RESEARCH IN PROGRESS

IMPROVING SAFETY AT SEAS

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Digitalization in the maritime industry has been suggested as means to achieve safe, economically, and environmentally sound marine traffic. Despite the increasing adoption of digital services and technology in the maritime industry in Finland, the number of accidents has not reduced significantly. This research article aims to explore the potential for improving waterway safety in Finland. The study analyzes waterway accident data to identify the user group most in need of safety improvements and proposes targeted safety measures better tailored to recreational boaters. The study suggests enhancing the physical infrastructure and related digital services of sea areas to provide better coordinated traffic at sea and situational awareness among seafarers, including non-professional seafarers. Finally, a roadmap for implementing these safety measures will be developed. The research provides a comprehensive framework for improving waterway safety in Finland, reducing accidents, and fatalities.

Keywords:
digitalization, waterway safety, recreational boaters, maritime, accident reduction

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1 Introduction

The pace of international development in traffic system automation has been rapid, driven by the goal of reducing human errors in traffic through increased automation and autonomy of vehicles and traffic control. Seafaring is no exception: more digital services have been approved by authorities and adopted by merchant and private mariners. Remotely operated and autonomous ships are being increasingly trialed and developed in the maritime industry (Aawa, 2016; Kepesedi, 2022). Equipping ships and fairways with positioning, navigation, sensoring, and communication technology has been suggested to achieve safe, economically, and environmentally sound marine traffic for all (socially sustainable seafaring) as communicated by the ministry in their societal objectives (Miettinen et al., 2021). However, despite these improvements we see limited progress in reducing the total number of accidents – the improvements are due to safer merchant traffic of big vessels - most accidents happened outside merchant traffic by recreational seafarers in 2017-2020 (Statistics Finland, 2022).

The aim of this research article is to explore the potential for improving the safety of waterway users in Finland by leveraging the opportunities provided by digitalization for vessels and waterways. Specifically, we aim to identify the user group that require the most attention in terms of improving their safety, assess the suitability of planned safety elements for addressing their needs, and develop a roadmap for implementing these elements to ensure the safety of all waterway users.

To determine the user group most in need of safety improvements, we conduct an analysis of waterway accident data. Based on this analysis, we propose targeted safety measures that are better tailored to recreational boaters. We suggest enhancing both the physical infrastructure and related digital services of territorial sea to provide better coordinated traffic at sea and situational awareness among seafarers - meaning all seafarers and even beyond official fairways. We believe that technology and its usage has reached a point where even non-professional seafarers can utilize digitally-enhanced fairway infrastructure for safer and more environmentally-friendly travel.

Overall, this research-based development intiative provides a framework for improving waterway safety, leveraging the opportunities provided by digitalization for vessels and waterways. By identifying recreational boaters as the user group most in need of safety improvements and tailoring safety measures to their specific needs, we aim to ensure the safety and reduce the number of accidents and fatalities in Finnish waters.

2 Analysis of accident data

In recent years, several new elements have been introduced to improve the safety of merchant traffic on well maintained fairways, resulting in a significant decrease in the number of accidents involving large ships. In fact, merchant shipping accounts for only 1-3% of the total accidents, and fatalities are very rare today.

However, despite this improvement, relaxed practices and an increasing number of vessels with high speed differences have led to more near-misses and limited progress in reducing the total number of accidents. More than 2000 accidents and approximately 50 annual fatal incidents happened outside merchant traffic in 2017-2020 (2022, Statistics Finland). Over 90% of these fatalities happen to recreational crafts and are a consequence of operating error while drunk leading to listing or cap sizing (ibid.).

But the picture changes when looking into the non-lethal accidents: they mostly happen under good daytime conditions during the weekends (ibid.). Of the accidents, motorboats form a clear majority (70%), but rigid inflatable boats (ribs) and sailboats are over-represented in accident statistics. The root causes for accidents are technical failures (68%) such as malfunctions of manoeuvring devices or engines, and human error/misconduct in 37% the accidents. Weather conditions are the reason for approximately 5% of the accidents.

As a consequence, we suggest that the most potential area for the development of safety at seas is to provide means for recreational watercrafters (motorboats, ribs and sailboats) to avoid, react and receive help for malfunctions, groundings, allusions, and collisions, and ultimately also receive search and rescue services (SAR) quickly enough on the accident site. This calls for a better joint situational awareness among all seafarers and safety organizations.

3 Digitalisation of vessels and traffic

At open seas, modern vessels have been semiautomatic for a long time, and this is now spreading towards regular traffic between harbours and to some extent, also recreational traffic. However, bigger vessels have to fulfil the requirements set by Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW, 1978). The trials with remote piloting and autonomous traffic (Aawa, 2016; Kepesedi, 2022) have shown the need for enhanced information to improve the perceptive, automated capabilities of the vessel and to provide potential for better situational awareness of the traffic situation for the mariners, e.g. on fairways or in the port area or on the fairways.

Categories of autonomous vessels are defined according to the operator's role on a ship (IMO, 2021). A Maritime Autonomous Surface Ship (MASS) is *"a ship which, to a varying degree, can operate independently of human interaction"*. IMO identified four *'degrees of autonomy*', of which two are manned, i.e. seafarers are on board, and two are unmanned (ibid.): ***Manned vessels*** are assisted with *automated operation processes and decision support systems* (type 1), *even remotely controlling* the vessel (type 2), *but the crew can intervene and override the systems*. When there is ***no crew on board*** the vessel is either *remotely operated* (type 3) or *operating autonomously* (type 4) without crew intervention (table 1).

Table 1: Degrees of autonomy

Manned Vessels	*Type 1: Automated operation and DSS* Both in merchant and increasingly in recreational traffic	*Type 2: Remote control, but crew can intervene* Helping merchant traffic on restricted areas at harbours and piloting.
No crew on board	*Type 3: Remote operation:* Regular merchant traffic in restricted areas and waterways	*Type 4: Autonomous operation:* Trials in merchant traffic (test beds and test areas).

As vessels are turning more automated and autonomous, towards types 3 and 4, there is a greater need for careful analysis of faults to improve. This involves continuously monitoring and improving the reliability and performance of the systems and their components' quality (Chaal et al., 2022), to create Safety

Instrumented Systems (SIS) with relative levels of risk-reduction (Safety Integrity Levels, SIL) for continous safety improvement.

In navy and merchant shipping, these ideas of automation is slowly becoming a reality towards types 3 and 4 (e.g. Kepesedi, A., 2022). The first trials show, that the behaviour of such vessels is different from traditional ships: they are following pre-planned routes, with limited set of maneuvers (Safety and Regulations for European Unmanned Maritime Systems[1] and SOLAS, 1974). This is to optimize time and fuel consumption for profit, to meet environmental and emission requirments and, only secondly, to participate in the communication, interaction with other traffic, not to mention participating in rescue operations in traditional sense at waters.

For recreational vessels, the first autonomous category, i.e. providing navigational aids – to increasing extent also decision support systems – are becoming common integrated with ECDIS[2] for new vessels. Still, recreational vessels are mostly relying on the traditional watchkeeping and elementary safety measures at seas.

However, lately improved self-services are being introduced to track merchang vessels and show maritime alerts (e.g. https://aluskartta.com; https://extranet.vayla.fi/pooki_www/merivaroitukset/list_fi.html).

Summary of Research in Progress

This is the outset of our research and development project aimed at improving the safety in territorial seas. We will focus on an area where can be leveraged to address unique local conditions. In the future, Finnish waters will witness the presence of both autonomous vessels and more accident prone recreational boats, which poses additional challenges for seafarers in terms of situational awareness.

To address these challenges effectively, it is necessary to enhance data accessibility for all seafarers, enabling them to develop a better understanding of each other's intentions and safe navigation routes. Given the diverse capabilities of different user groups in terms of maneuvering and communication at sea, the standard fairway,

[1] https://eda.europa.eu/docs/documents/SARUMS-Flyer-2012.pdf
[2] Electronic Chart Display and Information System, definitions by International Hydrgraphic organization IHO S-57 (content and display) and IHO S-52 (transfer) and complying with IEC 61174 test procedures.

weather, and traffic information often fails to meet the specific needs of each group. Therefore, we propose utilizing common, multisided platforms and developing applications tailored to the requirements of different user groups, thus taking advantage of suitable applications (Heikkilä et al., 2023; Parker and Van Alstyne, 2004).

The responsibility of authorities is limited to traffic on official fairways, but there is a clear safety discrepancy when it comes to providing guidance and assistance for recreational traffic outside waterways. Therefore, it is crucial to carefully examine the technical means by which safe routes in the archipelago can be identified. This may involve tracing traffic patterns, digitalizing currently fragmented oral information on traffic conditions, safety alerts, and environmental hazards, and utilizing VHF-radio for interaction with authorities and fellow seafarers, both through broadcast and point-to-point communication.

Digitalization has made these advancements possible, and the most crucial standardization efforts for improving safety have shifted from IMO to IALA[3] and ITU[4]. This transition is driven by the increasing autonomy of merchant traffic and the telecommunications limitations faced by recreational vessels. These organizations are focused on designing more efficient digital communication systems (e.g. VDES R-mode[5]) and integrated navigational aids. With the assistance of machine learning and artificial intelligence models, it is anticipated that these functionalities (e.g., as described by Pedersen et al., 2020) will expand to type 1 applications and remotely assisted services (type 2), thereby benefiting recreational vessels as well.

However, it is evident that achieving this requires collaborative, co-created design efforts and the willingness of authorities to enhance, open, and maintain safety-critical data. Similarly, developing robust communication infrastructure at sea is of equal importance. None of these advancements can be effective if they are not integrated into the education of recreational seafarers, emphasizing enhanced digital

[3] International Association of Marine Aids to Navigation and Lighthouse Authorities, "gathers together Marine Aids to Navigation authorities, manufacturers, consultants, and, scientific and training institutes from all parts of the world and offers them the opportunity to exchange and compare their experiences and achievements." (IALA, 2023).
[4] The International Telecommunication Union
[5] https://www.iala-aism.org/product/g1158/

seafaring skills and fostering a safety culture. Research is necessary to make informed decisions, identify effective transformational measures, and ensure the successful implementation of safer seafaring practices.

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