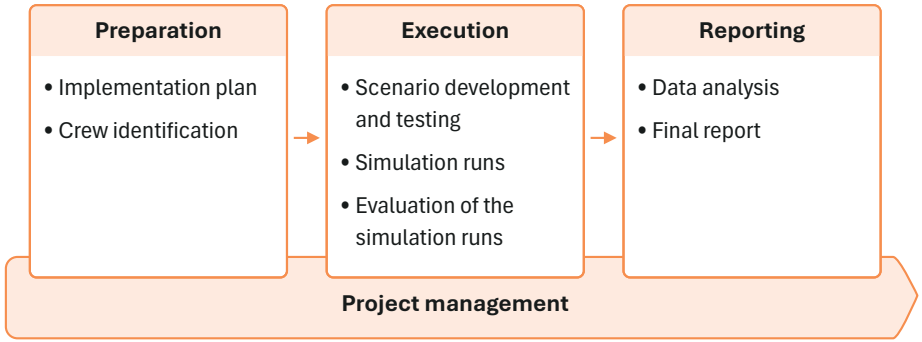
1.3 Reading guide

This document provides a concise overview of the approach, results, conclusions, and limitations (discussion) of the MOSWOZ simulator study. Chapter 2 outlines the research approach, including insights on the preparation and execution of this study. Chapter 3 addresses the results of the study regarding the research questions. Chapter 4 provides a section discussing the limitation of the study and chapter 5 concludes the key findings with regards to the main research questions and offers recommendations. Annex 1 ‘Data analysis report’ provides a more detailed overview of the data analysis and is referred to throughout the body of this document. Other reports that have been drafted prior to this final report are referred to in text, they provide a more comprehensive explanation on the topics mentioned.

2. Approach

A qualitative study was conducted to examine participants' behaviour during two maritime scenarios on the North Sea, set in the year 2030. These scenarios, along with corresponding research questions, were defined in advance by RWS during which Intergo advised on feasibility. This chapter offers a concise overview of the research phases, scenarios, participants, measurement instruments, and simulators used.

The study consisted of three phases: preparation, execution, and reporting.



2.1 Preparation

2.1.1 Implementation plan

The implementation plan defined the research approach and measurement strategy used in the simulation study and addressed the following key components:

- Alignment of scenario events with research questions: How events in the scenarios were linked to the study's research objectives.
- Crew and personnel roles: Identification of all participants and the conditions imposed (nationality and level of experience).
- Assessment instruments: The tools and methods used for data collection, further detailed later in this chapter.
- Procedure: Description of the activities carried out during the scenario runs.
- Data analysis plan: The approach for collecting and analysing the study data.

To ensure methodological quality, the plan was reviewed by an independent senior researcher from the Rotterdam University of Applied Sciences. Feedback from both the university and RWS was incorporated, after which the plan was formally approved by RWS.

A full description of the study design is provided in the '*Implementation Plan*' report [1].

2.1.2 Scenarios

Two scenarios were executed during two simulation days.

- Scenario 1 was performed by both an experienced and an inexperienced crew. The RoRo vessel sailed from IJmuiden to Newcastle, following a preset route through the IJmuiden Ver clearway. The scenario was designed to lead to a developing traffic situation involving an unresponsive vessel on a collision course, requiring the crew of the RoRo vessel to initiate an emergency manoeuvre to avoid a potential incident near the offshore wind farm.
- Scenario 2 was conducted with both an experienced and an inexperienced crew (scenario 2.1). The RoRo vessel sailed southbound from Oslo to Calais, navigating crossing traffic and fishing vessels near offshore wind farms. The crew was supported by an SBP, who initially guided the RoRo vessel and later coordinated two additional vessels. A VTMon operator monitored the wider North Sea area, providing warnings when vessels entered unsafe situations.

A separate variant of this scenario was executed without the SBP and VTMon, in which the crew of the RoRo vessel was escorted by an ERTV positioned in the area to provide support in case this was needed (scenario 2.2).

2.1.3. Participants

Part of the research were three groups of participants: RoRo vessel crew members, VTMon operators and SBPs.

The RoRo vessel crew in scenario 1 and 2 consisted of a captain, second officer and lookout/helmsman. One crew was experienced, one was inexperienced. The difference in experience for the crews and individual crew members was defined as the following:

- **Experienced**: The crew member is experienced with navigating a RoRo or RoPax vessel (at least 5 years). Additionally, the crew member has experience with the North Sea (at least 5 years) and sailing in vicinity of OWFs.
- **Inexperienced**: The crew member has little to no experience with navigating the North Sea (less than 2 times the last 5 years) and in vicinity of OWFs. In addition, the crew member has limited experience with their rank (less than 6 months). Preferably the crew members have experience with navigating a RoRo vessel, or at least a merchant vessel. The crew shall not have any experience with working on cruise ships, since bridge resource management generally deviates from merchant vessels.

The specific nationalities of the crew members are discussed and agreed by RWS. Requested nationalities of these crew members are mentioned in the '*Structured evaluation simulations'* report [2].

VTMon: Each scenario 2.1 included one VTMon operator, both of whom have a professional background as Vessel Traffic Services (VTS) operators. One of the VTMons also participated in the previous year's simulation study. This made it possible to compare the differences in experience between the previous and current supporting tools. Prior to the simulations, working instructions for the VTMon role, as provided by RWS, were shared with both operators. During the simulations, they used the Kongsberg support tooling and received training in advance to familiarise themselves with the system.

SBP: Similar to the VTMon role, each scenario 2.1 included one SBP. Both SBPs are trained Deep Sea pilots and have several years of operational experience. They also worked with the Kongsberg support tooling during the simulations and received training on system use beforehand.

Supporting roles, including the crews of simulated vessels, the coastguard, OWF operators and the ERTV crew, were roleplayed by Simwave simulation operators. Table 1 shows what scenarios were performed by the different participants.

Table 1. Participants per scenario

Participants	*Scenario*
RoRo vessel crew 1: captain, 2nd officer and lookout/ helmsman (experienced)	1 and 2.1
RoRo vessel crew 2: captain, 2nd officer and lookout/ helmsman (inexperienced)	1 and 2.1
RoRo vessel crew 3: captain and 2nd officer	2.2
Shore Based Pilots	2.1
VTMon operators	2.1

2.1.4 Simulators

Three different simulators were used during the scenarios, with up to three simulators operating in a single scenario as a maximum. An overview of the simulators is provided below:

- 360 Degree Full Mission Bridge: This simulator was used for the RoRo vessel in both scenario 1 and 2.1 (figure 1).



Figure 1. The 360 degrees FMB bridge used for the RoRo vessel in scenario 1 and 2.1

- 360 Degree Offshore Full Mission Bridge: This simulator was used for the RoRo vessel that operated separately in scenario 2.2 and had an ERTV escort (figure 2).



Figure 2. The 360 degrees offshore FMB bridge used for the RoRo vessel in scenario 2.2.

- Kongsberg desk with support tooling: This simulator was used by the VTMon and SBP during scenario 2 (figure 3).



Figure 3. The support tooling used by the VTMon and SBP.

Measurement instruments

During the simulation runs, triangulation of assessment instruments was applied by utilizing multiple tools for data collection. The following measuring instruments were employed:

- Observations: Observations focused on the sequence of events and decision-making processes, incorporating the ‘thinking out loud’ procedure that participants were encouraged to use. Observations were conducted by at least two human factors experts.
- Rating Scale Mental Effort (RSME): This instrument was used to measure

the experienced level of mental effort throughout the scenarios.
- Reflection report: Individual questionnaires addressing the topics relevant for the research question for each role were completed at the end of each scenario.
- Debriefing: A plenary debriefing was conducted with all participants, using a semi-structured list of scenario specific questions to facilitate discussion and gain a deeper understanding of the observations.
- Eye tracking: Eye tracking technology was used to measure the situational awareness of the VTMon.
- Simulator data: Key parameters such as Time to Closest Point of Approach (TCPA) , Closest Point of Approach (CPA), and distances to other vessels, wind turbines, and offshore wind farm boundaries were analysed at critical moments to assess detection times and identify potentially hazardous situations, including near-miss encounters.

2.2 Execution

Scenario development and testing

The scenarios and drafted events were integrated into the simulation environment and tested in advance by Simwave. In addition, a quality control of both the simulator and scenarios was conducted by Nautical Experts prior to the simulation runs. The findings and recommendations from this quality control were shared with RWS. Any required improvements or adjustments were implemented before the start of the simulations. For further details, see the '*Scenario testing report'* [3].

The Kongsberg support tooling was installed during the week prior to the simulation runs. Testing was carried out to verify system functionality. However, the time available to optimize the system's configuration and stability was limited, which led to constraints during the simulations. For further explanation, see Discussion 'Challenges with the VTMon support tooling'.

Simulation runs

The simulation runs were conducted over two days, on the 10th and 11th of June 2025. On simulation day 1, the experienced RoRo crew participated. They performed scenario 1 in the morning and scenario 2.1 in the afternoon. The VTMon and SBP operators received training and instruction in the morning and performed their roles during scenario 2.1 in the afternoon.

Simulation day 2 followed the same structure, but with an inexperienced RoRo crew. In the afternoon, scenario 2.2 was conducted in parallel with scenario 2.1, each using different RoRo crews and a different simulation environment.

Evaluation of the simulation run

After completing the simulation runs, an evaluation was conducted focusing on the following aspects:

- General evaluation: Assessment of the overall procedure during the simulation days and the functionality of the simulation equipment.
- Crew evaluation: Review of crew performance, any issues encountered, and the measures taken to address them.
- Scenario evaluation: Analysis of the scenario events, including key occurrences during each run.

Although not all events unfolded exactly as planned, targeted interventions by the research team made it possible to create or closely approximate the intended situations. A comprehensive evaluation is documented in the report *Structured Evaluation Simulations* [2].

2.3 Reporting

Data analysis

The reporting phase started with a data analysis. For each scenario, the results were analysed and used to address the corresponding research questions. The findings related to the main research questions are presented in the next chapter of this report, while detailed answers to the specific research questions are provided in Annex 1. Data Analysis Report.

Final report

The second step of the reporting phase involved compiling the final report, which is this document.

3. Results

3.1 Scenario 1. Round turn

3.1.1 Introduction

Scenario description

At the start of the simulation, the car carrier (OS1), a RoRo vessel, was en route from IJmuiden to Newcastle and was scheduled to pass through the clearway from IJmuiden Ver after crossing the southbound traffic lane. The vessel's track had been pre-programmed in the Electronic Chart Display and Information System (ECDIS). The scenario was designed to encourage a situation in which OS1 would likely need to initiate emergency steering and perform a round turn to starboard in response to a developing traffic situation. Wind and current conditions pushed the vessel toward the offshore wind farm (OWF). The scenario was performed twice with different crews (experienced and inexperienced), and lasted approximately one hour each.

A more detailed description on the scenario, the crew and simulated area, the scenario events and results is described in *'Annex 1. Data analysis report Scenario 1: Round turn'*.

Research questions

The main questions for this scenario are:

1) What is the crew sailing behaviour during high demand situations, in which a round turn manoeuvre might be considered?
2) What is the difference in performance of the sailing task between experienced and inexperienced crew?

To answer these questions, four sub-questions were formulated. For each of these questions the performance of experienced and inexperienced crews was compared.

1) What position does the crew choose in the clearway?
2) Does the crew consider a round turn to be a realistic manoeuvre in this situation?
3) Is the crew able to perform a round turn in the clearway?
4) What effect does the increase in crossing/entering and exiting traffic have on the crew?

3.1.2 Results of scenario 1

Position in the clearway

Although both crews operated within the clearway, the simulator data showed noteworthy differences in their positioning relative to the OWF. The experienced crew appeared to consciously avoid proximity to navigational boundaries, recognising the operational limitations of their vessel type and the space required for safe manoeuvring. In the simulation, they entered the clearway at 1.06 Nm from the OWF (Figure 4) and maintained this distance during normal

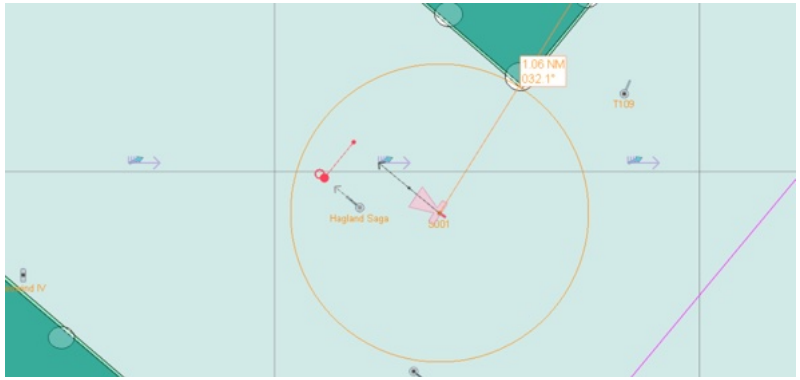


Figure 4. Distance between RoRo vessel with the experienced crew and OWF when entering the clearway of OWF IJmuiden Ver.

operations, adjusting course towards the centre of the clearway or reducing speed during emergencies while still maintaining at least 0.95 Nm clearance from the OWF. The crew generally reported low to moderate stress levels during these operations in the reflection reports.

During the debriefing, the inexperienced crew mentioned not to have explicitly taken the OWF into account when entering the clearway and were unaware of the distance regulations (the UNCLOS 500m safety zone), although they later expressed that maintaining 1 to 1.5 Nm from the OWF felt safe. Simulator data show they entered at 0.58 Nm (Figure 5) and decreased to 0.44 Nm while navigating through the clearway, indicating a discrepancy between their perceived and actual operating distance. They also reported neutral stress levels despite the reduced clearance.



Figure 5. Distance between RoRo vessel with the inexperienced crew and OWF when entering the clearway of OWF IJmuiden Ver.

Round turn consideration

During the debriefing, the majority of both experienced and inexperienced crew members stated that they did not consider a round turn to be a realistic manoeuvre in the given scenario. When faced with unresponsive vessels on a collision course, both crews opted for evasive manoeuvres, preferring proximity to static wind turbines over the risks of a dynamic threat. The reflections reports confirmed that the round turn was mostly rated as 'unlikely' or 'neutral/unsure'.

The observations showed that the second officer of the experienced crew initiated a portside evasive manoeuvre (Figure 6) under pressure, later acknowledged as a COLREGs violation due to reduced visibility, time constraints, and uncertainty about vessel intentions. The captain, in retrospect, indicated during the debriefing to prefer a moderate starboard alteration, using the available space, rather than a full turn, citing insufficient space and the risks associated with round turns in RoRo operations.

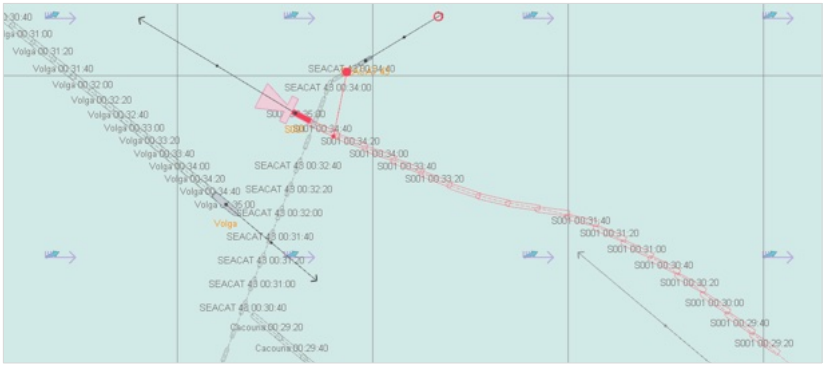


Figure 6. Track of RoRo vessel making an evasive portside manoeuvre to avoid vessel Seacat 43.

The inexperienced crew also opted for a starboard manoeuvre, entering the OWF to avoid a collision. At no point did they consider or attempt a round turn. Simulator data show they passed a wind turbine at just 0.04Nm, indicating

minimal available space (Figure 7). During the debriefing the captain considered a round turn too risky due to the vessel astern, preferring to take controlled action despite entering the wind farm.

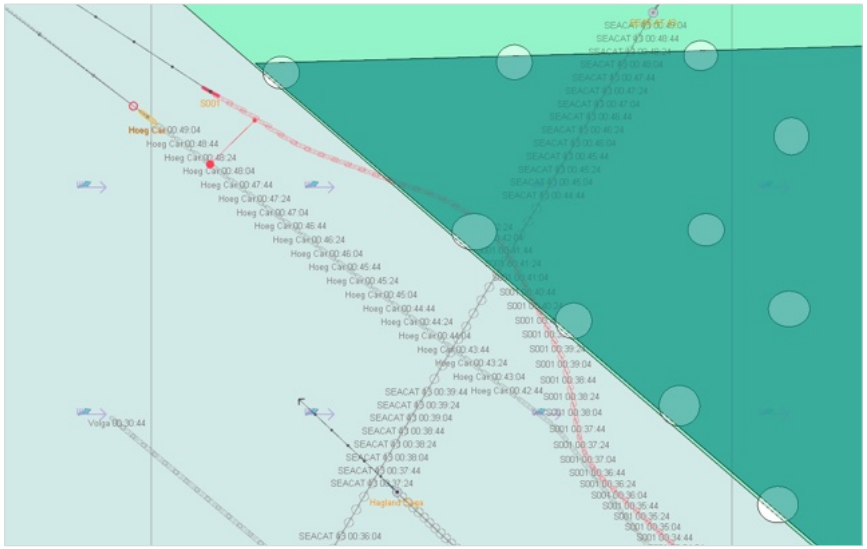


Figure 7. Track of RoRo vessel making an evasive starboard manoeuvre and going into the OWF.

Round turn performance

A round turn was successfully executed later in the simulation upon researcher request, but under altered conditions: lower speed, central positioning in the clearway, and increased distance to the OWF (Figure 8). In the original scenario, the crew did not attempt a round turn. Under altered conditions, the experienced crew demonstrated that a 360 degree round turn in the clearway is technically feasible. When instructed by the research team to perform manoeuvre, the vessel was at a halt, first manoeuvring astern to reposition the bow before completing the turn ahead. This differed from the original scenario, where the vessel would have been underway. The vessel was near the centre of the fairway, with approximately 0.54 nautical miles to the OWF; the minimum clearance during the turn was 550–600 metres, aligning with the modelled turning diameter.

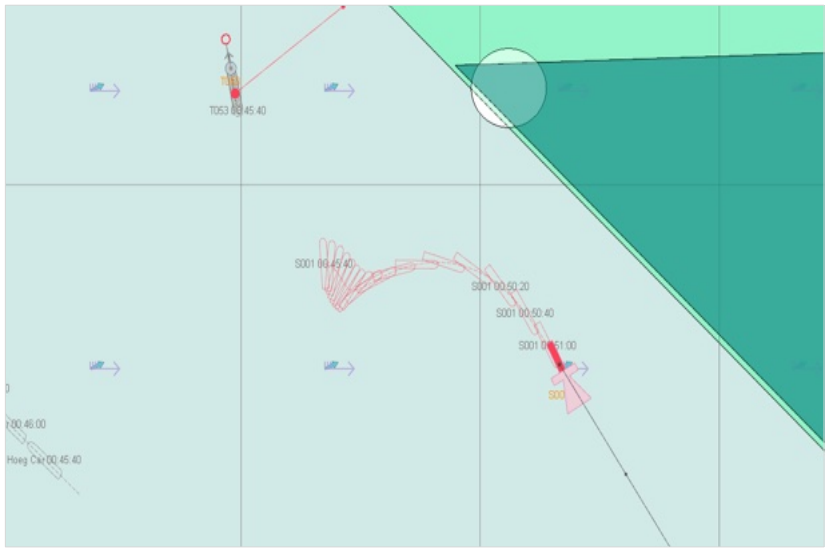


Figure 8. RoRo vessel making a 180 degree turn. The vessel is adrift at the initiation of the manoeuvre.

Estimates on the characteristics of the ship model used, see page 30-31, indicate that a round turn would also have been theoretically feasible during both emergency situations faced by the experienced crew, particularly due to sufficient distance to the OWF and central positioning. However, the crew opted for alternative evasive actions due to time pressure, visibility, and risk perception.

For the inexperienced crew, a round turn was not feasible at the time of the emergency: the vessel was travelling at 14 knots with only 0.44 nautical miles of space, further constrained by wind and current. The captain instead chose to steer into the OWF to avoid collision.

In conclusion, while a round turn is feasible under controlled conditions, the participating crews found it not practical during high pressure, real-time scenarios.

Effect of increasing and crossing traffic

The increase in crossing, entering, and exiting traffic did not lead to a significant rise in reported mental workload for either crew, as indicated by stable RSME scores during the initial monitoring phase. However, the crews' subjective experiences differed. The reflection reports showed that the inexperienced crew perceived the traffic as mostly too crowded and responded by slightly reducing speed when monitoring surrounding vessels. In contrast, the experienced crew described the situation as neutral and proposed procedural improvements, such as expanding manoeuvring space at entry and exit points through funnel shaped zones. In general, simulator data showed that both crews maintained safe distances from the OWF when passing through the clearway.

In some situations, crews need to perform emergency manoeuvres near other vessels (e.g. to avoid an unresponsive vessel approaching from portside). These manoeuvres require space. When space is limited, the number of available options to avoid the risky situation reduces. An increase in traffic density, especially in a clearway with already limited room, adds to the complexity of such situations. For example, during the simulation, the officer of the watch from the experienced crew made a quick decision to turn to port side. The officer stated during the debriefing to have the feeling that there was not enough time or space to consider other options. The inexperienced crew, facing a similar situation, steered towards the OWF, entering the area and passing close to a wind turbine. In both cases, the available space and options were limited. For example, a full round turn was not considered safe due to the presence of nearby vessels.

Overall, under normal conditions, increased traffic does not appear to affect the crew much. However, in critical moments, limited manoeuvring space can reduce the options available and affect situational awareness, especially when time is short and visibility is restricted.

3.1.2 Answers to the research questions – Scenario 1

What is the crew sailing behaviour during high demand situations, in which a round turn maneuver might be considered?

During mentally high demand situations involving time pressure, constrained space, reduced visibility and approaching traffic, both experienced and inexperienced crews showed a clear preference for evasive manoeuvres to port or starboard instead of executing a round turn. Although round turns were technically feasible under controlled conditions, during the debrief crew members stated that it was not considered a viable option during real-time decision-making.

Specifically, in similar situations where crews encountered an unresponsive vessel coming from port while inside the clearway of OWF IJmuiden Ver, crews opted for either a starboard manoeuvre towards the OWF or a portside manoeuvre (violating COLREGs) towards the middle of the clearway. Both situations led to potentially dangerous situations with one vessel entering the OWF and sailing in close vicinity to a wind turbine and the other vessel coming in close vicinity to other vessels and violating COLREGs.

Still, these options were preferred over a round turn in this specific situation. A round turn was only attempted later upon request, under static and low risk conditions.

In summary, crew behaviour during high demand scenarios prioritised straightforward and spatially efficient actions. Crews' options during situations like these were negatively influenced by constrained space, time pressure and reduced visibility. Round turns were not part of the operational response and were only feasible when conditions were significantly more favourable than during actual events.

What is the difference in performance of the sailing task between experienced and inexperienced crew?

The main differences in performance between the two crews concerned their positioning within the clearway, their approach to the OWF, and their response to an emergency manoeuvre.

Upon entering the clearway, the experienced crew maintained a distance of approximately 1 Nm from the OWF, creating additional manoeuvring space. In contrast, the inexperienced crew kept a distance of around 0.5 Nm and did not explicitly account for the proximity of the OWF. During the debriefing, they also indicated being unaware of any applicable distance regulations.

In the event where both crews were forced to make an emergency manoeuvre due to an unresponsive vessel approaching from portside, both opted to alter course rather than perform a round turn. The experienced crew executed a portside manoeuvre, which brought the vessel close to other traffic. Notably, the captain was not on the bridge at the time and did not support this course of action. The captain stated afterwards to have preferred using the available space on the starboard side. A round turn was not considered a viable option, as the available space was still perceived as insufficient and the manoeuvre could have had serious implications for the cargo.

The inexperienced crew, being closer to the OWF during the incident, chose to enter the OWF to avoid the unresponsive vessel and re-entered the clearway once the situation had stabilised. Entering the OWF with reduced visibility caused the crew to avoid the unresponsive vessel but almost lead to a collision with a wind turbine.

In summary, both crews chose evasive manoeuvres over a round turn in response to the situation. The experienced crew benefitted from a wider manoeuvring margin due to their initial positioning, yet both manoeuvres resulted in high risk situations.

3.2 Scenario 2. SBP, VTMon and ERTV support

3.2.1 Introduction

Description Scenario 2.1. VTMon and SBP support

In scenario 2.1 a car carrier (OS1), a RoRo vessel, sailed southbound from Oslo to Calais through the Traffic Seperation Scheme (TSS) west of Texel, where crossing traffic and fishing vessels near OWFs posed navigational challenges. During the scenario the crew of OS1 had a Shore Based Pilot (SBP) for support. A VTMon was included in this scenario as well. The simulation ran for approximately three hours.

The crew of OS1 consisted of a captain, a second officer and a lookout / helmsman. For this scenario we used a full mission bridge (FMB) simulator.

Both the SBP and VTMon used a Kongsberg support tooling, that were added to the simulated environment.

The SBP started with supporting OS1. Later in the scenario the SBP guided two additional vessels, resulting in guiding three vessels at the same time.

The VTMon operators' task was to actively monitor the relevant areas and only act as soon as unexpected or dangerous sailing behaviour has been identified. The VTMon encountered events throughout the North Sea area.

A scenario operator made sure that the events occurred at the right time. Besides that, the operator played the role of other ships that were part of the events.

The scenario was run twice: once with an experienced crew (day 1) and once with an inexperienced group (day 2).

Description scenario 2.2. ERTV support

Scenario 2.2 was essentially the same as scenario 2.1, with the exclusion of the SBP and VTMon. The crew of the RoRo vessel was informed that they had engine problems earlier this journey and therefore were escorted by an ERTV . The simulator operator played the role of the ERTV. At the end of the scenario

the vessel (OS1) experienced a blackout as a result of engine failure. For this scenario the offshore full mission bridge (FMB) simulator was used.

The crew of OS1 consisted of a captain and a second officer. The crew was unexperienced as described in 2.1.3.

Scenario 2.2 was run in parallel with scenario 2.1.

A more detailed description on the scenario, the crew and simulated area, the scenario events and results is described in *'Annex 1. Data analysis report Scenario 2: SBP, VTMon and ERTV support'*.

Research questions

The research questions within this scenario are categorized per role, respectively the crew of the RoRo vessel, the SBP and the VTMon. For each role a main research question and sub-questions were formulated:

Crew of RoRo vessel

1) What is the difference in performance of the sailing task between experienced and inexperienced crew?
   a) What is the effect of SBP deployment on the crew's sailing task?
   b) What effect does the increase in crossing/entry/exiting traffic have on the situational awareness and decision-making on the crews?
   c) What is the effect on the crew of the RoRo vessel when escorted by the ERTV? (Scenario 2.2)

SBP

2) What is the SBP task performance with advanced tooling?
   a) Does the SBP have enough available VTS support resources to perform the pilotage task? If not, what is missing?
   b) How many vessels can a SBP guide at the same time?

VTMon

3) What is the VTMon operator task performance with advanced tooling?
   a) Are current supporting resources adequate to carry out the VTMon task? If not, what is missing?
   b) Is the span of control for the VTMon in this specific scenario acceptable, given the available supporting resources?

3.2.1 Results of scenario 2.1

The results and answers to the research questions are categorized per role.

Crew of RoRo vessel

Difference in performance between experience and inexperienced crew

In scenario 2.1. both crews performed the sailing task effectively, with no critical incidents caused by crew actions. The reflection reports showed slightly greater confidence with the experienced crew, particularly in decision-making, while the inexperienced crew found the scenario manageable and made use of external guidance when available.

The reflection reports showed difficulty and stress levels were low across both groups. The SBP was seen as useful by the experienced second officer but unnecessary by the captain. Due to limited training with the support tooling the SBP misidentified a ship and gave the wrong information to the inexperienced crew. As a result, the inexperienced crew initially distrusted the SBP, but regained trust during the scenario.

Reported mental effort was unexpectedly high for the experienced second officer and helmsman (see Figure 9). It does not support the findings in the reflection reports and the debriefings. A possible explanation might be that the scale was not clear to them.

In summary, task performance was comparable, with differences mainly reflecting experience and attitudes toward support tools.

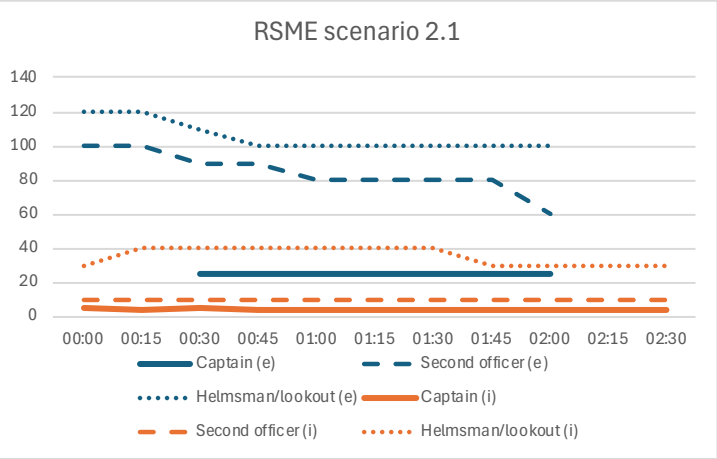


Figure 9. Mental effort during scenario 2.1.

Effect SBP on sailing task

During the debriefing crew members stated that SBP deployment generally supported the crew's sailing task by acting as an additional set of eyes, helping to reduce workload through course advice, traffic coordination, and hazard monitoring. Both experienced and inexperienced crews recognised this added value, particularly in unfamiliar waters. However, the impact varied between roles and crews.

The experienced second officer found the SBP highly useful, while the captain considered it unnecessary because of the familiarity with the area. The inexperienced crew initially questioned the SBP's reliability after a near-misidentification incident but gradually regained trust as the SBP provided helpful navigation support. Reflections confirmed that the SBP could offer assurance and relief in complex environments.

Even though the inexperienced captain noted to prefer pilotage in unfamiliar areas during the debriefing, the financial cost often discourages the use of traditional pilots. In that context, remote or digital alternatives such as the SBP were seen as a potentially more accessible and cost-effective solution.

Overall, the SBP was perceived as a valuable support, especially in less familiar situations, but its effectiveness seemed to depend on accuracy, contextual trust, and the crew's operational experience.

Effect increasing traffic

The increase in traffic had limited impact on the crews' situational awareness and decision-making under the given conditions. Both crews generally rated the traffic density as neutral and managed to maintain adequate spacing from other vessels. However, the experienced crew noted that unpredictable vessel movements and nighttime visibility occasionally required extra attention.

Shore Based Pilot

Support systems

From the reflection reports and the debriefing it appeared that the SBPs considered the available support tooling largely sufficient to perform the pilotage task, particularly for core navigation functions such as CPA and TCPA calculations, vessel highlighting, and access to essential traffic data. However, their performance was affected by limited familiarisation time, unfamiliarity with the simulated environment, and missing features such as real-time heading visibility and the ability to trace cleared alarms to specific vessels.

Although no critical functionalities were lacking, the overall effectiveness of SBP support depends on sufficient training, interface adaptation to operational needs, and operator experience. The IMO standard prescribes a minimum proficiency of the English language. in some cases, this is still considered too limited for remote pilotage. For those cases onboard presence remains necessary.

The supporting tools are promising but would benefit from improved preparation and configuration for the operational context.

Guiding capacity of SBP

Based on the scenario, SBPs reported in the reflection reports and during the debriefing being able to guide between three and five vessels simultaneously, depending on the availability of dedicated screens and their familiarity with the support tools. During the simulation, both SBPs managed up to three vessels at once without operational issues. Minor VHF communication overlap was observed but did not affect safety. Clear communication protocols were identified as essential when handling multiple vessels to prevent confusion.

VTMon operator

Support systems

The reflection reports and debriefings show that used supporting tools were assessed as largely sufficient for executing VTMon responsibilities, such as monitoring traffic outside the TSS, tracking vessels with a dragging anchor, estimating CPA and TCPA values, and issuing timely warnings. VTMon operators reported general satisfaction with the functionality of the support tooling and considered it a notable improvement over previous setup. However, several critical limitations affected overall performance.

Most notably, the alarm system was not fully configured to detect key risks, such as vessels entering offshore wind farms or navigating clearways with unauthorised dimensions. These blind spots led to multiple cases during the simulation where violations were either missed or detected too late. The lack of a bow passage measurement tool further limited the ability to assess close range collision risks. Eye tracking data and system usage logs also revealed gaps in area coverage, with some zones not being monitored due to custom display settings.

Finally, the limited time for training and familiarisation with the support tooling impacted the VTMons' ability to configure the interface effectively and respond efficiently.

While the support tooling offers considerable potential to support the VTMon task, observations and debriefing showed that its success depends on proper configuration aligned with operational needs and sufficient training. Only when these conditions are met can the support tooling be used effectively and reliably across a wide monitoring area.

Span of control

The span of control required to monitor the entire Dutch part of the North Sea proved demanding under the simulated conditions. Although one VTMon reported feeling capable of maintaining oversight, simulator data and observations revealed that several critical events were not detected. These included vessels entering offshore wind farms unnoticed and unauthorised use of clearways Hollandse Kust Zuid and Borssele, where the unauthorisation was due to vessels exceeding the permitted length, indicating that it is difficult to maintain full situational awareness across the entire area."During the debriefing both VTMons noted that, given the scope and intensity of the task, continuous monitoring without breaks should not exceed two hours. One VTMon proposed dividing the area into three to four sectors to improve manageability. Reflection data also pointed to factors such as unfamiliarity with location names, use of a new support tool, and overlapping alarms as contributing to moments of uncertainty or increased effort.

These findings suggest that the span of control might become a limiting factor in real operational settings.

3.2.3 Results of scenario 2.2

Crew of RoRo vessel

Effect of ERTV

In scenario 2.2. the debriefing showed that the escorting ERTV had a calming and reassuring effect on the RoRo crew. It increased alertness and confidence, particularly in anticipation of and during the simulated blackout. The ERTV's presence influenced decision-making by prompting the crew to prioritise communication with the ERTV over internal procedures. Overall, the ERTV reduced perceived risk and supported the crew's situational focus during a critical event. The captain noted that, if there is enough time, it is common practice to request a commercial tug instead, mainly due to financial considerations. However, an ERTV will deliver services against cost price, which is probably cheaper than a commercial tug.

3.2.4 Answers to the research questions – Scenario 2

What is the difference in performance of the sailing task between experienced and inexperienced crew?

Observations and simulator data showed that RoRo crews performed the sailing task effectively, manoeuvring from point a to point b with no critical incidents. In the reflection reports the experienced crew showed slightly more confidence, particularly in decision-making, while the inexperienced crew relied more on external guidance but found the scenario manageable. Stress levels and perceived difficulty remained low across both groups.

Observations and debriefings showed that SBP generally supported the sailing task by having the potential to reduce the piloted crews' workload (through course advice, traffic coordination, and hazard monitoring) though its perceived value varied. The experienced captain found it unnecessary, while the inexperienced crew initially distrusted it but regained confidence during the scenario. SBP effectiveness was seen to depend on accuracy, trust, and familiarity with the system.

The debriefing showed that the escorting ERTV had a calming and confidence enhancing effect, especially during the simulated blackout, and influenced decision-making by shifting priority toward external coordination. The increase in traffic had limited effect, though occasional unpredictability and reduced visibility required additional attention. One SBP omission briefly affected situational awareness, but was quickly corrected.

What is the SBP task performance with advanced tooling?

As stated above, SBPs considered the support tooling sufficient for core pilotage tasks, including traffic monitoring and collision avoidance. However, limited familiarisation time, missing functionalities such as real-time heading visibility, and challenges with system configuration affected their performance. The overall effectiveness of the SBP depends on sufficient training, alignment with operational needs, and operator experience. Remote pilotage may not be suitable in all contexts, particularly where language barriers exist.

In terms of guiding capacity, SBPs reported being able to support three to five vessels simultaneously, depending on screen availability and familiarity with the support tooling. In practice, both SBPs managed up to three vessels without operational issues. Clear communication protocols were identified as essential when piloting multiple vessels to avoid confusion.

VTMon operator

The current support tooling was considered generally sufficient for key VTMon responsibilities, such as traffic monitoring and collision risk assessment. Operators viewed the support tooling as an improvement over previous tools, but performance was affected by limited training, missing functionalities (e.g. bow passage measurement), and configuration issues (alarm management and setup). Critical events, such as unauthorized entry into wind farms, were missed. The required span of control proved demanding, with both VTMons

indicating the need for shorter shifts and smaller monitoring sectors to maintain focus. While workload remained within acceptable limits, the ability to monitor the entire Dutch part of the North Sea reliably seemed to be constrained under the simulated conditions. A proper system setup, targeted training, and clear alarm criteria may be a promising for improving the ability to monitor a larger area.

4. Discussion

This study provides useful insights into ship safety on the North Sea as envisioned for 2030. However, several limitations should be taken into account to interpret the findings accurately. These limitations result from both methodological choices and external factors that may affect the reliability and generalisability of the results. Recognising these constraints helps clarify the scope of the study.

Single playthrough limitation

The scenarios were performed a limited amount of time. This limits the ability to account for variation in participant responses. Factors such as chance, specific context, or individual differences may have influenced outcomes. Without repeated runs, it is difficult to assess whether the observed results are consistent or reproducible. As a result, the findings should be considered exploratory and interpreted with caution.

Challenges with the VTMon support tooling

Despite the joint efforts of all contributing parties to arrange the Kongsberg support tooling, the timeframe for executing the research was tight. Under normal conditions, learning to use the support tooling effectively requires at least a week of training and further familiarisation. Due to the constraints of the research schedule, this was not feasible. Given the limited time available, Kongsberg and Simwave successfully established a functional operating system.

Although the support tooling offers many capabilities, there was insufficient time to fully optimise the configuration or install all necessary parameters. To partly mitigate this, a Kongsberg engineer updated and adjusted the support tooling setup based on insights gained between simulation days.

VTMons and SBPs received approximately three hours of instruction from a Kongsberg expert, which provided a basic understanding of the support tooling. In practice, this proved sufficient for basic operational use. However, it did not allow users to take full advantage of the support tooling' capabilities.

During the simulations, certain critical events such as vessels entering OWFs without triggering alarms or the alarms going unnoticed highlighted the limitations of the setup and training. Additionally, one SBP misinterpreted system information and unintentionally provided incorrect guidance to a piloted vessel, resulting in a near collision.

With more comprehensive preparation and a setup tailored to user needs, it might be that such events could have been prevented. These observations emphasize the importance of adequate training for VTMon operators and SBPs and a carefully configured support system aligned with operational demands.

VHF reach and radar coverage

A final limitation of the simulation study is the assumption of uninterrupted VHF communication and full radar coverage across the entire area of operation. In practice, both VHF reach and radar visibility are subject to limitations. VHF communication range is affected by atmospheric conditions, antenna height, and terrain or structural obstructions, which can result in blind spots or signal loss beyond line of sight. Similarly, radar coverage can be reduced by sea clutter, weather conditions, or the radar horizon, particularly in low-lying offshore environments. These practical limitations may affect real-time situational awareness and vessel coordination at sea and should be taken into account when interpreting the results of this study.

5. Conclusion and recommendations

Given the limitations as described in chapter 4, this chapter presents the conclusions and recommendations. Conclusions and recommendations are categorized per role and related research question.

5.1 RoRo vessel crew

1. What is the crew sailing behaviour during high demand situations, in which a round turn manoeuvre might be considered?

In high demand situations, the participating RoRo vessel crews did not consider a round turn to be a realistic manoeuvre. When faced with unresponsive vessels on a collision course, the crews consistently opted for direct evasive actions (figure 10), including steering towards an OWF to avoid dynamic threats (figure 11). The round turn was generally rated as unlikely or uncertain and was not attempted during real-time decision-making. Although technically feasible under controlled conditions with sufficient space, reduced speed, and central positioning, crews did not select this option under operational pressure.

With the limited collected data, the study's findings indicate that crews preferred alternative evasive manoeuvres over round turns. This preference was influenced by limited manoeuvring space, time pressure, reduced visibility, surrounding traffic, a tendency to favour static risks such as wind turbines over dynamic risks posed by unresponsive vessels, and the perceived operational challenges of performing a full turn with a RoRo vessel.

This sailing behaviours shows that the participating crews tend to choose quick and predictable manoeuvres that can be carried out safely within the limits of the situation. High traffic density and reduced visibility sometimes made it harder to maintain full situational awareness, further limiting the options the crews considered.

An escorting ERTV showed a calming and reassuring effect on the RoRo crew with technical problems.

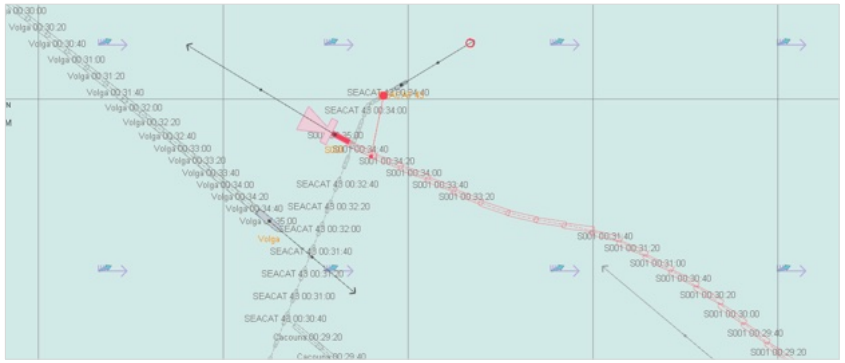


Figure 10. Track of RoRo vessel making an evasive portside manoeuvre to avoid vessel Seacat 43.

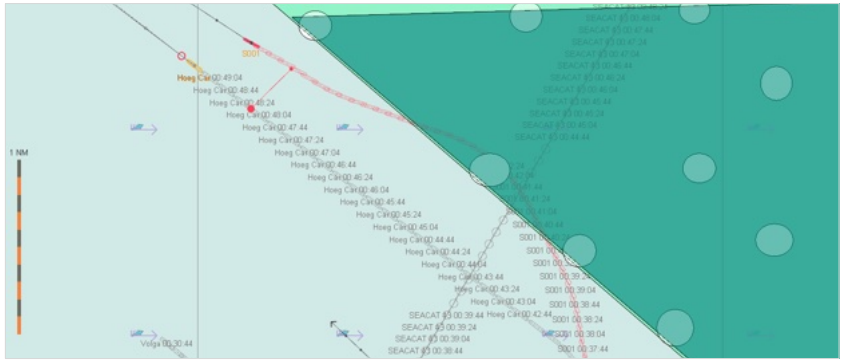


Figure 11. Track of RoRo vessel making an evasive starboard manoeuvre and going into the OWF.

To enhance navigational safety in high demand situations, several supportive measures could be considered. Scenario-based bridge training that reflects real world constraints such as limited space, visibility, and time pressure may help crews strengthen decision-making and prepare for realistic evasive manoeuvres. In addition, shore based pilotage could offer timely guidance in complex areas, particularly near OWFs, where local expertise and oversight may ease the burden on bridge teams. As a complementary measure, the role of the VTMon operator to actively monitor high risk zones could provide an added layer of situational awareness and early warning. Together, these measures may support more confident and well-informed decisions during time critical events.

2. What is the difference in performance of the sailing task between experienced and inexperienced crew?

The observed differences in sailing task performance between the experienced and inexperienced crew primarily related to spatial awareness, route planning, and decision-making under pressure. The experienced crew demonstrated a more proactive approach by maintaining greater distance from the OWF, thereby creating more manoeuvring space. This initial positioning provided more options when facing an unexpected situation. However, despite this advantage, the experienced crew still executed a risky evasive action that was not supported by the captain.

The inexperienced crew, by contrast, operated closer to the OWF and showed less awareness of spatial constraints and regulatory guidance. Their emergency response, entering the OWF, averted collision with the oncoming vessel but introduced new risks, including near contact with a wind turbine.

Overall, the experienced crew showed better anticipation and positioning, while both crews faced challenges in executing safe emergency manoeuvres under constrained conditions. Keeping the research limitations in mind, the differences in performance might suggest that experience contributes to more deliberate planning and spatial consideration, though it does not fully eliminate the risk of high consequence decisions in complex scenarios.

A further distinction between the crews was seen in their perception and use of the SBP. The experienced crew generally considered the SBP unnecessary due to their familiarity with the area, while the inexperienced crew regarded it as a useful aid to support navigation and decision-making.

Overall, both crews demonstrated effective performance, with differences primarily reflecting variation in judgement, spatial strategy, and attitudes toward external guidance.

The differences observed in spatial judgement and the use of advice (SBP) in this limited study suggest that additional attention should be given to how bridge teams prepare for high demand situations near offshore infrastructure. Instead of applying the SBP in the same way for all crews, its use could be better adapted to the specific needs and experience of each bridge team. The Dutch government could play an important role in informing and advising maritime companies on the usage of a DSP or SBP, the costs involved and possible considerations to take into account.

In addition, targeted training in evasive manoeuvres appropriate for areas such as OWF clearways, along with clear guidance on which procedures to follow during high-demand situations, may help ensure safer and more consistent responses. This combination of tailored support and scenario-based training could strengthen operational confidence and improve decision-making across different levels of experience.

5.2 VTMon

3. What is the VTMon operator task performance with advanced tooling?

The performance of the two participating VTMon operators using support tooling showed that core monitoring tasks, such as identifying drifting vessels, estimating collision risk, and issuing warnings, could generally be carried out effectively. Operators expressed satisfaction with the capabilities of the support tooling and regarded it as an improvement over previous setup. However, several limitations affected task execution. Key risks, including

unauthorised entry into OWFs, were not always detected partly due to incomplete alarm configuration. The absence of specific functionalities, such as a bow passage indicator, and gaps in screen coverage were identified as possible causes of reduced overall effectiveness.

Regarding span of control, monitoring the entire Dutch part of the North Sea seemed challenging under the simulated conditions. Multiple relevant events remained undetected, indicating that full situational awareness was difficult to maintain across such a large area. Continuous monitoring periods were estimated by the VTMons to be ideally limited to two hours to maintain focus and performance during demanding surveillance tasks. Possible contributing factors included limited training, system unfamiliarity, overlapping alarms, and unclear geographic references, all of which may have led to moments of reduced performance. The overall task load suggests that the monitoring scope may need to be reconsidered to reflect realistic operational limits.

The effectiveness of system support tools may be increased by configuring alarms and display settings to better reflect operational risks and user needs, including the integration of a bow passage measurement function. A task analysis based on the VTMon operator's responsibilities is recommended to help to configure and optimise the support tooling, ensuring all functional requirements are met.

With improved support tooling, the VTMon's task strategy could also be taken in consideration. During the simulation, VTMon operators applied a proactive monitoring approach, continuously scanning the area and taking action when necessary. If the tooling is fully optimised, a shift toward a more trigger-based strategy may be beneficial. In this approach, the VTMon primarily responds to system-generated alarms. With well-calibrated alarms, this would still support proactive intervention in risky situations, while potentially reducing workload by minimising the need for constantly scanning the complete area.

Based on the findings of this limited study, VTMon training should include comprehensive instruction on system operation, aimed at using the full functionality and effectiveness of the tooling. Additionally, if a continuous monitoring strategy is used, it may be helpful to limit shift durations and divide the monitoring area into smaller, more manageable sectors to support sustained attention and reduce the risk of missed events.

In conclusion, a balanced combination of support tooling optimisation, a clearly defined work strategy, manageable shift lengths, and well-structured monitoring zones may contribute to a more sustainable and operationally realistic implementation of the VTMon role in practice.

5.3 SBP

4. What is the SBP task performance with advanced tooling?

The SBP task performance using advanced tooling was generally judged as effective for core functions such as monitoring vessel positions, calculating CPA and TCPA, and providing navigational support. The two participating SBPs evaluated the available tools as largely sufficient to perform their tasks. However, their ability to use the system to its full potential was limited by short familiarisation time and a lack of experience with the simulated environment.

Despite these constraints, the SBPs were able to guide multiple vessels simultaneously without safety issues, indicating that the tooling is capable of supporting the task under the right conditions. They estimated that managing three to five vessels is feasible when sufficient displays are available, and operators are well acquainted with interacting with the system. Communication protocols proved to be essential, especially when working with multiple vessels at once. This highlights the importance of reliable system use, supported by adequate preparation and appropriate task structuring.

To improve SBP task performance with support tooling, it may be beneficial to conduct a task analysis, similar to what is recommended for the VTMon. This would support the configuration and optimisation of the tooling to ensure that all functional requirements for the SBP are met. From this study, it seems that

the SBP requires fewer system functionalities than the VTMon operator. Therefore, optimising the interface layout and establishing clear communication procedures could further support performance, particularly when guiding multiple vessels simultaneously.

It may also be helpful to offer more structured and scenario-based training, enabling operators to become familiar with both the system and the operational context. This might improve the effective use of available functionalities and support task execution under varying conditions.

In conclusion, optimising the SBP support tooling with attention to essential functions, interface clarity, and communication protocols may contribute to more consistent and reliable performance across different traffic and monitoring situations.

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List of abbreviations

Abbreviation	*Explanation*
AIS	Automatic Identification System
CPA	Closest Point of Approach
DSP	Deep Sea Pilot
ECDIS	Electronic Chart Display Information System.
ERTV	Emergency Response Towing Vessel
ETA	Estimated Time of Arrival
Events	Particular moments in simulation runs initiated by simulator operator evaluator or delegates. Events are used to describe the simulation run in a sequential order.
HKZ	Offshore wind farm Hollandse Kust Zuid
HKN	Offshore wind farm Hollandse Kust Noord
HKW	Offshore wind farm Hollandse Kust West
MOSWOZ	Monitorings- en Onderzoeksprogramma Scheepvaart veiligheid Wind op Zee. Offshore Wind Energy Shipping Safety Monitoring and Research Programme.
Nm	Nautical Mile. One nautical mile equals 1.852 metres
OS1	Own ship. Refers to the vessel the RoRo crew uses in the simualation

Abbreviation	*Explanation*
OWF(s)	Offshore wind farm(s)
RSME	Rating Scale Mental Effort
RWS	Rijkswaterstaat, an executive agency of the Ministry of Infrastructure and Water Management"
SBP	Shore Based Pilot(age) provides navigational guidance to vessels from a remote location, supporting safe and efficient passage in complex or high-traffic maritime areas.
TCPA	Time to Closest Point of Approach
Transit Passages	Passages trough an offshore wind farm intended to be used by ships <46 meter.
TSS	Traffic Separation Scheme
UNCLOS	United Nations Convention on the Law of the Sea
VHF	Very High Frequency, referring to the radio frequency range between 30 MHz and 300 MHz, commonly used for maritime communication and broadcasting.
VTMon	Vessel Traffic Monitoring. The process (or methodology) of monitoring ship movements in and around offshore wind farms.
VTS	Vessel Traffic Services are shore-based systems designed to monitor and manage vessel movements in busy or high-risk maritime areas to enhance safety and efficiency. In this report this often refers to Kongsberg 'Vessel Traffic Services' support tooling used in the simulations.

Annex 1. Data analysis report

The data analysis report provides a more detailed description on the scenario, the crew and simulated area, the scenario events and results. The report is subdivided into two parts, 'scenario 1: round turn and 'scenario 2: SBP, VTMon and ERTV support'.

7.1 Scenario 1: Round turn

Brief description of the scenario

At the start of the simulation, the car carrier (OS1), a RoRo vessel, was en route from IJmuiden to Newcastle and was scheduled to pass through the clearway from IJmuiden Ver after crossing the southbound traffic lane. The vessel's track had been pre-programmed in the ECDIS. For the purpose of the study, the scenario was designed to encourage a situation in which OS1 would likely need to initiate emergency steering and perform a round turn to starboard in response to a developing traffic situation. Wind and current conditions pushed the vessel toward the offshore wind farm (OWF). The scenario was performed twice with different crews and lasted approximately one hour.

Crew and simulated area

The crew of the RoRo vessel consisted of a captain, a second officer and a lookout or helmsman. This applied to both the experienced and the inexperienced teams. The difference (in experience) between the two crews was based on their familiarity with sailing in the North Sea, their experience operating near offshore wind turbines, and their level of experience within their respective ranks. Both crews performed the scenario using the 360 degree FMB simulator.

The simulation began with the RoRo vessel positioned southeast of the IJmuiden Ver clearway, south of the traffic separation scheme (TSS). The crew navigated across the TSS and entered the IJmuiden Ver clearway. Once inside, they encountered an unresponsive supply vessel approaching from the port side, which prompted them to carry out an emergency manoeuvre.

Scenario events

The following events occurred during the simulation(s):

Experienced crew

- Simulation start. OS1 travels northwest towards the clearway of IJmuiden Ver. Behind OS1 is another vessel following the same track.
- OS1 crosses the TSS and monitors a vessel oncoming from starboard side that is following the TSS. No action is needed.
- OS1 overtakes a vessel in the middle of the clearway that is navigating in northwestern direction.
- OS1 notices a supply vessel on the ECIDS/radar coming out of the southern OWF of IJmuiden Ver.
- OS1 calls the supply vessel on VHF but there is no response.
- OS1 goes into hand steering and decides (second officer, captain was not on the bridge) to make a portside manoeuvre to avoid a collision with the unresponsive supply vessel. OS1 did initially not take an oncoming vessel into consideration executing this manoeuvre.
- OS1 notices another vessel coming from portside.
- OS1 calls the vessel to request its intentions but receives no answer.
- OS1 makes a starboard manoeuvre to parallel the predicted path of the incoming vessel. OS1 also slows down preventing a collision
- OS1, avoiding both vessels without making a round turn, is requested by the researchers to make a round turn manoeuvre.
- OS1 informs the vessel astern and initiates a round turn. OS1 is at that point adrift and moves astern to move the bow of the vessel in easterly direction. After manoeuvring OS1 moves ahead and makes a starboard to fulfil a 360 degrees round turn.
- OS1 informs the previously warned vessel astern to make a starboard-starboard manoeuvre. End of scenario.

Inexperienced crew

- Simulation start. OS1 travels northwest towards the clearway of IJmuiden Ver. Behind OS1 is another vessel following the same track.
- OS1 crosses the TSS and monitors a vessel oncoming from starboard side that is following the TSS. No action is needed.
- OS1 overtakes a vessel in the middle of the clearway that is navigating in northwestern direction.
- OS1 notices a supply vessel on the ECDIS coming out of the southern OWF of IJmuiden Ver.
- The second officer leaves the bridge for a toilet break, the captain replaces the second officer.
- OS1 engages hand steering and initiates a starboard manoeuvre.
- OS1 enters the 500meter safety zone of the OWF. OS1 is unable to move back to portside, because of a collision hazard with the supply vessel.
- OS1 enters the OWF and navigates in close distance around a wind turbine, while changing course in north-westerly direction.
- OS1 monitors a vessel in the clearway that could obstruct its re-entry. The vessel then safely navigates out of the OWF and rejoins the clearway. End of scenario.

Research question 1: What position does the crew choose in the clearway?

Experienced crew

Debriefing

The captain estimated that performing a round turn safely would have required more than a nautical mile, which was not available given the vessel's proximity to navigational boundaries. Additionally, executing such a turn with a RoPax or RoRo vessel poses significant risks, including potential injury to passengers and movement or loss of cargo.

Reflection reports

On the question "How stressful did you experience navigating through the wind farms?" the 2nd officer and helmsman answered '*neutral*', and the captain responded with '*mostly not stressful*'.

Simulation data

The crew entered the clearway at a distance of 1.06Nm to the edge of OWF IJmuiden Ver, see figure 12. Distance between the RoRo vessel and the OWF remained roughly the same until the emergency manoeuvres. During the first emergency manoeuvre with the unresponsive supply vessel the crew choose to make a portside manoeuvre, manoeuvring more towards the centre of the clearway.

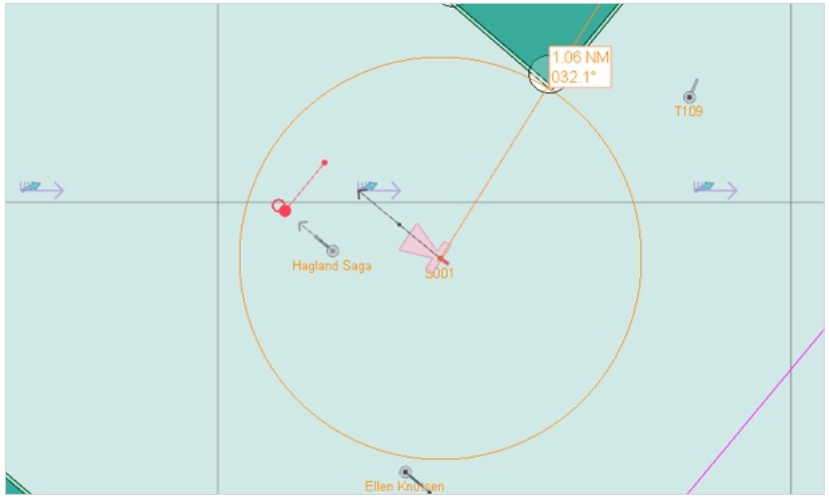


Figure 12. Distance between RoRo vessel and OWF IJmuiden Ver when entering clearway.

During the second emergency manoeuvre the crew made a starboard manoeuvre towards the OWF. At 0.95Nm to the closest part of the OWF (see figure 13) and 1.49Nm to the closest part of the OWF straight ahead the crew reduced speed.

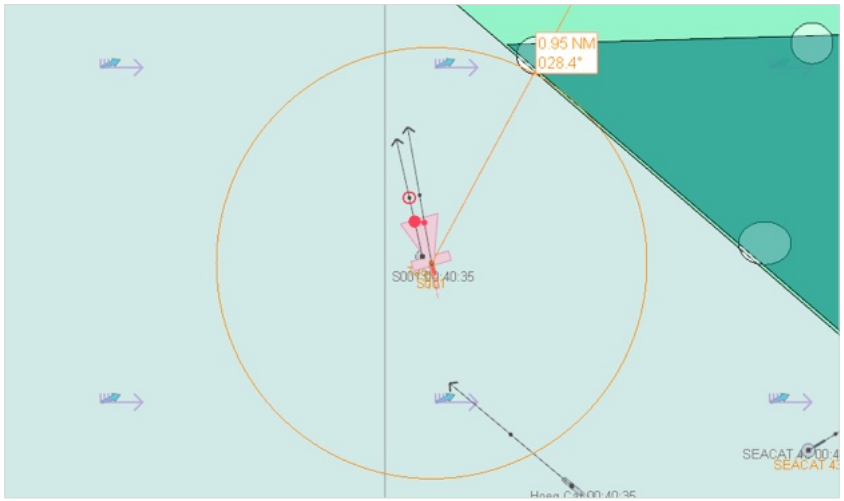


Figure 13. Distance of OS1 to closest part of the OWF when making a starboard manoeuvre to avoid colliding with another vessel.

The data from the observations and RSME did not yield relevant insights for answering the research question and were therefore not included in this section.

Inexperienced crew

Debriefing

The second officer reported that the OWF was not specifically taken into account when entering the clearway. They were unaware of any regulations regarding the minimum distance of 500 meters (safety zone) to be maintained from the OWF. The second officer considered a distance of 1 to 1.5 nautical miles to be safe.

The captain replied that navigating with 1Nm distance to the OWF is enough of a distance.

Reflection reports

On the question "How stressful did you experience navigating through the wind farms?" all crewmembers replied '*neutral*'.

Simulation data

The crew entered the clearway at a distance of 0.58 nautical miles from the edge of OWF IJmuiden Ver (see figure 14). This distance gradually decreased to 0.44 nautical miles at the moment the emergency starboard manoeuvre was initiated.

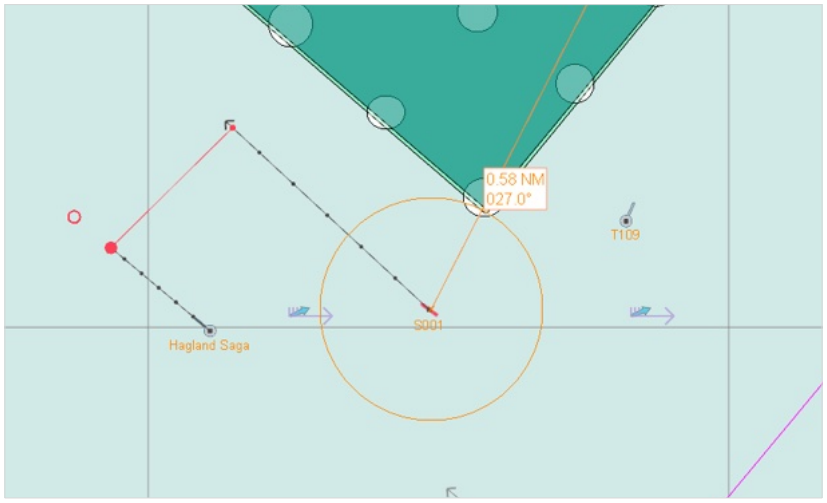


Figure 14. Distance of OS1 to closest part of OWF when entering the clearway of OWF IJmuiden Ver.

The data from the observations and RSME did not yield relevant insights for a nswering the research question and were therefore not included in this section.

Research question 2: Does the crew consider a round turn to be a realistic manoeuvre in this situation?

Experienced crew

Debriefing

The second officer (the captain was not present on the bridge at the time) decided to execute an evasive manoeuvre to port, despite an oncoming vessel approaching from that side. During the debriefing, the second officer explained that the decision was made under pressure and reflected an instinctive response. Contributing factors included darkness, concern about the proximity of wind farms on the starboard side, the lack of response from the approaching (collision) supply vessel via VHF, and the limited time available to assess and respond to the situation. In hindsight, the second officer regretted this decision and acknowledged, together with the captain, that the portside manoeuvre was not in accordance with the COLREGs in this situation, especially given that there was room to alter course to starboard.

The captain explained that, in this specific situation, to have opted for a moderate starboard manoeuvre of approximately 20 to 25 degrees, rather than an immediate full round turn. Peforming a round turn safely would have required more than a nautical mile, which was not available given the vessel's proximity to navigational boundaries (safety zone of the windfarm). Additionally, executing such a turn with a RoPax or RoRo vessel poses significant risks, including potential injury to passengers and movement or loss of cargo.

Although a portside manoeuvre was ultimately executed, the captain stated not to choose for a round turn over starboard either. Under the circumstances it was considered too risky due to limited space, the presence of boundaries, and the operational risks associated with carrying passengers and cargo. According to the captain, a controlled starboard alteration would have been sufficient to avoid the situation safely.

Observations

The crew was challenged to make a round turn twice during the scenario. On the first occasion the crew made an evasive manoeuvre to portside. The second occasion they made a starboard manoeuvre towards the OWFs, however not a round turn.

When requested by the research team the crew made a successful round turn manoeuvre to starboard side. However, because of prior events the vessel was in the middle of the clearway and had slowed down. This deviated from the original script in which the vessel was more to the side of the clearway and closer to the OWF and had more speed.

Reflection reports

In response to the question, *"Do you consider a round turn to be a realistic manoeuvre in the situation that occurred?",* the crew rated the manoeuvre between *'unlikely'* and *'neutral/unsure'*. The captain responded *'neutral/unsure'*, while both the second officer and the lookout rated it as *'unlikely'*.

The captain explained that the feasibility of a round turn depends on the vessel's speed, position, and the evolving circumstances. The second officer noted that the CPA/TCPA was very low, there was no response from the approaching vessel via VHF, and the available reaction time was limited.

Simulation data

During the scenario the experienced crew made three manoeuvres, two to avoid colliding with an unresponsive vessel and one forced manoeuvre (per request of the research team).

- **1. Emergency manoeuvre to avoid colliding with unresponsive supply vessel Seacat**. 30 minutes into the scenario the crew of OS1 initiated a portside manoeuvre to avoid colliding with an unresponsive supply vessel (Seacat 43). OS1 is at that moment 1.11Nm to the edge of OWF IJmuiden Ver ±17.5 kts. The (T)CPA between OS1 and the supply vessel is at that point 0.15Nm at 00:03:20. During the event OS1 and the supply vessel come within 0.20Nm from each other. With steering to portside OS1 steers

towards an oncoming vessel (Volga). Minimum distance between OS1 and the oncoming vessel is a minimum of 0.3Nm and less critical than the interaction with the supply vessel. Figure 15 shows the tracks of the OS1 and the manoeuvring of other vessels during this event.

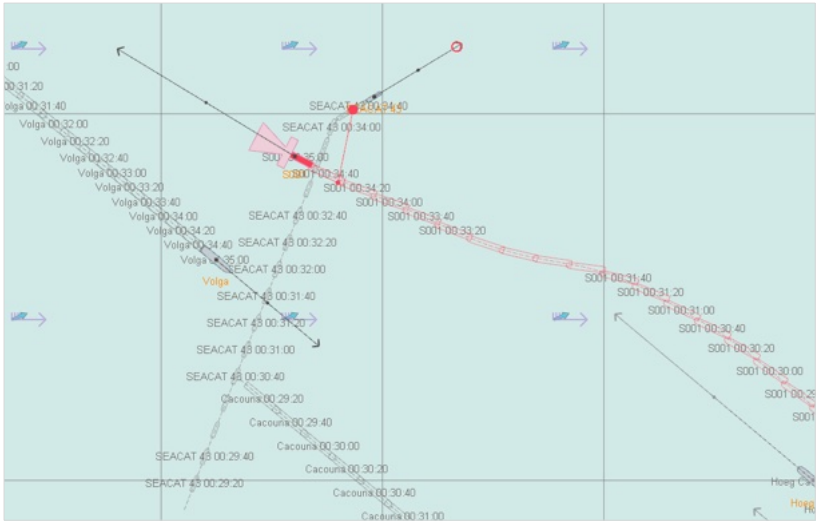


Figure 15. Tracks of OS1, Seacat 43 and nearby vessels during the portside manoeuvre of OS1. OS1's tracks are marked in red.

- **2. Emergency starboard manoeuvre to avoid colliding with unresponsive vessel Mubarraz.** Roughly seven minutes later OS1 faces another unresponsive vessel (Mubarraz) coming from portside. The captain decides to make a starboard manoeuvre to match Mubarraz direction. OS1 is at that moment doing ±17.5kts with a (T)CPA of 0.01Nm at 00:01:54 with Mubarraz. The simulator operator is forced to change the heading of Mubarraz at the last moment to avoid a collision, as this was not part of the research question. After this manoeuvre OS1 and Mubarraz are parallel to each other and heading in the same direction, towards OWF IJmuiden Ver. At OWF IJmuiden Ver at 1.49Nm straight ahead of OS1 and 0.95Nm to the closest edge of the OWF, OS1 reduces speed, comes to a halt (±0.54Nm to the edge of the OWF IJmuiden Ver) and slowly drifts caused by wind and current. The closest distance to Mubarraz and OS1 was 0.02Nm during the event. Figure 16 shows the tracks of OS1 and vessel Mubarraz during this event.

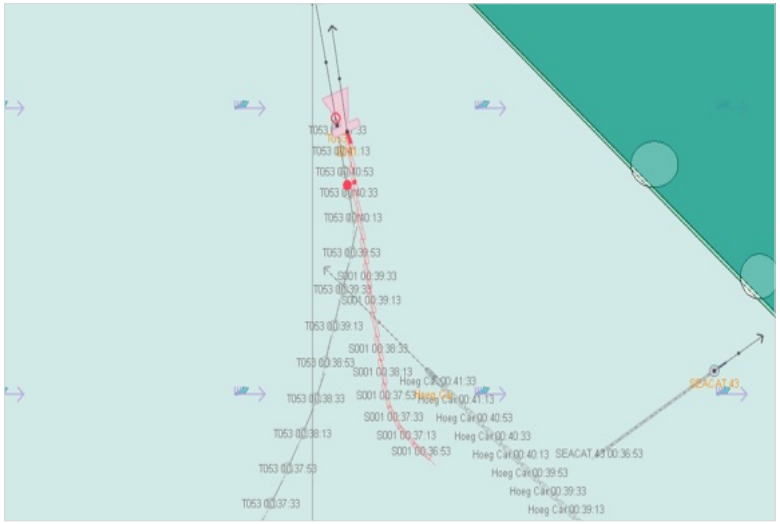


Figure 16. Tracks of OS1 and vessel Mubarraz during the starboard manoeuvre towards the OWF. OS1's tracks are marked in red.

- **3. OS1 makes a forced 180 degree turn.** After the event involving vessel Mubarraz, the research team requested the crew of OS1 to perform a starboard round turn if deemed feasible. At that moment, OS1 was drifting east-northeast at approximately 3 knots, with the bow facing north, and located 0.54 nautical miles from the edge of OWF IJmuiden Ver. To initiate the manoeuvre, OS1 first went half astern to shift the bow further east. When positioned at 0.48 nautical miles from the OWF, with the bow oriented more eastward, the vessel moved three-quarters ahead and applied 30 degrees starboard rudder to complete the 180-degree turn. The minimum distance between OS1 and the OWF during the manoeuvre was 0.29 nautical miles. Figure 17 illustrates the manoeuvre of OS1.

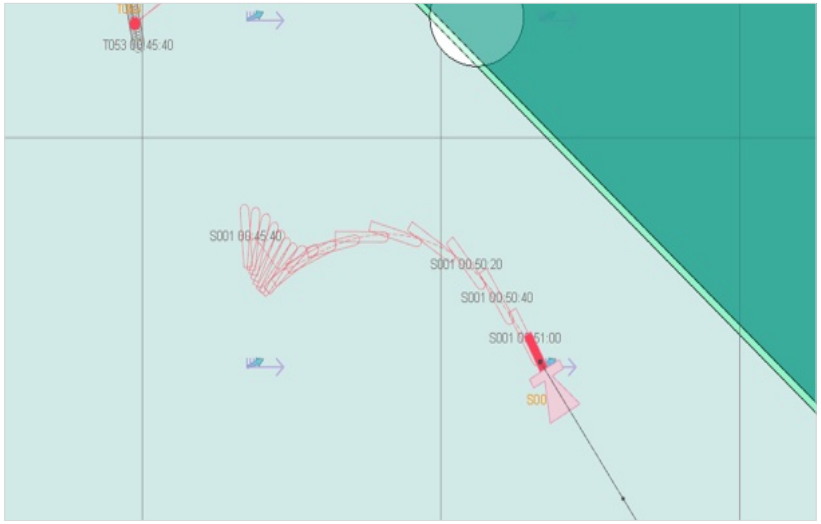


Figure 17. OS1 making a 180 degree turn. OS1 is adrift at the initiation of the manoeuvre.

The data from the RSME did not yield relevant insights for answering the research question and was therefore not included in this section.

Inexperienced crew

Debriefing

In this specific situation, the captain did not consider a round turn to be the appropriate manoeuvre. Time to react was limited, and with a vessel positioned astern, altering course to starboard to avoid a direct collision with the supply vessel was deemed the safest option. Although this decision led the crew and vessel into the OWF area, the captain justified it by noting that wind turbines are static structures and therefore pose less of a risk compared to moving vessels.

The second officer, who did not fully experience the emergency situation due to abscence for a toilet break, later suggested that a full round turn (360-degree manoeuvre) at reduced speed might have been a viable alternative. However, the captain disagreed, reiterating that the presence of the vessel astern made such a manoeuvre too risky.

Observations

In reaction to the incoming supply vessel from portside the captain decided to alter course to starboard and match the direction of the supply vessel in order to prevent a collision. This caused the crew to enter the OWF in which they navigated around one wind turbine before exiting the OWF and rejoining the TSS.

At no point during the simulation did the crew show signs of seriously considering a round turn.

Reflection reports

In response to the question, *"Do you consider a round turn to be a realistic manoeuvre in the situation that occurred?",* the crew rated the manoeuvre *'neutral/unsure'*.

Simulation data

36 minutes into the scenario the crew of OS1 initiate a starboard manoeuvre towards OWF IJmuiden Ver to prevent colliding with unresponsive supply vessel Seacat 43. At that moment OS1 is going 14 kts and is 0.44Nm away from the edge of OWF IJmuiden Ver. To avoid collision OS1 decides to enter the OWF and navigates around a wind turbine in full darkness. During this manoeuvre the closest distance between OS1 and the wind turbine is 0.04Nm. Figure 18 and 19 illustrate OS1 and the distance to the wind turbine at 0.04Nm apart from each other.

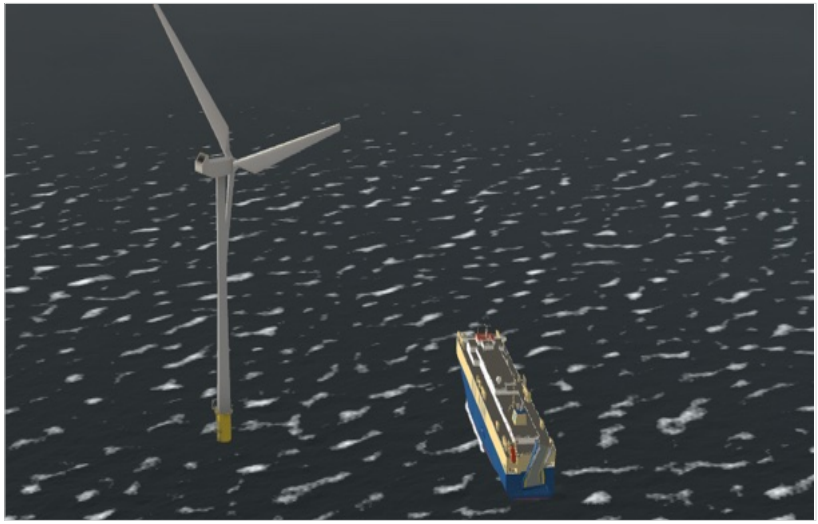


Figure 18. Rearview of OS1 and wind turbine at 0.04Nm apart from each other.



Figure 19. Sideview of OS1 and the windturbine at 0.04Nm apart from each other.

After passing the wind turbine OS1 navigates back to the clearway where it has to pay attention to a vessel that is in the clearway and heading in the same direction as OS1. During the manoeuvre OS1 keeps a speed of 14 kts. Figure 20 illustrates the tracks of OS1 during the event.

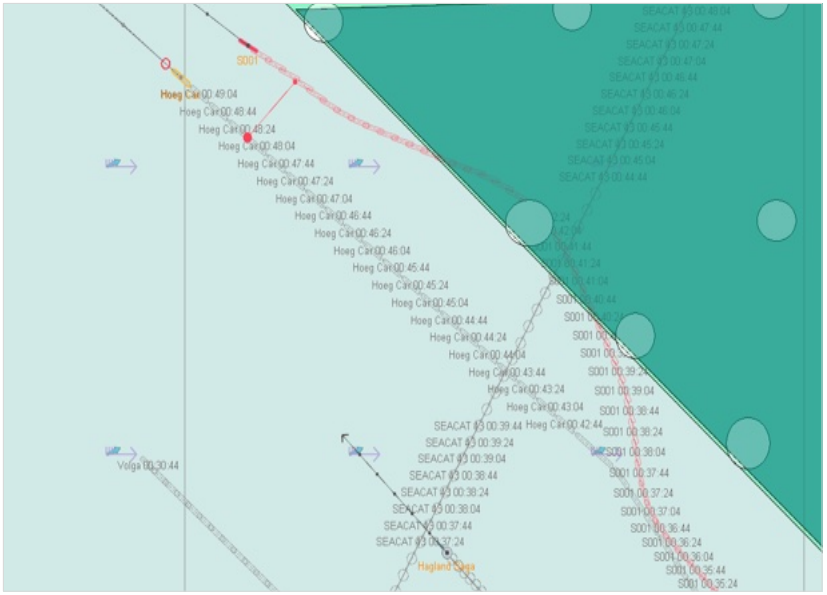


Figure 20. Tracks of OS1 during the evasive manoeuvre causing it to enter the OWF IJmuiden Ver. OS1's tracks are marked in red.

The data from the RSME did not yield relevant insights for answering the research question and was therefore not included in this section.

Research question 3: Is the crew able to perform a round turn in the clearway?

Experienced crew

Observations

The crew did initially not perform a round turn, instead the crew (second officer and lookout – the captain was not on the bridge at that moment) decided to make a portside manoeuvre to evade the incoming supply vessel.

The manoeuvre caused them to narrowly avoid the supply vessel, however the vessel got really close to an oncoming vessel on portside. The manoeuvre caused the vessel to be in the middle of the clearway.

A second vessel, coming from portside, was inserted in the scenario to force a round turn. As a result the crew (with the captain now on the bridge) made a starboard manoeuvre, no round turn.

In the end, the crew was requested by the research team to make a starboard manoeuvre. At this point the vessel was relatively in the middle of the fairway and had slowed down in speed. The round turn was made without issues. Distance to the nearest offshore wind turbine was approximately 550-600 meters.

RSME

During and prior to the first emergency manoeuvre the crew made they reported RSME scores of *'high effort'* and *'extremely high effort'*. The captain reported '*some effort'* to *'considerable effort'*.

For the latter part of the scenario, including the crew avoiding a second unresponsive vessel and making a force round turn showed somewhat similar RSME scores. Exception was the second officer that reported *'maximum effort'* for the final RSME score. Figure 21 illustrates the timeline of the scenario in relation to the experienced mental effort per role.

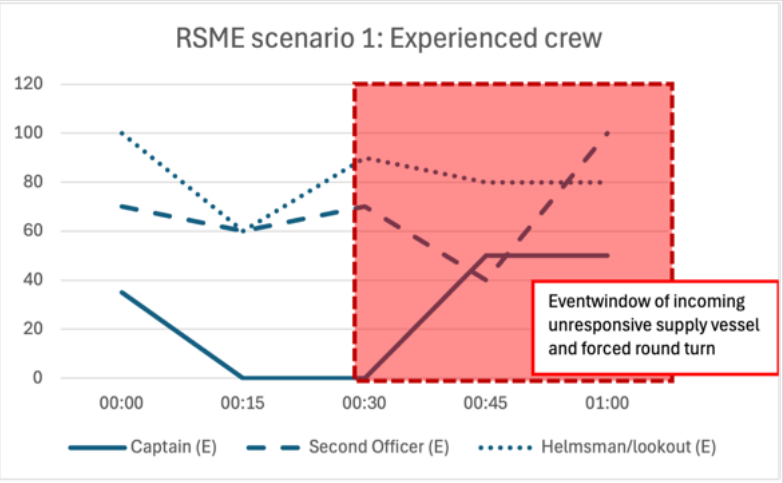


Figure 21. Graph showing mental effort scores over the course of the scenario, broken down by role, with the event involving the unresponsive vessel highlighted.

Simulation data

Description of the ship model Figaro (OS1) the RoRo vessel used in the simulator gives the following details on the turning circle starboard in deep water:

At full speed (20.9 kt), the model completes a 360-degree turn in 3 minutes and 8 seconds, under calm conditions with no wind (0 m/s) and no current (0 kt). The tactical diameter required for this manoeuvre is 1015.9 metres (approximately 0.55 nautical miles) *Description of Ship Model CARC04. Car Carrier M/S Figaro* [4]. See figure 22 for an illustration.

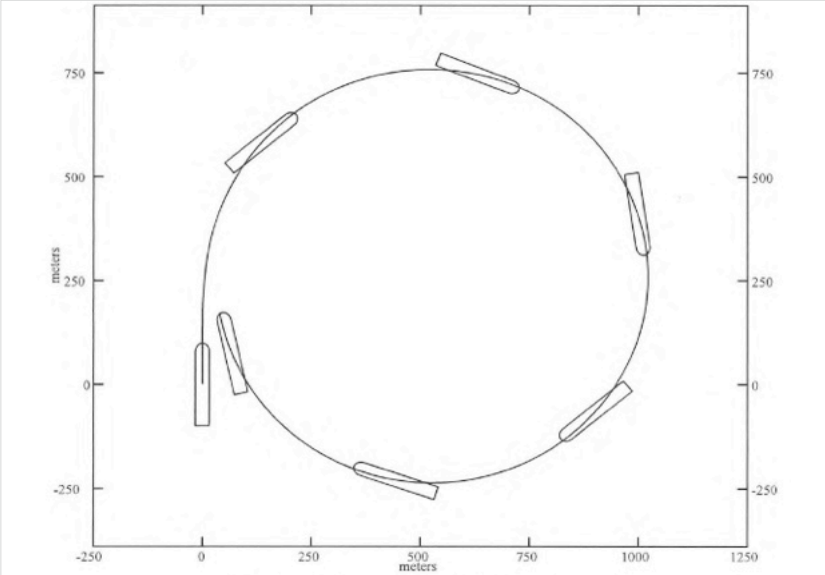


Figure 22. Turning circle starboard of M/S Figaro in deep water according to ship's model. Source: Description of Ship Model CARC04. Car Carrier M/S Figaro [4].

With these data available rough estimates can be made to check the feasibility of making a 360 degree round turn during the events encountered in the scenario.

- **1. Emergency manoeuvre to avoid colliding with unresponsive supply vessel Seacat.** At the initiation of the starboard manoeuvre, OS1 was travelling at 17.5 knots with a distance of 1.11 nautical miles to the edge of OWF IJmuiden Ver. Assuming the crew executed an optimised 360 degree turn, the reduced speed compared to full speed at 20 knots would slightly decrease the turning circle. However, the prevailing weather conditions, with a westerly wind at force 7 and an east-northeasterly current of 1.5 knots, are expected to increase it. Taking both effects into account, the required turning space is estimated to be approximately 0.55 to 0.6 nautical miles. Given the available distance of 1.11 nautical miles, a 180 degree starboard turn was considered feasible in this instance.
- **2. Emergency starboard manoeuvre to avoid colliding with unresponsive vessel Mubarraz.** Given the fact that OS1 was more in the middle of the clearway because of the previous portside manoeuvre it is expected that a starboard 360 degree round turn was feasible.
- **3. OS1 makes a forced 180 degree turn.** The initial position of OS1 is 0.54 Nm from the edge of OWF. In the scenario the crew decided to manoeuvre astern first to reposition the bow of the ship and then moves ahead completing the manoeuvre with relative ease. In case the crew decided to not go astern first but manoeuvre ahead, building up headway before initiating the starboard 180 degree turn, the situation is expected to not be feasible. Rough estimates that take wind and current into consideration and the space to build sufficient speed (3-6 kts) for effective rudder response of the vessel show that a total of 0.75 to 0.90 Nm is expected for these conditions.

The data from the debriefing and reflection reports did not supply any data on the crews' ability to perform a round turn in the clearway. Therefore they are not discussed in the section.

Inexperienced crew

Debriefing

No round turn was performed during the scenario. The captain did not consider this manoeuvre appropriate due to the presence of a vessel astern and the available space to alter course to starboard. Although this resulted in entering the OWF area, the captain judged it to be the safest course of action under the circumstances.

In hindsight, the second officer considered that a full round turn at reduced speed might have been a viable option. However, the second officer was not on the bridge at the time of the critical situation involving the approaching vessel.

Simulation data

Based on the vessel's characteristics and the turning circle data elaborated on page 30 – 31 the following can be estimated. Under the given conditions, a 360

degree starboard round turn at 14 knots is not considered feasible within the available 0.44 nautical miles. The required turning space is expected to exceed this distance, particularly due to the combined effect of wind and current pushing the vessel toward the offshore wind farm. Without additional space or corrective actions, such as reducing speed or initiating an astern manoeuvre, the vessel is unlikely to complete the turn without entering the OWF.

The data from the observations, reflection reports and RSME did not yield relevant insights for answering the research question and were therefore not included in this section.

Research question 4: What effect does the increase in crossing/ entering and exiting traffic have on the crew?

Experienced crew

Debriefing

The captain explained that in this particular situation, a busy crossing involving a TSS and a clearway between OWFs, the available manoeuvring space can become too restricted for vessels entering the clearway. As a solution, the captain proposed creating a funnel-shaped manoeuvring zone at both ends of the clearway. This would provide vessels with additional space at critical entry and exit points, reducing the risk of navigational conflict.

The OOW reported that during the emergency manoeuvre to portside the oncoming vessel on portside was not detected, almost causing a collision.

Observations

There were no notable interactions with crossing traffic for OS1, other than the crew monitoring nearby vessels on radar and ECDIS.

After entering the clearway of IJmuiden Ver the manoeuvring space of OS1, as intended by the script, OS1 was surrounded by vessels. Manoeuvring space seemed therefore limited.

When executing the emergency manoeuvre to portside it seemed that the OOW did not directly take the oncoming vessel in the clearway into consideration. Only after the simulator operator, roleplaying the oncoming vessel, asked the intentions of OS1.

Reflection reports

In response to the question, "*How did you experience the amount of traffic in the scenario?*", the crew all answered it to be '*neutral*'.

Additionally, on the question "*In general, how did you experience navigating through or near the wind farms?*" the second officer and helmsman answered '*easy*', and the captain responded with '*neutral*'.

RSME

The crew showed no increase in experienced mental effort during the first part of the scenario where the crew monitored crossing traffic, as well as other traffic entering the clearway of IJmuiden Ver (figure 23).

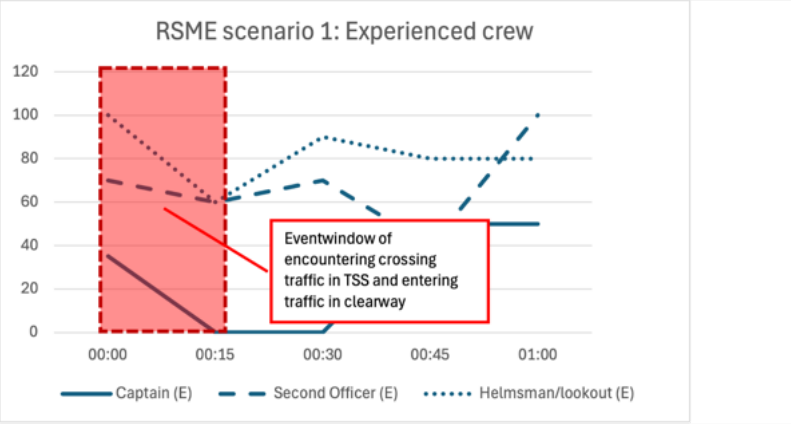


Figure 23. Graph showing mental effort scores over the course of the scenario, broken down by role, with the event of crossing traffic highlighted.

Simulation data

Simulation data showed no close interactions between OS1 and other vessels during the scenario, except during the events that required emergency manoeuvring. In the majority of other cases, the distance between OS1 and nearby vessels remained 1 Nm or more.

Inexperienced crew

Debriefing

The captain reported that during the emergency situation (incoming unresponsive vessel from portside) there was more focus on the nearby vessels than the OWF as the vessels are dynamic and the wind turbines are static.

Observations

The crew monitored (selected target vessels on radar / ECDIS) crossing vessels and a vessel that was at the beginning of the clearway and to be overtaken by OS1. OS1 slowed down a little (from 17 to 15 kts).

Reflection reports

In response to the question, "*How did you experience the amount of traffic in the scenario?*", all crew members responded with '*mostly too crowded*'.

Additionally, on the question "*In general, how did you experience navigating through or near the wind farms?*" all crew members responded with '*neutral*'.

RSME

The crew showed no increase in experienced mental effort during the first part of the scenario where the crew monitored crossing traffic, as well as other traffic entering the clearway of IJmuiden Ver (figure 24).

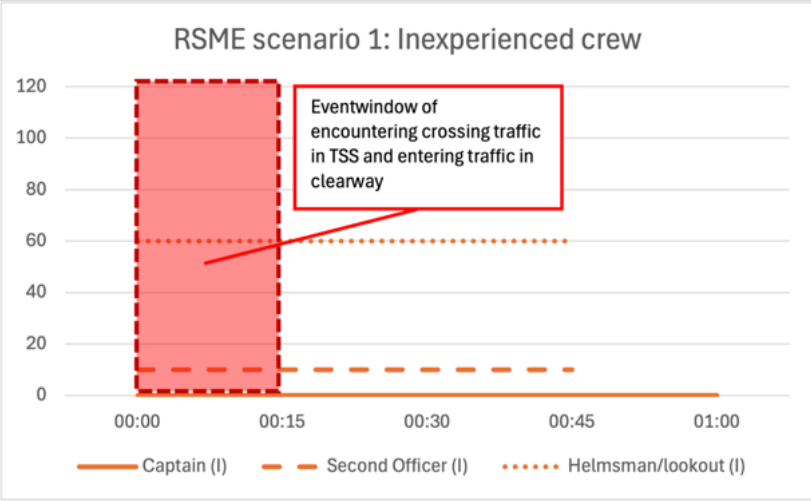


Figure 24. Graph showing mental effort scores over the course of the scenario, broken down by role for the inexperienced crew, with the event of crossing traffic highlighted.

Simulation data

Simulation data showed no close interactions between OS1 and other vessels during the scenario, except during the events that required emergency manoeuvring . OS1 navigated closer to the OWF than the experienced crew, maintaining a distance of approximately 0.44 tot 0.58 Nm to the OWF after entering the clearway.

7.2 Scenario 2: SBP, VTMon and ERTV support

Brief description of the scenario(s)

During scenario 2, a car carrier (OS1), a RoRo vessel, sailed southbound from Oslo to Calais, entering the traffic separation scheme west of Texel. Navigating through crossing traffic and fishing vessels near offshore wind farms presented several challenges.

The scenario had two variants. Variant 1 included VTMon and SBP support for OS1, with both roles using smart tooling as a support system. This variant was run twice: once with an experienced crew and once with an inexperienced crew.

Variant 2 excluded VTMon and SBP but included an ERTV escort, which navigated alongside OS1 through the TSS. This setup was based on the assumption that OS1 had experienced engine problems in the past and posed higher navigational risks, as explained to the crew. At the end of this scenario, OS1 experienced a blackout.

In total there were three separate simulation runs that lasted approximately 2.5 hours.

Crew and simulated area

The crew of the RoRo vessel in variant 1 consisted of a captain, a second officer and a lookout or helmsman. This applied to both the experienced and inexperienced crew. The crews performed the scenario using the 360-degrees FMB simulator. Additionally, this variant had a VTMon and SBP that each had their own working station in a separate room equipped with the support tooling of Kongsberg.

The crew of the RoRo vessel in variant 2 consisted of a captain and second officer. There was no VTMon or SBP and the simulator operator roleplayed the crew of the ERTV. For this scenario the offshore FMB simulator was used.

The simulation began with the RoRo vessel west of Texel in the TSS, heading southbound past OWF IJmuiden Ver and HKW. The VTMon was tasked with monitoring the entire Dutch North Sea area (in view of future windfarms to be built), with specified VTMon events distributed throughout the region. The SBP initially guided OS1 and was assigned two additional vessels to guide in the North Sea area as the scenario progressed.

Scenario events

The scenario events are described per scenario and separated per role for clarity. Events described are a selection of the most noteworthy events for the scenario.

Scenario 2.1: SBP and VTMon: Experienced RoRo crew

Crew RoRo vessel (OS1)

- OS1 overtakes cruise ship. No interaction required by the crew.
- OS1 alters course to starboard to avoid a fishing vessel.
- The captain of OS1 is requested on the bridge by the second officer.
- OS1 is requested by SBP to reduce speed to 12 kts and alter course to starboard to avoid vessel American Courage. SBP request to change heading to 215.
- OS1 informs SBP that they want to alter course to portside.
- OS1 suggested to alter heading to 220 and change to full ahead.

VTMon

- VTMon requests the intentions from vessel Seacat.
- VTMon calls vessel Skuns Centre and requests intentions. Skuns Centre is 100 meters out of the TSS and returns to TSS.
- VTMon requests the intentions of vessel Lucky Star
- Vessel Silver Emily starts drifting at IJmuiden anchorage 7 towards OWF Hollandse Kust Zuid (HKZ). Within three minutes VTMon notices Silver Emily and notifies Silver Emily on possible dragging anchor.
- VTMon notices motortanker Exmouth (270m LOA) inside of OWF Hollandse Kust Noord (HKN) and requests intentions. Exmouth is 0.22 Nm inside of the OWF and 0.16 Nm to a wind turbine and doing 15 kts.
- SBP requests VTMon information on Exmouth coming out of the OWF.
- VTMon requests intentions from vessel Rubyfish. Rubyfish is manoeuvring around the area where Exmouth is bound to exit the OWF.
- VTMon requests vessel Peterel to make arrangements with vessel Cavallier.

- VTMon requests intentions from vessel BB Sovereign that is outside of the TSS.
- VTMon requests intentions from vessel MSC Eleonora that is outside of the TSS.
- VTMon informs vessel Gallion that its entering a closed area, OWF Hollandse Kust West (HKW).
- Vessel Stark Kvarven is NUC. VTMon notices NUC vessel within one minute and warns surrounding vessels.
- VTMon requests intentions from vessel Lucky star that is on the edge of the TSS.
- Vessel Rigel (LOA 90 meters) without Automatic Identification System (AIS) navigates through OWF Borssele. VTMon does not notice this event.
- VTMon requests status from vessel Stark Kvarven. Stark Kvarven is still NUC and unable to anchor.
- VTMon requests ERTV to proceed to Stark Kvarven and gives permission to ERTV to navigate through OWF HKW kavel VII. The VTMon informs Stark Kvarven on incoming ERTV.
- VTMon requests vessel Blue Snapper to alter course to avoid a collision with another vessel.
- Vessel Elisa (LOA 90 meters) without AIS navigates through the transit passage of HKZ without VTMon noticing.
- VTMon requests intentions vessel Shakespear that is out of the TSS.
- VTMon requests vessel Gorinhem to manoeuvre back to the TSS.
- Vessel Artos is NUC south of Texel and goes unnoticed by the VTMon.
- VTMon requests intentions of vessel Belle Confidence.
- VTMon requests intentions from vessel Fadda.
- VTMon requests vessels Kongsberg1 to keep clear of the anchorage.
- VTMon asks ERTV if it is appropriate to pass through the OWF with the current weather conditions.
- VTMon informs IJM8 Rony that it entered a closed area (OWF Nederwiek Zuid) and request the vessel to alter to portside and exit the area.
- Vessel Fugro Zephyr drops anchor in the middle of clearway OWF IJmuiden Ver. There is no contact between VTMon and MV Fugro Zephyr.
- NUC vessel Star Kvarven informs VTMon that they are able to anchor. VTMon advises not to anchor and await the ERTV to make a tow. VTMon advises ERTV to tow Star Kvarven north of Maas approach.
- VTMon requests intention from Cacouna and warns them for the OWF ahead.

SBP

- SBP contacts OS1 and requests situation update on traffic conditions, OS1 course and speed and request OS1 to reduce speed to 12 kts.
- Vessel Tantalus request pilotage by SBP. SBP requests status update from Tantalus (speed, heading and ability to increase speed). SBP request Tantalus to increase to full ahead.
- SBP requests Tantalus to change heading to 301. After a minute the Tantalus is requested to change to heading 320. One minute later they are requested to change heading to 330 and after four minutes to heading 337.
- Tantalus requests new heading from SBP. SBP requests heading 000.
- SBP communicates with VTMon on intentions of motor tanker Exmouth that is currently inside of HKN and bound to exit the OWF.
- SBP informs Tantalus on three vessels to starboard side and requests to maintain speed and heading.
- SBP requests heading 020 from Tantalus.
- SBP requests new heading for vessel Figaro (OS1).
- SBP requests vessel Figaro (OS1) to reduce speed to 12 kts and move to starboard to avoid vessel American Courage. SBP request to change heading to 215.
- Vessel Hoeg Car requests pilotage from SBP (now piloting three vessels). SBP requests Hoeg Car to maintain heading and speed.
- SBP request Hoeg Car to alter heading to 315 and later 320.

Scenario 2.1: SBP and VTMon: Inexperienced RoRo crew

Crew RoRo vessel (OS1)

- OS1 and SBP have contact on pilotage. OS1 is to maintain heading and speed.
- OS1 is requested by SBP to change heading to 236, 233 and afterwards 255,
- OS1 captain dismisses SBP requested heading and sets heading 270. Captain dismisses SBP request because of vessel Lucky Star that is nearby and on collision course with OS1 if the heading of SBP is followed.
- OS1 does a hard starboard manoeuvre to avoid vessel Cavalier.

(Full restart) 30 minutes into the scenario the simulator crashes. A full restart of the scenario is done.

- OS1 informs SBP on heading and speed.
- OS1 informs SBP that they change course to 200 and go full ahead.

VTMon

- VTMon warns vessel Cavalier on close TCPA with another vessel. Vessel informs VTMon that they alter course to avoid collision. VTMon checks with OS1 if they overheard this conversation. VTMon informs vessel Cavalier on vessel Blue Snapper that is in the vicinity.

(Full restart of the scenario)

- VTMon advises MV Stark Kvarven to be aware of close CPA's with nearby vessels.
- VTMon requests intentions of MV Fugro Zephyr.
- VTMon requests intentions of OS1.
- VTMon requests intentions of FV Ameer. VTMon contacts SBP to verify if this message was understood. FV Ameer is on course with OS1. FV Ameer changes direction to avoid collision with OS1.
- MV Silver Emily starts drifting from IJmuiden Anchorage 7. Within 4 minutes the VTMon contacts MV Silver Emily and notifies the vessel on possible dragging anchor.
- VTMon requests intentions from MV Exmouth. MV Exmouth has OWF 1 Nm ahead and changes course to starboard to avoid entering the OWF.
- MV Star Kvarven is NUC. Within one minute the VTMon contacts Star Kvarven. The VTMon warns every vessel in the vicinity of MV Star Kvarven on to keep clear of the NUC vessel.
- VTMon informs MV Lucky Star that they are very close to the vessel ahead. MV Lucky Star alters course to starboard and gives way to MV Volga.
- MV Elisa (LOA 90 meters) without AIS navigates through the transit passage of HKZ without VTMon noticing.
- VTMon contacts ERTV and requests ERTV to proceed to NUC MV Star Kvarven. VTMon informs MV Star Kvarven of incoming ERTV with an estimated time of arrival (ETA) of one hour.
- VTMon requests intentions of MV Gallion.
- MV Fugro Zephyr drops anchor in the middle of clearway OWF Ijmuiden Ver. 17 minutes later the VTMon request the intention of MV Fugro Zephyr. No further action is requested.
- VTMon has contact with NUC MV Stark Kvarven and ERTV on towing arrangements.
- MV Artos is NUC south of Texel and goes unnoticed by the VTMon.
- VTMon informs OWF watch officer that NUC MV Star Kvarven is possibly drifting inside of the OWF.
- VTMon requests intentions of MV Exmouth that has OWF 1 Nm ahead.
- MV Danita is UNC. Within two minutes VTMon contacts MV Danita and requests information on the situation. MV Danita recovers control and informs VTMon.
- FV IJm8 Rony is inside OWF Nederwiek Zuid. 8 minutes later VTMon request intentions of FV IJm8 Rony and informs that the vessel is not allowed in the OWF.

SBP

- SBP contacts OS1 and requests position, speed and heading. OS1 is to maintain heading and course
- SBP requests OS1 to change heading to 236, then 233 and afterwards 255.
- SBP is notified by OS1 that they follow captain's navigational orders.
- SBP requests OS1 to change heading to 250 to avoid vessel Blue Snapper.
- Vessel Tantalus requests pilotage.

(Full restart of the scenario)

- OS1 informs SBP on heading and speed
- MV Tantalus requests pilotage. SBP requests Tantalus to maintain current heading and speed.
- SBP requests OS1 to change heading to 250 and pass astern of FV Blue Snapper.
- SBP requests OS1 to stay inside the TSS.
- MV Hoeg Car requests pilotage. SBP requests position, speed, heading and destination of MV Hoeg Car. SBP request MV Hoeg Car to maintain heading and speed.
- SBP contacts FV Ameer to request intentions in regard to OS1.
- SBP requests MV Hoeg Car to change heading to 315.
- SBP requests MV Tantalus to change heading to 000
- SBP requests OS1 to change heading to 230.
- SBP requests intention of MV Lobelia that has CPA of 0 with piloted MV Hoeg car. MV Lobelia confirms to pass astern of MV Hoeg Car. SBP confirms with MV Hoeg car that MV Lobelia will pass them astern.
- SBP requests MV Tantalus to change heading to 015 and afterwards to 035.

- SBP contacts OS1 on FV Mahones speeding up to 12 kts and is on course to meet OS1. OS1 is requested to slow down.
- SBP requests OS1 to change heading to 215.

Scenario 2.2: ERTV guidance

Crew RoRo vessel (OS1)

- OS1 overtakes cruise ship without further interaction.
- OS1 notices and monitors the fishing vessel coming from starboard side.
- OS1 and ERTV communicate on position and course
- OS1 notice fishing vessel on perpendicular course to TSS. No action required from OS1.
- OS1 experience a blackout caused by an engine defect.
- OS1 contacts the ERTV to inform them on their situation and requests for assistance. ERTV proceeds towards OS1.
- ERTV approaches OS1 and prepares to make a tow. End of scenario.

The following research questions and answers are related to the crew of the RoRo vessel.

Research question 1: What is the difference in performance of the sailing task between experienced and inexperienced crew?

The answer to this question reflects the performance of the RoRo crews that operated during scenario 2.1, which included the SBP and VTMon. The crew from scenario 2.2, which involved ERTV guidance and excluded SBP and VTMon, differed too much in context and is therefore not considered in this research question.

Debriefing

The SBP was viewed differently by both crews. The experienced second officer found it useful, but the captain saw no added value given the familiarity with the area. The inexperienced crew were initially sceptical after a misidentification incident but gradually regained trust and used the SBP's advice. The captain noted the value of local knowledge but also cited cost as a reason to avoid using pilots in practice.

Observations

Both crews performed the sailing task effectively without noteworthy incidents caused by the crew itself. The experienced crew occasionally had to focus on unpredictable traffic during night-time, while the inexperienced captain found the situation more manageable than in earlier scenarios.

Reflection report

In general, no notable differences were reported between the groups regarding the perceived difficulty of navigating through or near offshore wind farms. With the exception of the experienced captain, who rated the task as very easy, all other participants reported a neutral experience. Reported stress levels were low across both groups and particularly low for the experienced captain. Perceptions of traffic density followed a similar pattern. While the inexperienced captain expressed some hesitation in decision-making, the experienced captain appeared confident throughout.

RSME

The RSME results show higher reported mental effort for the second officer and helmsman of the experienced crew, while these roles reported lower scores in the inexperienced group. This outcome is unexpected, as the inverse was anticipated, with the experienced crew presumed to be less mentally challenged by the scenario. No clear explanation for this discrepancy is available. What can be observed is that mental effort remained generally stable, with only minor peaks. However, sustained scores near 100 over extended periods are considered undesirable (figure 25).

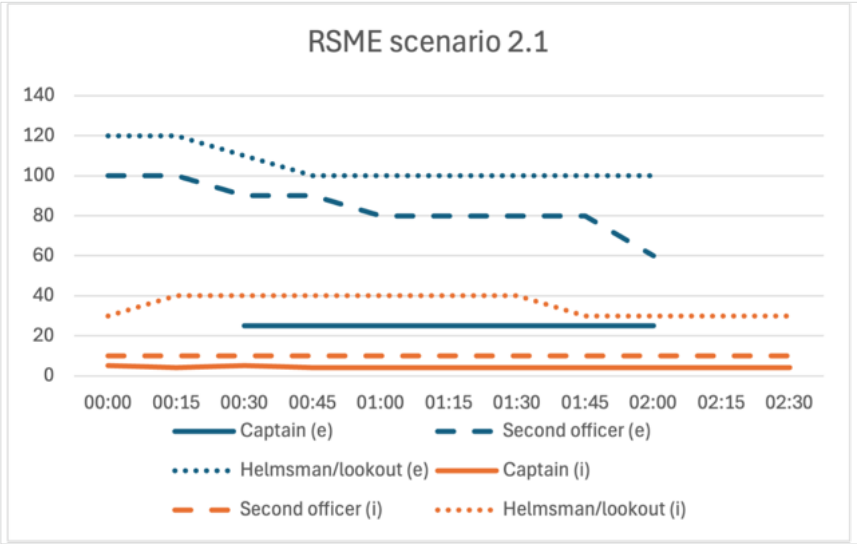


Figure 25. Graph showing mental effort scores over the course of scenario 2.1, broken down by role for the inexperienced crew.

The data from the simulation data did not yield relevant insights for answering the research question and was therefore not included in this section.

Research question 2: What is the effect of SBP deployment on the crew's sailing task?

Debriefing

The experienced RoRo crew gave mixed responses regarding the impact of the SBP on their sailing task during the debriefing. The OOW (second officer) described the SBP as "very useful," noting that the pilot's specific knowledge of the area helped in advising on optimal course and speed. In contrast, the captain stated that the SBP was unnecessary, as he believed the crew already had sufficient experience in the area. In a real situation, the captain would not have requested SBP support.

The inexperienced crew generally rated their experience with the SBP and its influence on their sailing task as mostly positive. The captain reported having had negative experiences with pilots in real-life situations and expressed difficulty fully trusting them. This was reinforced at the start of the scenario when the SBP mistakenly identified the RoRo vessel, nearly causing a collision. This incident caused the captain to seriously question the SBP's reliability. However, as the scenario progressed, trust was gradually restored, and the captain began using the SBP's navigational advice. The captain noted generally preferring to use an SBP when navigating in unfamiliar areas, as the local knowledge is valuable and offers the crew an opportunity to rest. Still, the captain acknowledged that the financial cost of using a pilot is often a reason not to do so in practice. In that context, a remote pilot could be a beneficial alternative. The second officer added that the SBP was helpful at times, particularly in advising on nearby vessels requiring attention.

Observations

Observations generally indicated that the SBP functioned as an additional or alternative set of eyes to support the RoRo crew in their sailing task. By advising on course and speed, monitoring potentially hazardous situations, and coordinating with other vessels to arrange safe passing, the SBP demonstrated the ability to reduce the crew's workload.

However, sufficient training with support tooling is required.

Reflection reports

In the reflection report, the experienced captain noted that SBP support can serve as an additional assurance when navigating in unfamiliar waters. On the other hand, the inexperienced second officer reported that it can also be confusing, referring to the earlier incident in which the SBP misidentified vessels and provided incorrect advice.

RSME

Both the experienced and inexperienced crew expressed a high level of appreciation for the SBP's support. The score given by the inexperienced second officer was slightly lower, which was attributed to a suboptimal piece of advice caused by a misinterpretation of the vessel's position by the SBP, see figure 26.

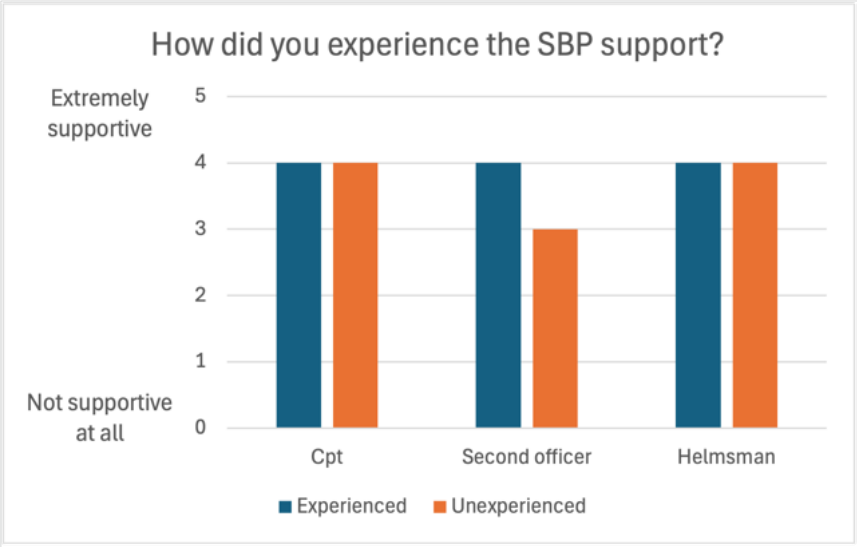


Figure 26. Graph showing the RoRo vessel crew members' perceived level of support from the SBP during the scenario.

The data from the simulation data did not yield relevant insights for answering the research question and was therefore not included in this section.

Research question 3: What is the effect on the crew of the RoRo vessel when escorted by the ERTV?

The answer to this question reflects the performance of the RoRo crew that operated during scenario 2.2, which involved ERTV guidance and excluded the SBP and VTMon.

Debriefing

The overall effect of ERTV guidance was a reduction in stress for the crew, primarily due to the reassurance provided by having the ERTV available in case of a blackout. The crew reported increased alertness throughout the scenario, as they had been informed that their vessel had experienced multiple blackouts in the past, making them more conscious on the possibility of having a blackout during the simulation.

During the blackout event, the availability of the ERTV led the crew to deviate from their standard procedural sequence. Instead of first contacting the engine room for a situation report, the crew immediately informed the ERTV of the blackout as both crew members were convinced it was a blackout caused by engine problems. They also chose to contact the ERTV before notifying the coast guard, focusing first on managing the immediate collision risk with a nearby vessel.

Dropping anchor was not considered a preferred response, as the risk of drifting remained and the presence of a nearby offshore wind farm further limited this option.

Observations

Observations during the scenario indicated that few high demand events occurred, resulting in a relatively low operational workload for the crew. It was observed that the crew maintained visual awareness of the ERTV and engaged in periodic radio contact. When engine problems arose, the observed response sequence began with immediate contact to the ERTV, followed by communication with surrounding vessels to issue a warning.

Reflection reports

The reflection reports indicated that the crew found navigation near the wind farms to be challenging. They described the overall traffic density as neutral, with some activity but not to a degree they considered crowded. The crew reported that they were able to maintain good situational awareness and expressed confidence in the decisions they made. Both external and internal communication were evaluated positively.

RSME

The mental effort was scored below 'considerable effort' for both crew members. Except for the end, when the engine broke down and a blackout occurred. There were individual differences between the crew members: the captain's scores were higher than the second officer, see figure 27.

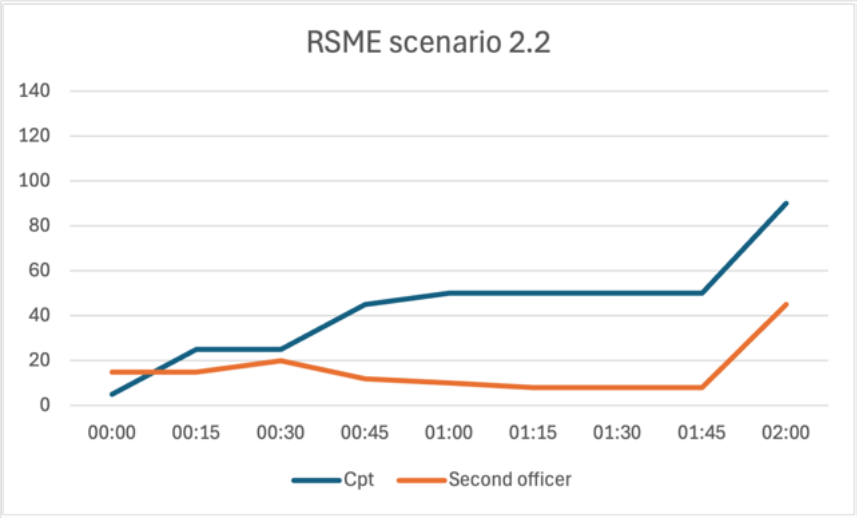


Figure 27. Graph showing mental effort scores over the course of scenario 2.2, broken down by role for the RoRo crew.

Simulation data

Simulation data shows that at the moment of the blackout, the RoRo vessel (OS1) is 2.48Nm away from OWF HKW kavel VII see figure 28.

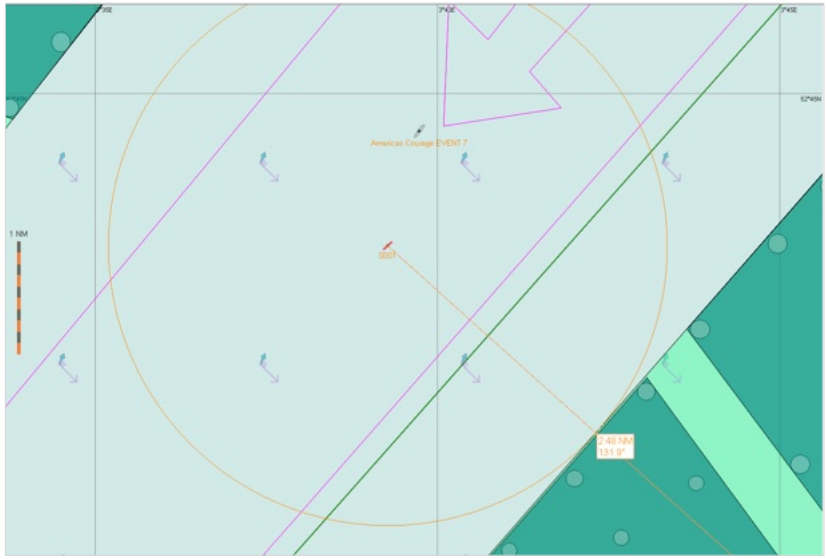


Figure 28. The distance between OS1 and the nearest OWF at the moment OS1 experienced a blackout.

At the moment of blackout the ERTV was positioned northwest of OS1 at a distance of 2.53 nautical miles. At a speed of approximately 10 knots, it would have taken the ERTV around 15 minutes to reach OS1 and begin the towing procedure. Given the prevailing weather conditions, with wind at force 7 from the northwest and a current of 1.5 knots from the east-northeast, OS1 would have remained inside of the TSS without facing any immediate danger.

Research question 4: What effect does the increase in crossing/entry/exiting traffic have on the situational awareness and decision-making from the crews?

Debriefing

The experienced crew reported that they occasionally had to focus on the traffic that sometimes acted unpredictably. The nighttime condition, obstructing clear sight, made this more challenging.

The inexperienced captain reported that the traffic was more manageable then during the first scenario, when they experienced denser traffic.

Reflection reports

In response to the question, "*How did you experience the amount of traffic in the scenario?"*, the crew generally answered it to be '*neutral'* with the exception of the experienced captain that rated it as '*never too crowded'*.

Additionally, on the question "*In general, how did you experience navigating through or near the wind farmss?"* the crew reported it to be '*neutral'* apart from the experienced captain that scored '*very easy'*.

Simulation data

Simulation data generally showed no close interactions between OS1 and other vessels during the scenario. In most cases, the distance between OS1 and nearby vessels remained at or above 1 nautical mile. An exception occurred at the beginning of the simulation run with the inexperienced crew, when the SBP mistakenly identified a nearby vessel as OS1. This resulted in incorrect navigational advice that could have led to a near collision, had the captain of OS1 not intervened.

The data from observations and RSME did not yield relevant insights for answering the research question and were therefore not included in this section.

Research question 5: Does the SBP have enough available support tooling to perform the pilotage task? If not, what is missing?

Debriefing

The SBPs required time to become familiar with the Kongsberg support tooling. The limited training and introduction time prior to the scenario negatively influenced performance, particularly in the initial phase. In addition, the SBPs were unfamiliar with the 2030 scenario environment and needed time to adapt to the new offshore wind farms and their associated names.

Overall, both SBPs evaluated the support tool positively. The tool gave a good overview and had promising functionality. However, they noted that effective use of such a system requires tailoring to the user's operational needs. During the scenario, the SBPs experienced distractions due to irrelevant alarms and identified missing functionality, such as the inability to view a vessel's heading when hovering over it. This feature would support quicker and more precise navigational guidance for piloted vessels.

A further limitation of remote pilotage observed during the simulation was the delay in information updates. Changes in vessel speed and direction were not immediately visible, which impacted situational responsiveness.

While remote pilotage presents a viable and potentially more cost effective alternative, potentially encouraging more captains to opt for pilot support, the SBPs also highlighted a limitation. Remote guidance is not considered feasible for vessels with crews who do not speak English or have limited English proficiency. In such cases, piloting would need to take place from the bridge to ensure effective communication.

Observations

During the scenario, one SBP provided several reflections on the SBP role, which were observed and noted as part of the evaluation:

- The SBP remarked that there were four vessels in the area, each making navigational decisions independently from their own perspective. These decisions could conflict with one another and suggested that it would be more effective to have a single decision maker coordinating the overall traffic situation.
- It was observed that the SBP encountered limitations with the alarm list functionality. Specifically, the SBP noted that once an alarm disappeared, it was no longer possible to trace it back to the corresponding vessel, which hindered situational awareness.
- The SBP commented on the high volume of information displayed on the screen, stating that processing this information effectively required skill and familiarity with the system.

Throughout the scenario, the SBP was observed actively experimenting with various functions of the support tooling in order to become more familiar with its capabilities and improve operational effectiveness.

Reflection reports

In response to the question, "*How would you describe the available support tools to perform your role*?", the SBPs responded positively, describing the tools as either "*completely sufficient*" or "*mostly sufficient*."

The main functionalities used in task execution included panning and zooming for on-screen navigation, calculating TCPA and CPA values between vessels with a focus on the piloted vessel, and highlighting the piloted vessel on the screen.

The SBPs identified several functionalities as essential for effective task performance. These included panning and zooming, CPA and TCPA calculations between vessels, indication of vessel bearing and heading, and access to information such as vessel name, course, speed, destination, length, and draught.

No critical functionalities were reported as missing in the support tooling. However, the SBPs noted that more time to familiarise themselves with the system would have further improved their ability to perform the task.

RSME

The RSME scores for experienced mental effort among the SBPs ranged between *'some effort'* and *'considerable effort'*. Only minor peaks in reported mental workload were observed, and there were no further indications that the SBPs were mentally overloaded during the simulation runs. See figure 29 for the SBPs RSME score throughout the scenario.

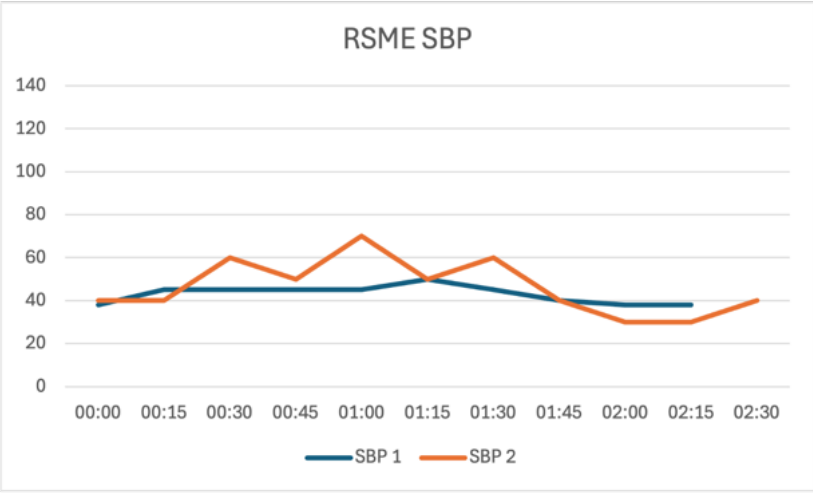


Figure 29. Graph on reported mental effort (RSME scores) for the SBPs during the simulation runs.

The data from the simulation data did not yield relevant insights for answering the research question and was therefore not included in this section.

Research question 6: How many vessels can a SBP guide at the same time?

Debriefing

Both SBPs independently provided input on the number of vessels they felt could be safely piloted simultaneously under the traffic conditions observed in the scenario. One SBP reported feeling comfortable piloting up to four vessels, provided that each vessel could be monitored on a dedicated screen. Adding a fifth vessel might be feasible once the SBP is fully familiar with the support tooling. The other SBP advised a strict maximum of five vessels, under the condition that the SBP is both experienced in the role and well-acquainted with the support tools.

Observations

During the simulation runs, both SBPs piloted up to three vessels simultaneously. It was occasionally observed that some VHF communication between the SBP and the vessel crew was missed by one of the parties. This was attributed to overlapping transmissions of VHF communication between other vessels. These instances did not result in operational issues, as the missed messages were promptly repeated by either the SBP or the crew.

Reflection reports

In response to the question, “How many vessels can an SBP guide at the same time at most?”, one SBP indicated a maximum of three to four vessels, depending on the number of available screens. The other SBP reported a maximum of five vessels, also conditional on having sufficient screen availability for monitoring each vessel.

One of the SBPs noted the importance of having a clear procedure for initiating communication with other vessels. This is particularly relevant when a single SBP is piloting multiple vessels, as using the same voice for several ships may cause confusion if proper identification protocols are not in place.

RSME

Figure 29 shows no clear differences in experienced mental effort when adding vessels for pilotage for the SBP.

The data from the simulation data did not yield relevant insights for answering the research question and was therefore not included in this section.

Research question 7: Are current supporting tools adequate to carry out the VTMon task? If not what is missing?

Debriefing

The VTMons reported overall satisfaction with the support tooling. One of the VTMons had also participated in the initial simulator study conducted the previous year, during which an improvised VTMon support tool was used. In comparison, the VTMon stated that the smart support tooling provided greater confidence in monitoring a larger area and contributed to improved performance. One VTMon noted that using larger monitors than the current three 27 inch screens would help improve visibility and spatial awareness.

Both VTMons agreed that implementing a comprehensive system like the support tooling requires effective alarm management. This includes the need for predefined alarm criteria and the avoidance of alarm overload, which could lead to alarm fatigue. Examples of important alarm criteria mentioned were alarms triggered when vessels are in close proximity to an offshore wind farm or when a vessel exceeds the maximum permitted length for navigating a clearway within an OWF.

In general, both VTMons considered the support tooling to be sufficient in terms of functionality and usability. However, they emphasised that such systems must be properly configured to match the user's operational tasks. Furthermore, they stressed the importance of sufficient training and hands-on practice to use the system efficiently. Due to time constraints within the scope of this study, such training could not be fully realised.

Observations

Observations during the scenario indicated that, with the current configuration of the support tooling, the VTMon operators were able to efficiently perform several safety critical tasks, including:

- Monitoring vessels with a drifting anchor
- Monitoring vessels operating outside the TSS
- Identifying vessels that were NUC
- Advising vessels to avoid hazardous areas, such as those affected by an NUC situation
- Estimating ERTV arrival times in emergency situations
- Issuing timely warnings in cases of close CPA or TCPA between vessels.

However, the current system setup showed limitations in the identification of certain risk situations. The VTMons were either unable or only partially able to detect the following:

- Vessels entering an offshore wind farm undetected, primarily due to alarm criteria not being properly configured around OWF boundaries
- Vessels without AIS passingand exceeding maximum dimensions (LOA to big) passing through OWF passageways unnoticed.
- Vessels becoming NUC outside of the range of the support tooling area.

These observations suggest that while the smart support tooling supports a wide range of safety enhancing tasks, proper configuration of alarm settings is essential. Without well-defined alarm criteria, critical risks such as unauthorised entry into OWFs may go unnoticed, posing a serious threat to ship safety and the OWFs.

Reflection reports

In response to the question, *“How would you describe the available support tools to perform your role?”*, the VTMon responded positively, describing the tools as either "*completely sufficient*" or "*neutral*." The neutral rating was attributed to limited training time with the support tooling.

The functionalities most frequently used by the VTMon included CPA and TCPA estimation, zooming and panning, accessing vessel information such as speed and draught, and the use of available alarms.

One specific functionality reported as lacking during the scenario was a bow passage measurement tool. The VTMon noted that such a tool would support the assessment of potential collision risks between vessels. Additionally, VHF communication was carried out using hand-held devices, which was considered suboptimal for effective communication.

Eye tracking

Eye tracking data indicated that the VTMon focused primarily on specific areas where scenario events occurred, while other parts of the monitoring area received little to no attention. Figure 30 illustrates this pattern. In the example, a vessel was navigating through the corridor of OWF Borssele, where passage was not permitted due to the vessel’s dimensions (red circle). The operator’s gaze (represented by red spots) was concentrated on the area surrounding the events involving OS1.

Further analysis of the camera recordings revealed that the operator had adjusted the system settings in such a way that OWF Borssele was no longer visible on the display (figure 31). This suggests that effective monitoring depends not only on operator awareness but also on ensuring that system settings are appropriately configured to include all relevant areas.



Figure 30. A heatmap on the VTMons gaze during part of the scenario. The orange circle shows a risky situation and the heatmap indication show the area where the VTMon was focused on.



Figure 31. Custom setup of the support tooling by the active VTMon. This custom setup does not include OWF Borssele.

Simulation data

On multiple occasions events occurred in which the VTMon did not notice or noticed a dangerous situation late. Examples of these are:

- Motortanker *Exmouth* (200 LOA) inside of an OWF and 0.13 Nm away from the closest wind turbine, unnoticed by the VTMon (figure 32).

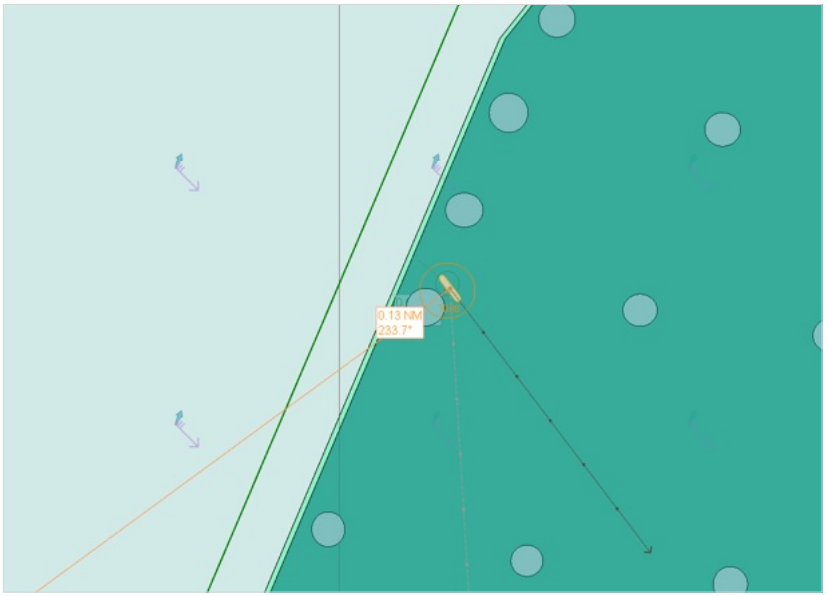


Figure 32. Motortanker Exmouth inside of an OWF, unnoticed by the VTMon.

- Fishing vessel *IJMS Rony* inside of OWF Nederwiek Zuid before getting warned by the VTMon that the OWF is a restricted area (figure 33).

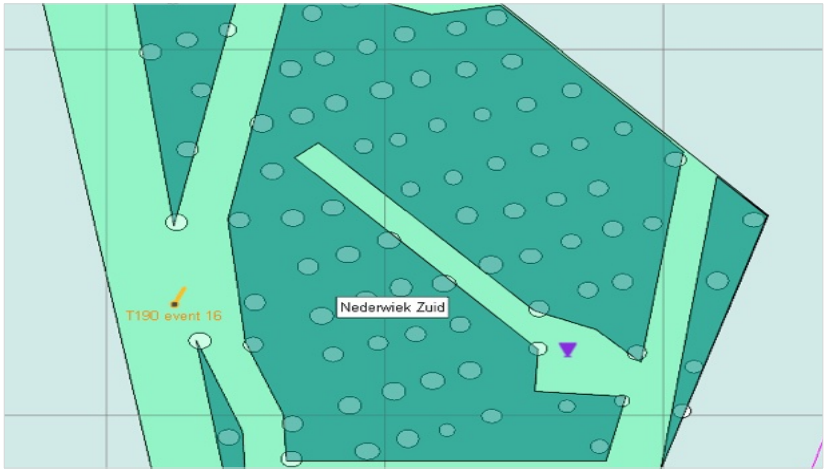


Figure 33. Fishing vessel IJMS Rony inside of OWF Nederwiek Zuid.

- The vessel Elisa, operating without an AIS signal, passed through the transit passage of OWF HKZ unnoticed, despite its dimensions exceeding the limits allowed for entry into the clearway (figure 34).



Figure 34. Motorvessel Elisa, passing through the transit passage of OWF HKZ.

- The vessel *Rigel*, operating without an AIS signal, passed through the corridor of OWF Borssele unnoticed, despite its dimensions exceeding the limits allowed for entry into the corridor (figure 35).



Figure 35. Motorvessel Rigel, passing through the transit passage of OWF Borssele.

The data from the RSME did not yield relevant insights for answering the research question and was therefore not included in this section.

Research question 8: Is the span of control for the VTMon in this specific scenario acceptable, given the available supporting tools?

Debriefing

The two VTMon operators expressed differing views on their ability to monitor the entire Dutch North Sea area. One VTMon concluded that the area was too large to maintain sufficient situational awareness, particularly given the limited training time and level of familiarity with the support tooling. In contrast, the other VTMon reported feeling capable of monitoring the assigned area effectively and stated that no noteworthy events were missed. However, observations showed that several relevant events were in fact overlooked.

Both VTMons agreed that, based on the demands of the task, a single shift should not exceed two hours without a break or a change to a different task. In response to the question of whether and how the Dutch North Sea area should be subdivided, the VTMon who found the area too large, advised dividing it into three to four separate sectors.

Observations

During the simulation runs, both VTMons failed to detect several risk related events. These included the unauthorised use of OWF passageways by vessels exceeding permitted length limits, as well as vessels entering offshore wind farms undetected and passing in close proximity to wind turbines (see 'Simulation data' on page 45-46). These incidents occurred without any warnings from the support tooling, suggesting that, in the absence of a properly configured system, the VTMon is not able to effectively monitor the entire Dutch North Sea area.

Reflection reports

On the question "How stressful did you experience playing this role?" both VTMon reported "neutral". Situations rated as most stressful were not knowing the exact location names (due to areas being new as the simulation ran the 2030 situation), using a new support tool, no bow passage measurement possible, very thick radar echoes, a too large area to monitor and occasionally multiple alarms (three) going off.

On the question "*How much were you aware about what was happening around you?*" both VTMon reported "*Mostly aware*".

Additionally, on the question "Were you able to identify potential hazards during the simulation?" VTMons responded with "Yes, almost always" and "Neutral".

RSME

The RSME scores of the VTMon generally show scores ranging between "some effort" and "considerable effort". On one occasion a short and relatively small peak showed scores of "high effort". These RSME scores imply no indications that the VTMons were mentally overloaded during the simulation runs. See figure 36 for the VTMons RSME score throughout the scenario.

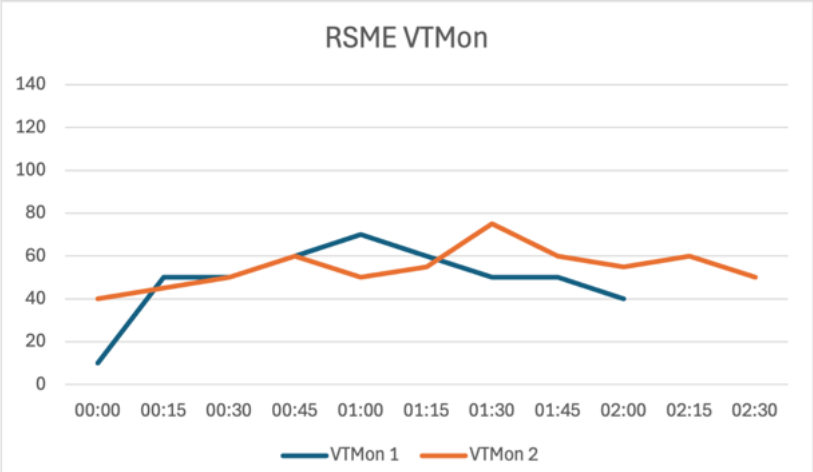


Figure 36. Graph on reported mental effort (RSME scores) for the VTMon operators during the simulation runs.

Simulation data

See *'Simulation data'* on page 45-46 for multiple missed events by the VTMon



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