CHAPTER 7 - Making the Case: Simulators for Offshore Renewable Energy Installations Navigational Risk Assessment

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Résumé : *Dans l'analyse qui suit, les auteurs examinent si et comment les simulateurs de manutention des navires peuvent être utilisés pour compléter les études d'évaluation des risques de navigation existantes (NRA) - en particulier celles concernant les installations d'énergie renouvelable offshore (OREI). Afin d'atteindre leur but, ils ont mené une étude pilote expérimentale qui a permis d'observer, d'évaluer et de quantifier le comportement de la navigation à proximité d'un parc éolien offshore (OWF). Par la suite, ils examinent les paramètres typiques qui sont également identifiés dans les modèles et les méthodes existantes de l'NRA. En outre, ils suggèrent des façons possibles de tirer profit des exercices de simulation dans le but d'améliorer la quantification de ces paramètres. Enfin, ils ont inclus une discussion sur la façon dont les simulateurs peuvent être utilisés pour compléter les ateliers traditionnels des parties prenantes dans le cadre de la notion visant à optimiser davantage l'utilisation de l'espace maritime limité.*

***Abstract**: In the analysis at hand, the authors consider if, and how, ship handling simulators can be used to feasibly augment existing navigational risk assessment (NRA) studies – particularly those concerning offshore renewable energy installations (OREIs). In order to achieve their aim, they have conducted an experimental pilot study that allowed them to observe, assess and quantify navigational behaviour in the vicinity of an offshore wind farm (OWF). The authors also suggest how simulators can be used to improve the quantification of various parameters that are used in existing NRA models and methods. Lastly, they discuss how simulators can be used to augment traditional stakeholder 'workshops' to further optimise the use of limited sea-space.*

1. Background

In recent years, governments, and organisations such as the European Union (EU) and the United Nations (UN), have advocated for an increase in renewable energy use (UNCTAD 2016). One of the most attractive schemes in this domain is wind energy. As the demand for wind energy grows, it has become necessary to build more wind-farms, with an increasing number being built offshore.

OWFs offer several advantages over their onshore equivalents (Mehdi et al., 2016). There is better wind resource, and the wind speeds are more consistent at sea. Wind turbines can also potentially be scaled-up to much greater sizes than would be possible onshore, leading to increased and efficient energy generation. OWFs can be constructed close enough to heavily populated shores to reduce energy transport cost, and yet be distant enough not to cause visual and noise pollution. These are the factors which have primarily led to an increased exploitation of marine areas for wind energy generation – and the surge of interest in '*blue-growth*' activities.

There are, however, certain drawbacks of OWFs that also need to be taken into account. These drawbacks include difficult conditions for construction and maintenance, limitations in deep water installation technology, and impacts on the marine environment and maritime operations.

The issues mentioned above are often seen as barriers and limitations to larger scale offshore wind farm growth. To address these issues, the European Commission (EC) has initiated several research projects, including MARE-WINT. This project aims to "reduce [the] cost of energy by improving reliability of wind turbines and their components and optimising operation and maintenance (OandM) strategies".

A major concern to be addressed by the MARE-WINT is the impact that OWFs have on any vessel operations in the vicinity. Maritime accidents near OWFs generally lead to a shut-down, which leads to inefficient energy production to control and manage the risk of the developing situation. This, of course, has an impact on the availability – and by extension, the reliability – of an offshore wind farm. Similarly, in cases of vessel-turbine collisions, the damage to turbines can be substantial; the downtime and maintenance cost of a severely damaged wind turbine is not something a wind farm owner would like to incur. Reducing the risk to maritime operations is a vital step towards meeting the overall aim of more efficient energy production.

As the number of OWFs increases, however, such accidents may become unavoidable. A wind farm leads to more obstructions in the water for ships to avoid; the presence of a wind farm near a shipping lane effectively narrows the area in which vessels can operate, therefore increasing the traffic density. There is also, of course, an increased risk of accidents due to the increased maritime traffic as a result of activities related to offshore wind farms. Thus, the presence of wind turbines, near ports and shipping routes, may lead to an increased risk of navigational accidents – such as contact between turbines and vessels, collision between vessels, and grounding of vessels – all with potentially serious consequences. While operating, wind turbines may also cause problems with a ship's on-board navigation equipment. The potential accidents that maritime operations face due to offshore wind farms can be classified into 5 different categories, as found in literature (Mehdi and Schröder-Hinrichs 2016):

- Navigational accidents involving passing vessels (Powered and Drifting).
- Navigational accidents involving wind farm support vessels.
- Accidents during OWF installation and decommissioning operations.
- Accidents during emergency maritime operations such as SAR.
- Accidents in harbours and ports that deal with offshore activities.

It is important to reiterate that each of the 5 risk areas mentioned above can have potentially dire consequences for both the maritime and offshore wind industries. There are other maritime risks, as well, which can be associated with OWFs – risks to fishing vessels, for instance. This study, however, focuses solely on reducing accidents involving passing vessels near OWFs.

2. Problem Description

Despite the fact that maritime accidents in their vicinity have been largely avoided thus far, the mandate of various stakeholders with regards to renewable energy may soon lead to undesirable and unsafe scenarios for the shipping industry. Indeed, the continued, rapid diversification and increase in the number of offshore renewable energy installations (OREIs) is a source of growing apprehension for the maritime industry. To alleviate the concerns of stakeholders, the industry relies on the use of sophisticated risk assessment models, methods and frameworks. Although these existing tools are sophisticated and robust, 4 potential areas of improvements can nevertheless be identified through literature review and surveys (Mehdi and Schröder-Hinrichs 2016):

- Harmonisation of frameworks across different countries to improve transboundary planning.
- Developing integrated navigational risk and energy efficiency frameworks to balance the needs to both industries simultaneously.
- Improving stakeholder communication before, during and after navigational risk assessments (NRAs).
- Improving the quality of input data for existing frameworks and models, to reduce 'over-design' or 'under-design' for safety, and optimise use of limited sea space.

The current analysis aims to address the latter two areas of improvement in particular, which are explored in further detail in this section.

2.1 Improving the quality of input data for existing frameworks and models

Although the maritime industry has an abundance of experience when it comes to *established* offshore installations (e.g. oil platforms, bridges, floating docks, etc.), *emerging installations* (e.g. OREIs – wind, wave, tidal generators) are still fairly novel developments. Unquestionably, the knowledge, experience, models and methods used for NRAs around *established* installations are still applicable for the most part when it comes to OREIs; however, the *values* of the parameters used in existing models and methods may differ significantly when applied in the case of OREIs. Quantifying any *differences* in navigational behaviour parameters around *established* (e.g. oil platforms) and *emerging* (e.g. wind, tidal, waver generators) offshore installations is a challenge – particularly because data from the latter is quite sparse. The scarcity of the data is primarily due to the fact that OREIs have been around for 'only' around 25 years and have not reached the level of 'maturity' that other, established, installations have achieved. Furthermore, there are continual developments and improvements – floating offshore turbines, novel materials in wind, tidal, wave generators, trans-national energy farms, to name but a few – that need to be considered adequately during NRAs. In fact, one may even go so far as to argue that each OREI – even one which is in the same sea-area as another – is unique, and requires an updated quantification of input parameters, so that the navigational risks can be accurately modelled.

2.2 Improving stakeholder communication before, during and after NRAs

The other major concern to be addressed in the current work is that both energy policy makers, as well as operational-end stakeholders from the offshore renewable industry, are largely disconnected from the NRA process. This is despite the fact that energy and maritime stakeholders, including seafarers, are consulted before permission can be granted for OREIs. The 'disconnect' between stakeholders from different industries arises mainly due to the fact that people have different priorities and backgrounds. In traditional stakeholder workshops, there is always the risk that stakeholders from varying backgrounds may not be able to get their points across adequately to all other stakeholders. Furthermore, various stakeholders may not be able to adequately describe or comprehend the differences between base-case and future-case scenarios, without 'experiencing' the scenarios first-hand. This could lead to situations where decision-makers make generalised assumptions and propose generic solutions for very specific problems that may arise. Subsequently, this may cause OREIs to be either over-designed or under-designed for navigational safety, leading to inefficient and/or unsafe use of sea-space.

2.3 Proposed solution

To address the aforementioned research 'gaps', the present analysis puts forwards the use of simulation exercises. Previous authors have demonstrated the value of maritime simulation in the maritime teaching and learning process. Indicative examples include: Baldauf et al. (2011; 2016a; 2016b) and Benedict et al. (2013). Additionally, important work pertaining to simulator experimentation is observed in the rail transport industry, with the contributions from Naweed et al. (2013), and Dunn and Williamson (2012) standing out.

Simulators can also be used to create virtual 'future' scenarios that allow participants (seafarers as well as other stakeholders) to experience first-hand the conditions, dangers and hazards that maritime operations may face around OREIs; MARIN (Maritime Research Institute Netherlands), for example have conducted simulator trials to explore the effect of OWFs on ships' navigational equipment. Simulation trials by MARIN have also been used to recommend safe passing distances between shipping lanes and OWFs. The use of simulators to improve maritime safety and security has been demonstrated by Baldauf et al. (2016), amongst other authors. Simulation studies specifically for NRAs around OREIs, while rare, have been explored before by authors such as Ohlson (2013).

The authors hypothesise that by observing operational behaviour in a simulated environment, and by collecting feedback from exercise participants, they can gather data that can be used to improve and augment the input values for parameters used in various models and methods. They also hypothesise that simulator exercises can bridge the gap of information and expectations between all stakeholders involved, by allowing them to experience the scenarios first-hand. The authors anticipate that such exercises can also allow decision-makers to understand the specific problems associated with a proposed OWF area, and to propose specific, rather than generic, solutions that adequately address any potential concerns. In turn, this would then allow stakeholders to make potentially improved decisions about critical scenarios with a lower margin of error and uncertainty – and thus truly optimise the use of space in increasingly crowded marine environments.

3. Methodology

The primary aim of the current work, then, is to determine navigational behaviour around OWFs, and identify the type of data that can be measured using simulator exercises. To do so, a sea area around an OWF was created via simulation; then, the authors instructed groups of participants to sail near that installation as safely and efficiently as possible. As the participants sailed, the authors recorded the vessels' track and trajectory to determine their navigational behaviour in terms of CPAs (Closest Point of Approach), i.e. the safe passing distances they maintain to the offshore turbines.

3.1 The simulator

The study was carried out in the MaRiSa (Maritime Risk and System Safety) lab at the World Maritime University (WMU). Within this lab, there are several simulators including a ship-handling simulator. This latter simulator allows participants to 'experience' a scenario first-hand, by allowing them to sail a given vessel in a selected sea area with pre-determined maritime traffic and environmental conditions. Simulator instructors can choose to vary the ship-types, the ship traffic, environmental conditions (e.g. wind, waves and visibility), as well as physical features such as bathymetry, installations in the water, etc. In addition to this, simulator instructors may also choose to add, remove or modify features such as TSS (traffic separation scheme), buoys, markings and lights, tugs, etc. which can influence the navigational risk of a sea area. In some studies, the simulator instructors can also influence events on-board a ship, e.g. engine failure, fire-on-deck, etc., to explore the behaviour of participants in varying scenarios.

Several benefits have already been identified in relation to simulation training; the maritime industry already uses simulators for training in ship handling quite extensively. These simulators provide real time training on well-equipped bridges that strongly resemble modern ships. The simulator under discussion physically consists of a ship's bridge and contains all basic equipment required for ship-handling as specified by SOLAS (e.g. radar, AIS, rudder and engine controls, etc.), as shown in Fig. 1. In addition to the basic equipment, it is also possible for participants to communicate 'internally' with other areas on-board, e.g. the engine room, or 'externally' with shore-side users such as VTS (Vessel Traffic Service).

Fig. 1 – The ship handling simulator. Note the control panel between the two navigators' chairs. The three screens in the centre provide the 'outside' view as one would see from a ship realistically. On either side are 'equipment' screens showing the radar and AIS interfaces, amongst others.

In addition to the simulator, the lab also has additional facilities like a SenseFloor, which allow researchers to monitor the walking patterns of participants. SenseFloor can be used to monitor which equipment the participants look at under high-stress or risky situations. It can be combined with measurements from eye-tracking goggles to verify and validate findings. Other simulators in the MaRiSa lab include a ‘Safety and Security Trainer’ (Fig. 2), which allows participants to virtually explore a ship and deal with on-board issues, as well as a HECSALV damage stability simulator and a station for ship manoeuvring predictions.

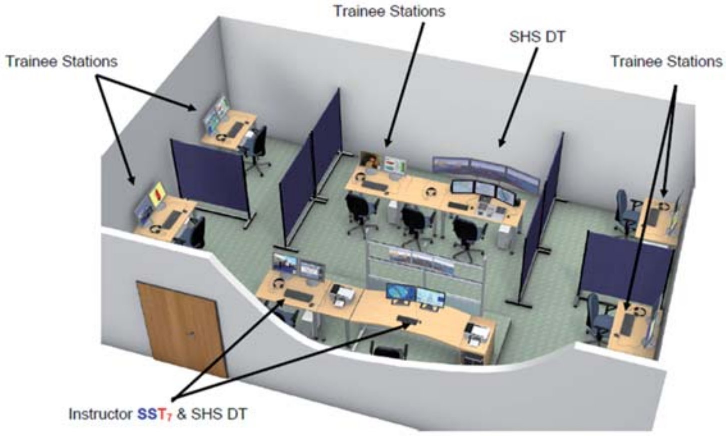

Fig. 2 – Configuration of the combined Ship-handling and Safety and Security Training Simulator

3.2 The sea area

For the current study, the researchers relied solely on the ship-handling simulator. The Öresund region between Malmö, Sweden and Copenhagen, Denmark, shown in Fig. 3, was chosen as a baseline for the simulated sea area.

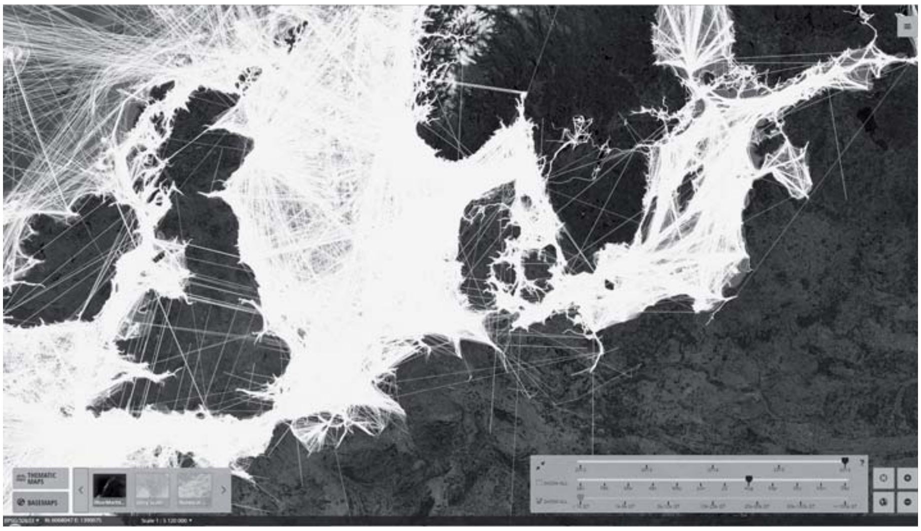

Fig. 3 – A map showing vessel tracks (white lines) in the North and Baltic Seas. Courtesy: havbase.no (maintained by *Kystverket* – the Norwegian Coastguard)

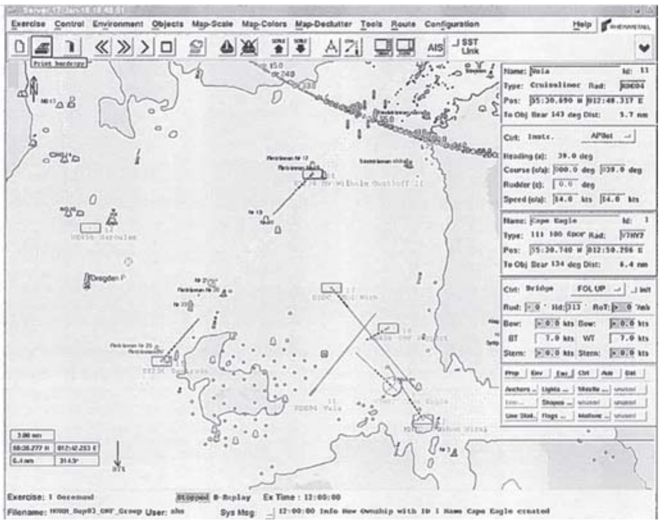

Fig. 4 – An electronic chart showing the studied sea-area in more detail. Note the small circles, denoting the turbines in the Lillgrund wind farm.

This area already has a medium-sized OWF, ‘Lillgrund’, with 48 wind turbines as shown in Fig. 4. The area has moderately high shipping traffic, and serves as an important entry/exit connecting the Baltic and North Seas. The region was chosen primarily due to the good availability of data pertaining to ship traffic and environmental conditions.

3.3 The scenario

Within the region, the authors created an artificial traffic scenario, albeit based on realistic data obtain via AIS (Automatic Identification System). AIS data allows one to visualise the vessel tracks and ship traffic distribution in a region and thus can be used to ascertain the types of ships, as well as the number of ship movements in a given sea area.

As mentioned earlier, the participants were instructed to sail as safely and efficiently as possible from Point A to B, as shown in Fig. 4. Whilst navigating, the participants were asked to resolve any risky navigational situations that may arise, involving either the other vessels (rectangles shown in Fig. 5), or the OWF.

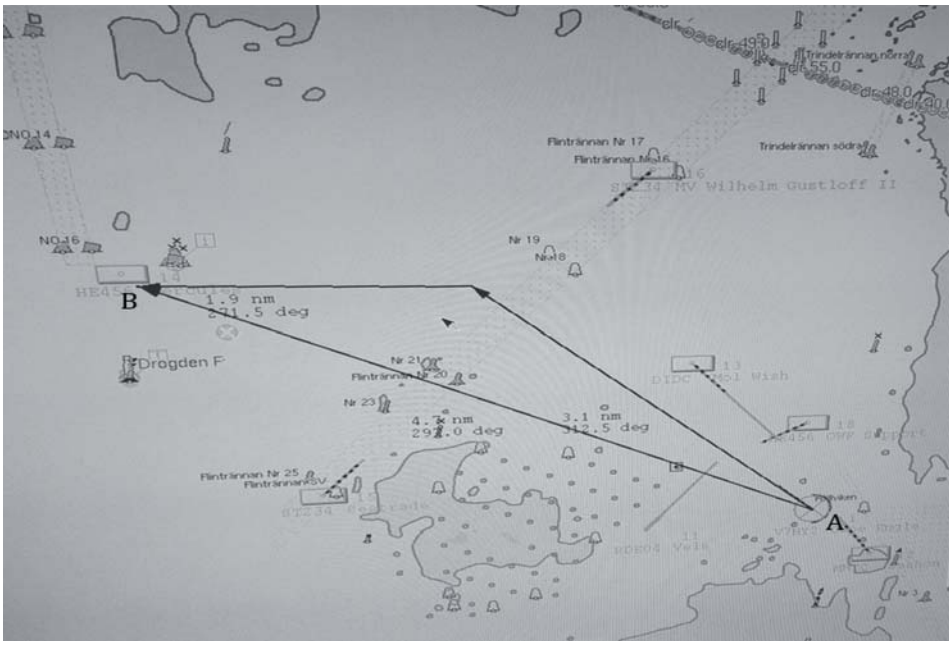

Fig. 5 – A map showing the scenario 'on-screen'. The 'own-vessel' is represented by an 'X' within a circle, shown at the initial position, 'A'. Participants were asked to reach 'B' as safely and efficiently as possible.

All participants were given the same 'own-ship' to sail: a small chemical tanker (L = 115.0m), with a maximum speed of 14 kts. Each participant encountered the same traffic scenario as shown in Fig. 5, with exactly the same vessel types and characteristics; all vessels apart from the one under the control of the participants were assigned pre-determined speed and course settings based on AIS records, and controlled by the simulator throughout the exercise. The other vessels did not react in any way to the participants' actions but were responsive to communications initiated by the participants.

As each group of participants sailed near the OWF, their progress was recorded. In particular, the authors were interested in measuring the safe-passing distances to the OWF, as this is a core indicator of safe/unsafe navigational behaviour. Fig. 5 shows an example of how the distance between a vessel and the nearest offshore turbine is measured by looking at the vessel track. The distance, x, is calculated as the perpendicular distance between the vessel, and the turbine closest to the vessel. In the case of Fig. 6, $x = 500$m.

Fig. 6 – Measuring the distance between a turbine and vessel.

3.4 The participants

The study observed 7 different groups of participants as they sailed near the OWF, with their performance shown in the figures that follow. Six (6) of those teams consisted of two (2) members each – a captain giving instructions, and a helmsman on the controls; one (1) group of participants consisted of four (4) members – a captain, helmsman, first officer, and second officer. The participants had diverse backgrounds and belonged to 12 different nationalities, with sea-faring experience ranging from three (3) to twenty-two (22) years at sea. It is important to reiterate that the focus of this study was not on the relationship between participant background and navigational behaviour. Rather, the focus was on determining navigational behaviour in general, to establish whether this information can feasibly be used to improve NRA models.

4. Results

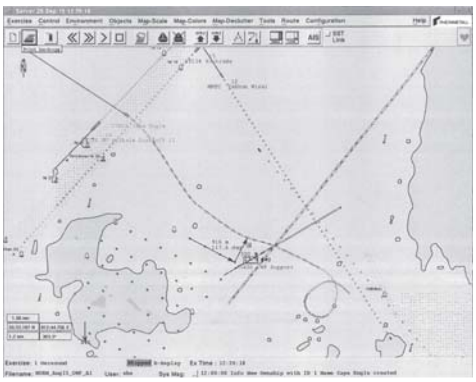

Fig. 7a – Overview of route taken by group A1

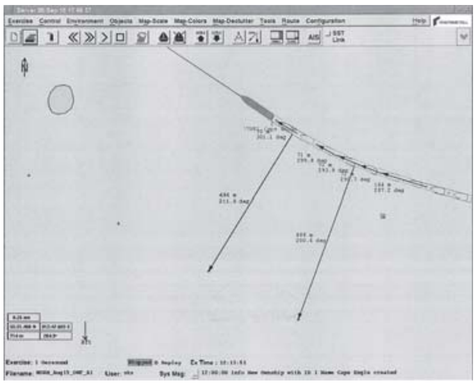

Fig. 7b – CPA to offshore wind farm for group A1

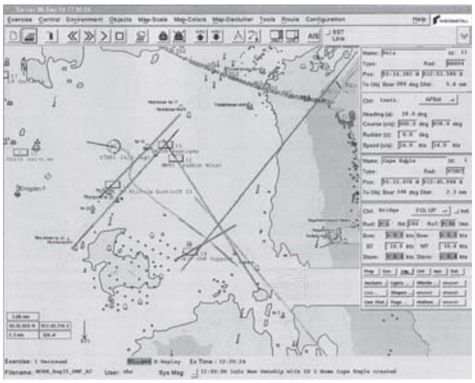

Fig.8a – Overview of route taken by group A2

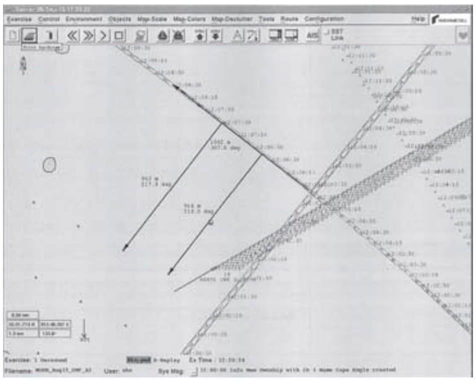

Fig. 8b – CPA to offshore wind farm for group A2

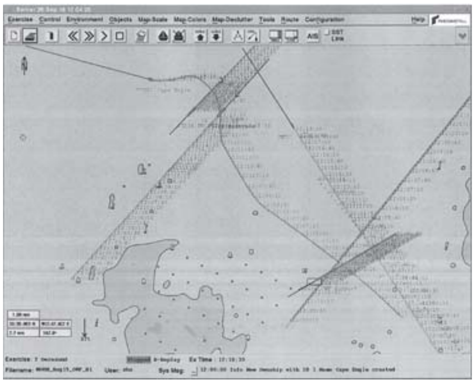

Fig. 9a – Overview of route taken by group B1

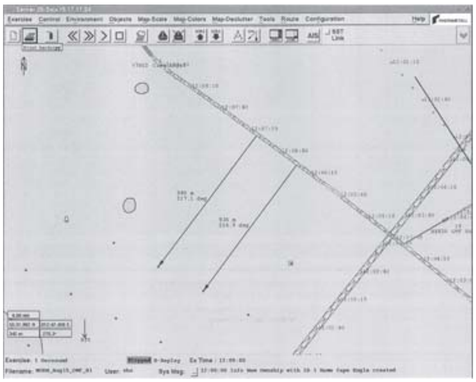

Fig. 9b – CPA to offshore wind farm for group B1

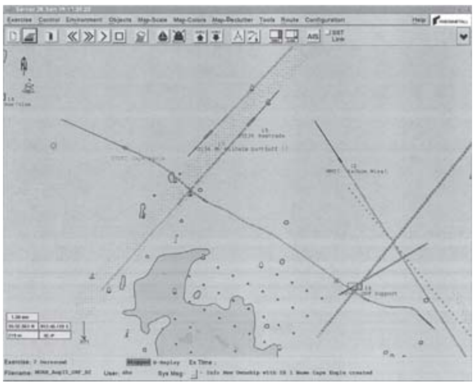

Fig. 10a – Overview of route taken by group B2

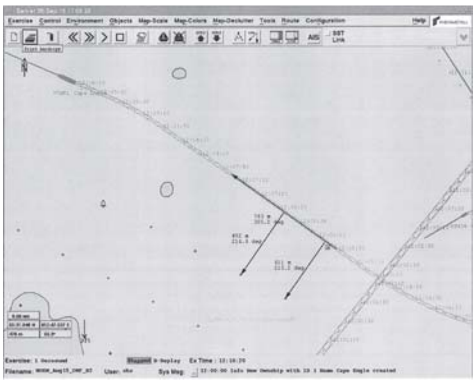

Fig. 10b – CPA to offshore wind farm for group B2

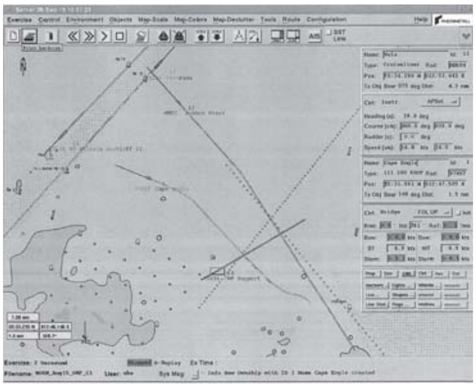

Fig. 11a – Overview of route taken by group C1

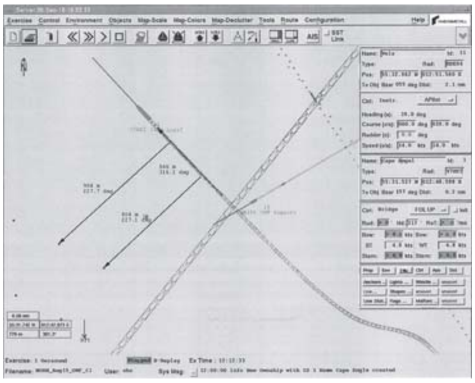

Fig. 11b – CPA to offshore wind farm for group C1

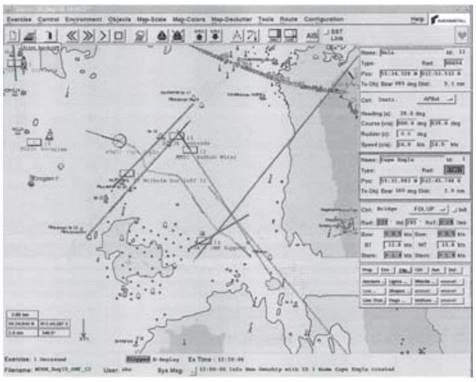

Fig. 12a – Overview of route taken by group C2

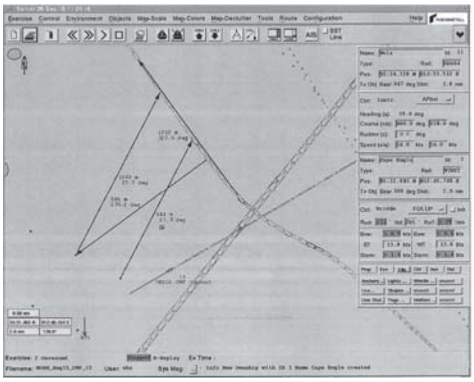

Fig. 12b – CPA to offshore wind farm for group C2

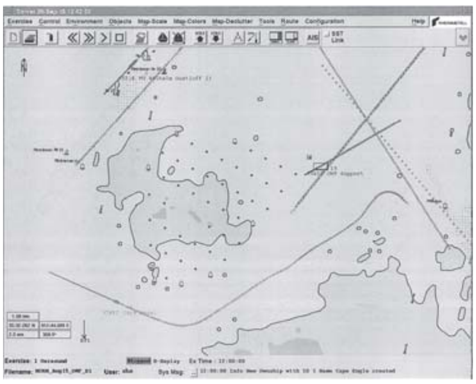

Fig. 13a – Overview of route taken by group D1

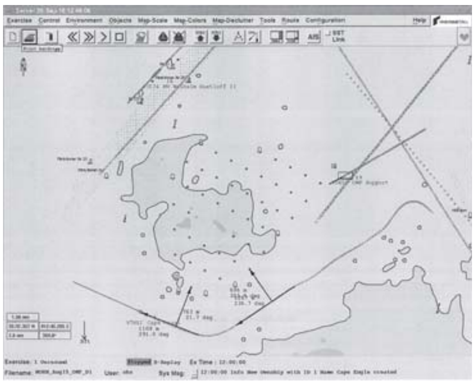

Fig. 13b – CPA to offshore wind farm for group D1

Table 1 – CPA (Closest Point of Approach) and CTW (Course Through Water) of each group whilst passing wind turbines.

Group	CPA to 1st OWT (m)	CTW (°)	CPA to 2nd OWT (m)	CTW (°)
A1	488	290	484	302
A2	914	308	963	308
B1	936	307	980	307
B2	411	305	452	305
C1	804	316	904	318
C2	854	323	986	328
D1	696	337	763	291
Average	729		790	
Range	525		534	

In general, the results indicate that seafarers may choose longer routes, instead of more direct tracks, to resolve high-risk encounter situations with other vessels. In other words, there is an apparent preference of safety over efficiency. This is evident particularly in the cases for groups A1 and D1: in group A1, the participants performed a 'full-circle' manoeuvre (Fig. 7a) to resolve the traffic situation before proceeding on-route to their destination, whilst group D1 took a long detour to the south to avoid the traffic altogether (Fig. 13a).

It is also interesting to note from both the exercise results, and the post-exercise discussion, that the participants prefer to maintain a larger CPA to the vessels than to the OWF. From the discussion in particular, it is evident that seafarers perceive a turbine-contact accident as a lower risk than a vessel-collision accident. This finding is reinforced by the observed results: none of the groups maintained a CPA of more than 1000m to the OWF, despite some participants taking extra precautions to avoid a *vessel-collision*. Indeed, several participants passed much closer to the wind turbines than anticipated – occasionally even at distances less than the UNCLOS mandated 500m limit,[1] as was the case for Group A1. The reasoning behind their preference to maintain a larger CPA to *other vessels* than to the OWF was two-fold:

- 'Easier to avoid a fixed-target than a moving target' – given the unpredictability of other human operators, and uncertainty about a vessel's manoeuvres, it is natural that the participants felt more apprehension towards the moving vessel rather than the fixed offshore turbines.
- The perception that a contact accident with an offshore turbine might have lower damage and consequences for the vessel than a collision or grounding accident was also a contributing factor leading to the preference to maintain a larger CPA to other vessels than to the OWF.

1) UNCLOS Art. 60(5). Source: Fink (2005).

Thus, whilst the participants were all aware of the 500m UNCLOS limit, many felt that without the intervention of shore-side stakeholders such VTS, or the provision of 'Notice to Mariners', they were not obliged to maintain this minimum distance in the prevailing traffic and environmental conditions. The participants explicitly stated that their priority was to avoid a vessel-collision accident, and for this, they may be willing to sacrifice some safety margin with regards to the OWF. That being said, participants also indicated that they would consider maintaining a larger CPA to the OWF if the conditions were different: for instance, bad weather, dangerous cargo on-board, larger ships or variations in vessel traffic may have convinced them to opt for an even longer detour, so that they could achieve a larger CPA to the OWF, whilst also maintaining adequate CPA to other vessels in the vicinity.

Lastly, although the current work does not explicitly explore this relationship, there seems to be no apparent correlation between experience and choice of 'safer' route. The more experienced seafarers were as likely to opt for a longer or shorter route as the less experienced participants. This, however, may be an inconclusive result arising from the fairly small sample size of only 7 participant groups.

5. Discussion

In existing NRA methods, vessel traffic distributions – obtained via AIS – are a core piece of information. Often, however, this AIS data is taken 'as is' instead of being modified for future-case scenarios. In other words, when an NRA is conducted, it is a general assumption that the vessel traffic distribution will not vary or shift *significantly* after an OREI is built. As seen from the results in this pilot study, that may not always be case, especially in heavy traffic scenarios. It is also noteworthy that participants approaching the OWF do not follow a uniform distribution (as is assumed in most NRAs), but vary significantly based on how they evaluate the risk of the scenario. The authors intend to validate this finding by evaluating AIS data for a sea-area before and after an OREI is installed. The authors assume that AIS data alone may give a good indication of ships' tracks but not provide much (if any) insight into situational contexts, e.g. with respect to visibility, communication and other factors. The present approach of using AIS data also lacks sufficient consideration of navigators' risk assessment.

Moreover, the lifecycle of OREIs also means that there may be an evolution in the types, sizes and physical characteristics of vessels operating in their vicinity as time passes. This factor, as well as many possible 'future' environmental variations, are often not taken into account during NRAs. By not considering such 'future-case' scenarios and developments, there is always the very real risk that an OREI may be over- or under-designed in terms of navigational safety. Simulator observations have a significant potential to rectify these drawbacks: the results can be used in conjunction with AIS data, for instance, to improve predictions of vessel traffic distribution patterns and safe-passing distances under varying future case scenarios and environmental conditions.

Simulators also provide for an added level of information to augment existing NRA models: the relationship between various different parameters can also be proactively explored in more detail than is possible using traditional methods. For instance, if a user wants to determine the effect that a TSS or a VTS has on navigational behaviour around an OREI, they could either rely on past-data pertaining to unrelated systems (e.g. oil rigs) or they could conduct a simulator study, which would provide them with more accurate and applicable data. Even more complex behaviour, such as human-machine interaction, the usability of equipment to avoid navigational risks around OREIs etc., can be studied feasibly in a simulator. This information can, in turn, be used to better quantify the parameters in existing NRA methods and models.

As demonstrated in the current work, simulators also provide a good platform to gather opinions from operational end-users. Seafarers, having 'experienced' the scenarios first-hand, are able to provide more directed feedback than would perhaps be possible through a traditional stakeholder study. As a result, the use of simulation exercises can be used to quantify seafarers' opinions and behaviours in various different scenarios. The feedback from simulation studies can also be used to better design and select feasible risk-control options around an OREI including investigating and even optimising their potential impacts.

Following the improved quantification of parameters, and the implementation of directed risk control options, stakeholders can truly optimise the use of limited sea-space for both maritime and offshore energy purposes. Finally, it is also important to mention the cost associated with a simulator study. For the MaRiSa lab, the cost of setting-up and conducting a study was approximately 1000 euro per day. In the current study, 7 groups of participants were observed and evaluated within 3.5 hours, i.e. approximately half a day. It is feasible to evaluate a statistically significant sample of at least 100 participants in 10 working days amounting to a total of euros 10,000. Each of the participants can be asked to participate in a base-case scenario and a 'modified' scenario in which there is a variation in either the environmental or technical conditions within 30 minutes: 10 minutes set-up time, 10 minutes per scenario, and 10 minutes briefing/debriefing. Given the basic equipment, familiarisation with the simulator can be conducted as a very short group-demonstration. Considering the cost of typical stakeholder workshops, it is reasonable to conclude that with improving, cost-effective technology, simulators can indeed provide better value for money.

6. Future Work

Given the potential of simulator studies, the authors intend to conduct further investigations. As the immediate next step, they will conduct a study comparing AIS data before, during, and after an OWF is installed to validate the findings of the current work. Their aim will be to establish if a larger sample of simulator observations can be used to provide ‘corrective’ factors for AIS data, which will improve the quantification of vessel traffic distributions.

In addition to the AIS study, the authors intend to explore the differences in qualitative responses between traditional stakeholder consultations and simulator experimentations, to comparatively gauge the benefits and drawbacks of the two approaches. This planned study will also explore if seafarers are able to identify hazards and risk-control options more effectively in a simulator. Lastly, they will conduct a questionnaire study to evaluate whether seafarers follow the same navigation behaviour in practice as they do on paper. This questionnaire study will survey seafarers on the typical CPAs they maintain, and their performance will be evaluated in the MaRiSa simulator as a follow-up.

7. Conclusions

Maritime transport is essential to the normal functioning the world’s economy as over 90% of the world’s trade is carried by sea; the specific mode of transport is also, by far, the most cost-effective way to move goods and raw materials en masse around the world (IMO 2016, George 2013). With water covering almost three-quarters of the earth’s surface, and with the vast majority of all international trade transported by sea, shipping activities are considered as the backbone of globalization and vital for all "just-in-time economies" (Dalaklis 2012). It has already been discussed that the possibility of a maritime accident is increased in the vicinity of offshore renewable energy installations (OREIs); therefore, ensuring the safety of vessels transiting near these very high cost structures is a high priority. In the analysis at hand, the authors consider if, and how, ship handling simulators can be used to feasibly augment existing navigational risk assessment (NRA) studies and particularly those concerning OREIs. A pilot study is conducted to determine whether observable data from a simulator exercise can be used to improve the quantification of parameters in existing NRA models. The results indicate that simulators are indeed a viable option for this purpose; the core benefit of using a simulator is that one can create and study a ‘future-case’ scenario and use the information to augment past data. In addition to providing improved and more applied quantification of parameters, simulator experimentation can also harness better input from operational end users.

Improvements in the cost-effectiveness of computing and technology also mean that simulators are becoming more feasible economically. It is indeed safe to say that simulators may provide a more cost-effective alternative to traditional stakeholder workshops, whilst simultaneously improving the proactive quantification of parameters in existing models and methods.

To conclude, given the increasingly complex maritime and marine plans in Europe, simulators can provide a more comprehensive picture of future-case risk, leading to safer, more efficient and sustainable maritime operations around OREIs.

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