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Assessing the potential of risk-based regulations for emerging maritime technologies

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The maritime regulatory landscape has traditionally been reactive, with regulations often shaped in response to past incidents. However, the rise of advanced technologies, particularly the unmanned vessels, demands a shift toward proactive framework. This paper explores the benefits and challenges of adopting risk-based legislation within the evolving field of maritime technology, with a focus on the operation of unmanned vessels in the Gulf of Finland. Through a comparative analysis of current regulatory regimes in Estonia and Finland, this study demonstrates how risk-based regulations could be suitable approach to foster innovation and contribute to decarbonization goals.

Keywords: *risk-based laws, unmanned ships, maritime transport, decarbonization*

1. Introduction

Emerging technologies, that create opportunities, risks and challenges require clear regulations. Shipping is on the verge of major technological changes due to the need to meet emission targets (IMO 2023). One of the emerging technological advancements is the adoption of completely automated, unmanned vessels as means to reduce the harmful effects of shipping (Agarwala 2024). To understand fully the holistic impacts of unmanned ships, there is need for testing such vessels at sea, in the conditions where such vessels will later be used. There are several discussions on how to make regulations more effective to align with new developments (Gunningham 2007).

New technologies present new vulnerabilities, the full effects of which are largely unknown. This creates new challenges for regulatory approach addressing such technologies that are not yet fully developed. This is especially in maritime sector due to its international nature.

As the authors live at the shores of the Gulf of Finland, this article concentrates on the challenges of testing in this region, with particular focus on the Estonian and Finnish regulatory approaches due to similarities in their governance systems. The distance between the capitals of Estonia (Tallinn) and Finland (Helsinki) is 80 km by bird flight. A connecting ferry route makes up one of the busiest international ferry shipping routes in the world. More than 8 million passengers and more than 50% of the goods that arrive to Finland on trucks are carried on the same route (U. P. Tapaninen 2024). There have been several initiatives to introduce new technologies to the routes, including unmanned vessels or fully electric ships (Navigator 2024) and both countries are developing and testing such vehicles to achieve enhanced maritime safety and the climate goals while keeping economic feasibility. This gives an excellent opportunity for understanding the effects of different approaches to the regulations and their impacts on innovation.

Through the years, there have been several approaches to regulatory development and enforcement (Baldwin and Black, Really Reponsive Regulation 2008). In maritime domain, most of the safety regulations have been created retrospectively (SOLAS, MARPOL). However, the latest regulations (Polar Code) are proactive and use risk-based approach. The Gulf of Finland, due to its crossing shipping routes of East-West and North-South, has been under investigation of possible use of proactive approach for several years (Kujala ja M. Hänninen 2009) (Haapasaari, et al. 2015), (Valdez Banda 2017) (Kulkarni, Banda ja Kujala 2020) and is an area for vessel traffic services

(VTS). To add to such environment unmanned ships, even for testing, would need some sort of proactive procedures (Kerem 2024).

There are several approaches to regulations on the scale of maximum regulation in form of command and control to minimum regulation where the regulatory aspects are delegated to the market players in hopes of the self-regulating markets (Ayres and Braithwaite 1992). In case of testing unmanned vessels in the Gulf of Finland, there are regulations in place for the ships in the area through VTS. However, the testing of unmanned vessels is a gray area. As such vessels would be without human on board, guided by AI or preprogrammed for some route, guided from distance with situational awareness technologies (Agarwala 2024), there is lot that is unknown and, in some cases, also in direct conflict with current rules and regulations (Liu 2022)(for example, the demand of minimal manning (MSOS 2001, §11(13)). Hence, this article seeks to address the following question: Could the risk-based approach to regulations be a solution for emerging technologies in the maritime domain, in particular for the use of the unmanned vessels in the Gulf of Finland?

This paper is organized as follows: Section 2 outlines the methods applied in the study. Section 3 presents the background of our study, which is further analyzed in Section 4. Thereafter, Section 5 presents the conclusion and offers directions for future research.

2. Methods

This study adopts a pragmatic approach to exploring the usability of risk-based regulations. Comparative legal research served as a foundation for analysis of two legal systems and comparing similar regulations in different states. The essence of risk-based regulations is analyzed in contrast to existing legal frameworks in Estonia and Finland. The comparative analysis was used through the lens of functionalist methodology, drawing on a functional method perspective using the Brand's conceptual framework for functionalism (Brand 2007). The study's functionalist perspective emphasized the understanding of how each regulatory approach operates and enabled a detailed evaluation of the interplay between regulatory design and practical application. This methodology was deemed suitable for the study due to the practical nature of current article and the core research question.

3. Risk-based approach to regulations

To understand the possible suitability of risk-based approach to govern the issue of testing unmanned vehicles in Gulf of Finland, thorough understanding of risk-based approach is needed.

Definition of risk varies widely – in this article, the risk definition is regarded in holistic way, including all possible risks that arise from the use of unmanned vessels without focusing on any specific risks which has been the approach of other authors (Aven 2011), (Anderson 2009), (Kelsen 1945), (Molamohamadi, Samani and Karimi 2024), (Valverde, Levi and Moore 2005). Risk governance is viewed as a means of shifting the responsibility for drafting final regulations from legislators to the regulated subjects (Verling, et al. 2023), as a tool to "hollow out the state" (Black 2005), as a tool for individuals and enterprises, to manage "the effect of uncertainty on objectives" (ISO 2022). In legal research, "risk" is often regarded as synonyms to "dangers" and "uncertainties" (Valverde, Levi and Moore 2005). Risk governance is viewed also as a method to contain the risks that modernization itself creates (Beck 1992) (Oberdiek 2010).

The first introduction of risk-based norms was in environmental protection (Hornstein 1992) and the financial sector, followed by labor and healthcare regulations. The driving force behind risk-based norms is often the need for cost-effective implementation of regulations while minimizing regulatory resource use. (Black 2005). However, the use of risk-based approach varies largely between the sectors and countries due to different governance philosophies and expectations. The essence of the risk-based approach lays on it is attention on possible risks, their probability and impact of potential adverse outcomes (Rothstein, Borraz and Huber 2012) and it can be argued that although risk-based methods seem to be adjustable and give freedom, to apply these, there is need for prescriptive measures to enforce these in some sort of form of control (Colgianese ja Mendelson 2009). Current article uses the risk-based approach as defined by Rothstein et al. (Rothstein, Borraz and Huber 2012).

4. Risk and safety management in maritime domain

In the maritime domain, risk management has been integral to the development of IMO standards, many of which have emerged in the last few decades (Soares, Texeira and Antao 2010). As the shipping industry serves as a cornerstone of global trade, its risk landscape continues to evolve, and as such identifying risk factors and ensuring their continuous mitigation remain critical priorities (Christensen et. Al., 2022).

Since 2004, IMO has set target to develop goal-based standards for safety, environmental and security regulations that ships are required to meet in different stages of their life cycle and are developed in five tier program as can be seen in Figure 1 (IMO 2004). For the development of regulations for new technologies, the first stage is creating goals. For unmanned shipping, the goals come from the decarbonization regulations (IMO 2024), (Ölçer ja Alamoush 2024). Second stage of the process governs the regulations for the technology yet in development – defining functional requirements that address all relevant hazards and provide their mitigation regulation in a way that leaves space for future technological developments. Third step requires verification of conformity – comparison of the actual situation to the goals and functional requirements. The guidelines state that such regulations should include the mechanism of how the rules and regulations meet functional requirements (17.1.1.) and be based on analysis of proven and established technologies and be based on clear qualitative and quantitative criteria (18.2 and 18.3). As not all technological aspects of unmanned vessels can be defined through qualitative and quantitative criteria, risk-based approach might offer a solution to overcome this gray area, enabling the producers to use self-assessment of their technology and its capabilities to best achieve the result described by guidelines. However, in addition to international collaboration under IMO, the tradition of maritime is to use classification societies as mediators between the regulators and ship owners. Such societies are approved to carry out certain controls on behalf of the regulators as tradition for maritime trade. Some of them have concluded their suggestions for moving forward and state the need for not enforcing fully current regulations on unmanned vessels to enable the innovation (Lloyd's Register 2024) (DNV 2024).

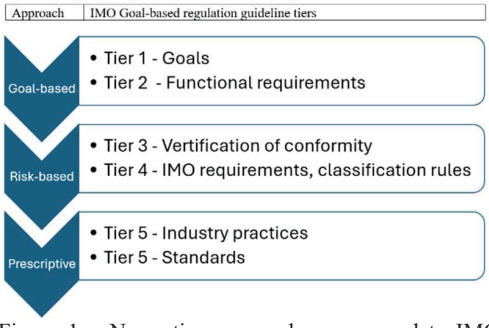

Figure 1 – Normative approaches compared to IMO Goal-based regulation guidelines, compiled by the authors.

5. Unmanned vessels in Gulf of Finland

IMO regulations apply to international transport and typically govern vessels exceeding a certain size limit (mostly those with a gross tonnage (GT) of more than 500). Currently, IMO has not issued any regulation regarding the unmanned vessels and such regulation is under development (IMO 2024). Additionally, the term" autonomous or unmanned ship" is yet to be defined at the international level to guide the establishment of the required legal standards (IMO 2019). In the absence of an agreed definition, for the purposes of this paper, unmanned vessel means the vessel without humans on board, either completely independent in action or remote controlled by humans on shore. The interim guidelines for testing such vehicles were approved in 2019, but do not carry statutory weight (IMO 2019). In the interim, this allows each country the autonomy to regulate activities within its jurisdiction, in their national waters as they deem fit.

Estonia and Finland share a similar basis to regulations, as both are members of EU, the North-Atlantic Treaty Organization (NATO) and the Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM).

In Estonia, the use of all vessels falls under the jurisdiction of Transpordiamet (Transport Board). In Finland, Traficom (Finnish Transport and Communications Agency) is responsible for these matters. In Estonia, the maritime navigation is regulated by the Maritime Safety Act (MSA) (Riigi Teataja 2003). This act does not have any reference to unmanned vessels. Additionally, the definition

of "watercraft" does not reference manning. Furthermore, the §4 (1) of the same act requires all vessels entering territorial waters to have the certificates mandated by international conventions. These includes compliance with the STCW 73/78 convention (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers) and COLREG (Convention on the International Regulations for Preventing Collisions at Sea), both of which require a crew on board. Similarly, MSA §3 sets these requirements also to vessels carrying the Estonian flag with the exception to the small crafts and crafts operated on rivers and lakes. §19 (3) gives special rights to Transpordiamet to waive technical, safety, seaworthiness, manning, personnel accountability and loading requirements specified in the same act provided vessel's safety is ensured and special circumstances regarding her operation area are considered. This grants Transpordiamet the authority to make decisions on a case-by-case basis.

Finland follows a similar approach. Finland's Ship Manning Act's (SMA) §13a specifies a case-based permission that may be given for the trials of unmanned vessels for a maximum period of two years (Eduskunta 2009). This is permitted under the conditions that the trial poses no danger to the vessel or her surroundings and applies only to Finnish vessels operating in Finnish waters provided it does not conflict with Finland's international obligations. The same article allows for additional conditions to be set, final decision is made by Traficom.

Both countries have similar procedure described by their regulations. Both countries have conducted trials of unmanned vessels (J. Joensuu 2018), (Hellerma 2023). In both cases, the vessels were monitored from the shore and accompanied by another vessel and operated in pre-designated area with low traffic volume. Neither country has vessels operating on commercial routes that are remotely guided or fully unmanned. According to a Traficom report issued on 3rd October 2024, the main aim is not on testing unmanned vessels, but rather on evaluating the vessels equipped with features that support the human decision making. Traficom views this as means of promoting environmental sustainability, primarily by optimizing routes and speed (Traficom 2024). However, the two-year limit cannot be extended and hence it enables only trials, not the use of unmanned vessels in commercial traffic. This created contradiction between the aim and the actual regulation.

A review of both agencies' websites reveals no guidelines on how to apply for an unmanned vessel license. The Finnish website includes a reference to a form for vessel trials for newbuilds. The Estonian website contains no information. There is no publicly available data on how often such permissions have been granted, though both regulation state that such permission is necessary. However, based on news reports the number of cases appears to be fewer than ten in both countries, despite the several companies and research institutions declaring their work on unmanned vessels (Lehtilä 2017), (J. Joensuu 2018), (ERR 2023) (Trialoog 2024) . Reasons for that were analyzed by Kerem (Kerem 2024) and Jänes (Jänes 2024) in their thesis. According to Kerem, the primary challenge for the developers is lack of standards. To develop and test effectively, they prefer clear requirements to ensure compliance.

6. Discussion

While inspecting in detail the situation with unmanned vessels in Gulf of Finland, the regulations are far from ready for the use of unmanned vessels – even testing these depends today on the decision of the regulator and the conditions for issuing the permit are not clear. Industry has expressed the need for clear terms (Kerem 2024) and the same has been expressed by the regulator's representatives (Jänes 2024). A two-tiered model of risk-based regulation is recommended for testing the unmanned vehicles and their first stages of use to enable the data gathering necessary for developing industry standards. The first tier of such regulation would be self-assessment of risks involved by the producers, users or testers of such vessels. As the current regulations foresee the permission to be issued by the regulator, the second tier of such regulation could be the review of the self-assessment by the regulatory body and issuing the required permit. This would require no change in current law, publishing the procedure by the corresponding Maritime Administration would be sufficient to close the gap. To fully understand the possible effect the risk-based regulation would have on testing of unmanned vessels, the authors conducted a Strength-Weakness-Opportunities-Threat (SWOT) assessment.

6.1 Strengths of risk-based regulations

The strengths of risk-based regulations are in its aim to mitigate the possible risk to help to achieve the best outcome possible while giving the subjects the possibility to influence the outcome. The use of risk-based regulations in case of the unmanned vessels would enable the regulator to lay the responsibility of the assessment of possible hazards, dangers and risks to the person using the vessel while maintaining the possibility to evaluate the self-assessment before approving it. Such two-tier model has several advantages over purely prescriptive or command-based approach as the process is started by the partner who has the best knowledge of what issues such technology might possess and the regulator has a possibility to evaluate the self-assessment before issuing the permits for the use of technology.

Risk-based norms are considered to be less costly for the regulators as costs are transferred to the subjects of the regulations. However, for the subjects, the cost of self-analysis, both through the need to educate the personnel as well as conducting the risk assessment itself might be overwhelming – the indication to this is the desire for the standards as shown by Kerem (2024). Nevertheless, sharing the responsibility between the industry and the state demands close co-operation, hence making it possible to find the possible problem areas easily during the risk assessment phase, first on industry level and second on state level, before issuing a permit or acceptance letter.

6.2. Weaknesses of risk-based regulations

The weaknesses of the risk-based regulations are the under-regulation and bias during enforcement.

First weakness is identifying the risks. New technology can bring along unforeseen risks which are difficult to detect.

Second weakness derives from persons making the risk assessments and persons evaluating the thoroughness of the assessment. Both would need to be experts on their field, but there seldom are any in cases of completely new technologies. This can be mitigated by aiming to achieve a comparable or improved *status quo* with new technologies, using BAT (Best Available Technology) standard (IMO 2013). While the evaluation of risks on paper might be well justified and involve experts, the outcomes of a risk-based analysis must also be enforced and followed.

Provided developer has followed the guidelines set by the legislator for the risk-based analysis, has fully implemented and enforced the regulatorily prescribed norms, and yet an accident occurs, determining responsibility and liability becomes a complicated issue. As discussions on artificial intelligence have indicated, liability issues will become increasingly complex with new technologies and should be considered as one risk (Kretschmer, et al. 2023). This sets the target for making the guidelines for the risk assessment – it should be detailed enough to point out any types of risks that need to be assessed as well as give guidelines how this should be done, while allowing exceptions that rise from the technology itself be described by the developer.

6.3 Opportunities of risk-based regulations

The opportunities for the risk-based regulations in case of unmanned vessels would lie on making the public feel safe that the procedures of monitoring and evaluating each project are in place. Two-tiered solution gives a procedure that is possible to be followed by bystanders. It also enables to collect data to form the standards in later stage.

As the new technologies are in constant development, this approach would enable to use on unmanned vessels some technologies that are not even discovered yet and test these in real-life situations. The social acceptance of such technologies depends on how people perceive such vessels – as demonstrated above, the risk-based approach, considering all possible hazards tackles the moral issues that public might be facing with such technology.

6.4 Threats of risk-based regulations

The main threat to the use of the risk-based regulations stands in their acceptance by the industry. Should the developers of new technologies find the compliance and self-assessment to be too complicated or too expensive, it might cause them to search for states where the regulations demand less. In addition, it depends on the willingness of the policymakers to adopt such regulations and enforce these.

As a conclusion of SWOT analysis, the two-tiered risk-based regulation would be a good solution for emerging technologies in the state where the goals and functional targets are set, and verification of conformity is yet not possible to achieve.

5. Conclusions

This study analyzes the case of testing the unmanned technology in Gulf of Finland, between Estonia and Finland. The comparison of current situation highlighted both the benefits and

challenges of existing regulations, showing that while steps have been taken to enable testing, long term regulatory clarity is still lacking.

Through a detailed analysis and SWOT evaluation the study showed that two-tiered risk-based approach could be a solution for such innovative technology, especially starting the specific use case from the self-analysis of the producer. Such approach would be valuable until there is enough data for alternative solutions.

Risk based norms emerge as promising option for governing technologies that are not yet developed to a high maturity level but require a regulatory structure. They offer flexibility while ensuring safety and compliance. They also introduce new challenges, such as expertise gaps and accountability issues.

Emerging technologies would benefit of risk-based norms to provide a structured and flexible framework. This approach allows setting regulations and performance targets while ensuring that new technologies evolve safely, securely and environmentally friendly. As the example from Gulf of Finland has shown, industry needs clear, yet flexible rules to foster innovation.

Future research could explore how risk-based regulations can be effectively integrated to address complex challenges across sectors and with other new technologies in maritime domain. Due to the limits of this article, the actual risks involved were not identified and analyzed, such works could be carried out in future. This could contribute to development of globally harmonized regulatory frameworks.

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