Platforms for Smart Fairways - Enhancing Services for Autonomous Maritime Traffic and Other Emerging Uses of Territorial Sea

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Abstract

Digitalization has brough about new services to assist navigation, and first autonomous vessels are already in use. This poses also challenges to the fairways, i.e. routes on sea that are designed to secure maritime traffic with physical navigation aids. How should fairway be augmented in future? And, most importantly, how can we make it happen?

We use Finnish territorial waters as an example to illustrate how on-going changes of seafaring are taken into account in design of autonomous maritime infrastructure by experts. We use multi-staged Delphi-method to derive the elements of importance for safeguarding autonomous maritime traffic.

We suggest starting to improve services at critical points of present fairways. Authorities should ensure the integrity of data and services of merchant traffic first, and thereafter establish jointly an open platform where recreational user can design, try, implement, and test services to their specific needs. This reasoning stems from theoretical underpinnings of communities of interest in self-regulating their environment. The platform could also provide a viable economic solution for speeding up new valuable mobile service designs.

Keywords: platform, service, maritime, infrastructure, autonomous.

1. Introduction to the need to improve fairways as an infrastructure

Public infrastructure consists of common installations, facilities, and services, typically owned and provided for public use by governments, regions, municipalities, or communities (Fox and Smith, 1990). Because infrastructure is of common interest, it is most often established and maintained by the public sector. Examples of infrastructure include transportation infrastructure, information and communication infrastructure, water and sewage systems, energy production and delivery infrastructure, safety, and healthcare (Uddin et al, 2013). Infrastructure investments are also a central part of public policies to enhance the standard of living, equal opportunities for citizens and providing facilities for running businesses on equal terms (Égert et al., 2009). Recently, there has been growing attention and concern about the deteriorating infrastructure, or misplaced investments, e.g., on road infrastructure from the carbon emissions reduction point of view (Glaeser & Poterba, 2020; Heathcote, 2017). So, despite infrastructure investments forming a minor part of public spending, they have a long-term effect on spurring economic activities and nudging the behaviour of citizens (Drzik, 2019).

Similar to road traffic, digitalisation is increasingly being utilised in maritime transport with an aim to creating more efficient and sustainable transport (Sanchez-Gonzalez et al., 2019). The first autonomous ships are being tested and International Maritime Organisation (IMO, 2022) is working on to integrate these new technologies in its regulatory framework. In future, vessels with different levels of automation will be sailing in our waters (Tsvetkova and Hellström, 2022). At the same time, the variety of users of waterways is increasing due to the rising number of pleasure boats, jet skis etc. These trends challenge us to renew the maritime infrastructure (Brinkman and Sarma, 2022). For example, fairways, i.e., harbour approach channels that are designed for safe navigation of vessels (Gucma and Zalewski, 2020), still rely heavily on decades old, static beacons, lateral marks and leading marks.

Many public infrastructures could benefit from digitalization; for example, trials with autonomous road traffic have shown the need for enhanced information from infrastructure to improve the automated capabilities of the vehicles and provides potential for of the development (Manivasakan et al., 2021). It is not sufficient to automate the vehicle only in relation to static road objects, but the automatic vehicle must adapt to dynamically changing traffic situation (see e.g., Bergman et al., 2021; Cho & Kim, 2022), such as interacting with road users, observing moving and

URI: https://hdl.handle.net/10125/102753
978-0-9981331-6-4

newly placed objects, alternating routes, changing weather conditions and illumination on roads. Marine traffic has faced similar needs for a long time (Giannopoulos, 2004), but now the technology is maturing for autonomous maritime traffic, i.e., maritime autonomous surface ships (MASS), assisted with remote piloting and port digitalization (UNCTAD, 2020)

Thus, the Finnish maritime authorities set up to find out how the future fairway infrastructure could support more digitalised vessels and how fairway infrastructure could further improve safe, efficient and environmentally sustainable traffic (Miettinen et al., 2021). The purpose of this paper is to study *what are the most important and challenging elements needed in future maritime fairway and who should be responsible for the investment and provision of the services*. Building on the Delphi study we suggest that common fairway infrastructure could be considered as a platform, which would allow developing and provisioning mobile, digital services on multisided 'markets' of unanticipated uses beyond the original intent of guaranteeing safe waterways for merchant traffic.

2. Theoretical considerations

- *"The early history shows, that contrary to the belief of many economists, a lighthouse service can be provided by private enterprise"* (Coase, 1974) –

Typically, a fairway suffers from an investment inappropriation problem: Once the infrastructure is built, it may not be feasible or possible to restrict its use exclusively to investors/owners, which limits the making of profit from its use. Restriction of use may not even be desirable, if there is surplus capacity available. Transportation infrastructure has a substantial positive externality effect to the society as a hole: The value of the waterway investment comes from its positive long-term effect on economic activities. By reducing transportation costs the prices of final goods are lower, and consequently, consumer surplus bigger. Hence, the fees for fairway use are typically on the low side, not covering the investment costs, but marginal costs of maintenance. It can also be industrial policy to subsidize logistics costs, and to secure supplies, too.

Hence, the investment to common fairway infrastructure could be considered as a sunk cost. The use of it is a maximization of future income with the attempt to reap benefits from network externalities (Coase, 1974).

The usual theoretical claim against open or unlimited use of common resource is that rational and self-interested individuals will not act to achieve common interests, unless the number of individuals is small, or there is enforceable regulation taking place (Buck, 1992). The premise for such situations is that any person, who cannot be excluded from obtaining the benefits of a collective infrastructure, has little incentive to contribute to the joint effort, but to free-ride on the effort of the others instead. An extensive literature discusses the effect of free riders, concluding that common resources would inevitably be destroyed because of lack of care (Hardin, 1968) and overuse of the common resource - in our case leading to congestion, or deterioration of the common infrastructure, e.g. markings, etc. To avoid such *tragedies of the commons* the central governing body should maintain the common pool of resources and set rules so that it cannot be overused. The governing body can intervene indirectly through taxes, prices, or directly with controls and regulations, such as selling permits, licenses, or limiting the use of the common resource (Buck, 1992).

Against this backdrop, textbook economics would suggest that there is no incentive for private investors to invest in public infrastructure and hence it is a matter of public bodies to invest and run such infrastructure. However, public sector is known for its cost minimizing behaviour, so if they cannot appropriate the full cost of the use of the infrastructure, how can necessary upgrades, new features, or changing be grounded to the public? Will it lead to under-investment (e.g., Drzik, 2019), or even over-use to the extent of congestion and deteriorating safety waterways with excess traffic?

Building on Coase's seminal ideas about voluntary governance Ostrom (1990) suggests an alternative solution to govern the commons. With an infrastructure example of a common village grazing land, she claims that the local herders have accumulated knowledge on the carrying capacity of the common grazeland in the long term. Thus, community members have interest and first-hand information on the users, needs and usage patterns, and thus are capable of avoiding the tragedy of the commons without requiring top-down regulation (Ostrom 1990, 2009). Ostrom's main argument is that local communities can establish enforceable and observable rules over time to avoid overusing common resources. As always, the truth and practice lie somewhere in between the extremes of local and centralized government.

Recent literature on platforms provides an interesting continuation to the discussion of governance of infrastructure: There is a growing tendency to boost platform ecosystem's performance by fostering its innovative capacity via strategizing on openness of the platforms (Hagiu et al., Gawer, 2014), i.e., allowing peers to create new bindings and services on a shared, digital platform by utilizing the (positive) network effects on multisided markets. Some seminal works show that, the strategies of platforms in relation to their control on access and resources are different; and that, their innovative capacity is leveraged according to the degree of openness. Overall, a platform's organizational continuum (internal vs industry platform), its ownership structure (proprietary vs shared), and its strategic aim (emphasis on quality vs growth) are main determinants framing a platform's level of openness, as can be seen in Figure 1, and may change over time (Gawer, 2014, pp. 1245–1248; Eisenmann, 2008, pp. 33–38, März, 2021, depicted in Fig. 1.)

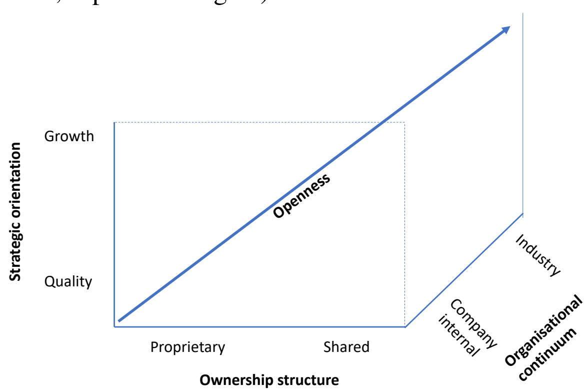

Figure 1. Strategic considerations of open platforms.

The high innovative capacity of platform-based businesses is due to their aggregation of resources and knowledge for complementaries (Gawer, 2014; Jacobides, 2018). When implemented correctly, on multisided markets the transacting parties can benefit both from economies of scope ('base for expertise') and economies of scale ('reach on the markets') simultaneously by co-operating openly (Jacobides, et al., 2018; Parker & van Alstyne, 2008). Parker and Van Alstyne (2005) show that in some networked platform conditions prevailing, the investment costs might be bearable in return of mutual long-term value-creation even under non-profitable pricing schemes. This makes platforms a lucrative option to enhance and develop fairway services for both traditional and new user groups.

3. Study design

For the study we deploy iterative Delphi method. It is one of the most popular techniques for technological forecasting and prioritizing issues for managerial decision-making (Landeta, 2006; Okoli & Pawlowski, 2004). Although it was initially developed for military use cases, it is widely adopted in business and social science as a means of soliciting expert opinions (e.g., on port digitalization, González-Cancelas et al., 2020). Typically, the goal is to achieve the most reliable consensus on a given topic among a group of experts. This consensus provides then a solid background for making decisions on future actions, but on the other hand it may limit the exploration of radical ideas at the outset (Friis-Holm Egfjord & Sund, 2020). The method has been used in many different ways and is suggested to be combined with other methods (Melander, 2018).

Our purpose with the Delphi method was to support the Finnish Transport and Communications Agency (Traficom) in visioning future smart fairways. Traficom is an authority responsible for setting the Finnish regulations and rules for the fairways and, together with the Ministry of Transport and Communications, has already for some years been preparing key action plan for traffic automation (Miettinen et al., 2021). Experts were identified from a project project consortium, consisting of 23 organizations representing authorities, fairway service providers, technology providers, shipping lines, maritime authorities, IT provider companies, universities and maritime companies. Their expertise covers a wide range of topics, such as navigation, shipping, piloting, marine technology, maritime law, nautical charting, hydrology, information systems, digital technology, cyber security, AI ethics, information systems, and maritime business. In the interviews, we seek to expand the vision by interviewing not only the consortium stakeholders, but also additional experts to cover areas that the consortium was lacking, such as emergency services and navy expertise.

We specifically took inspiration from recommended Delphi procedures outlined by Melander (2018) and by Okoli and Pawlowski (2004) where the technique combines several methods and serves a dual purpose of soliciting opinions from experts and having them rank these according to importance. The study proceeded in several steps:

Pre information collection: 33 experts responded to a questionnaire asking their judgment on a year at which the smart fairway could be opened for vessels, and which is the primary target group and what improvements should be achieved with the smart fairway.

Semi-structured interviews of 23 experts were conducted to get more in-depth understanding of the current fairway system and related services, and to cast light on development work that is related to the maritime transport and fairways.

An initial list of future fairway's services was extracted and agreed in an on-line meeting with several representatives from the Traficom, the Finnish Transport Infrastructure Agency and the researchers.

Workshop: The workshop facilitated by Traficom was organised as a Microsoft Teams™ meeting, where 25 experts were divided in three groups. These groups used Miro- board™ to comment and add the list of elements. They also articulated their views on the importance and challenges related to each of the element. The positions of elements were plotted on a grid showing each elements position in terms of challenge and importance as derived from the workshop by the researchers. This presentation method was compatible with another on-going development project regarding European Maritime Single Window (EMSW).

Verification and analysis: The diagram and the Miro-board™ were sent back to the experts for review. Several comments and suggestions were received in separate meetings and the results were discussed by email between all participants. Revised version of the diagram was constructed on the basis of comments, and verified. The outcome was a common view of the future fairway elements and main development needs. This formed the basis for the final analysis.

4. The case of Finnish fairways

- *"While listening to the visions on how autonomous vessels are sailing our seas, I started thinking whether all these fancy ships would navigate towards the ports using the old fairway infrastructure with all those red and green buoys and other sea markings. Shouldn't also the future fairways be smarter?"* (Pilotage director, Interview 16.10.2020) –

The fairway infrastructure consists of shipping routes with physical markings, signals, and services for safe navigation, as well as of digital maps of lanes with guaranteed minimum depths and surveillance and rescue services. The infrastructure is compatible with global and national standards and sets the basis for professional education on seafaring. Fairways are public infrastructure, funded by taxpayers, and open to everyone with adequate skills of safe seafaring.

Most fairway services (such as pilotage and vessel traffic services, VTS) are subsidized. Distinguishing factors of Finland - and Nordic countries in general - are their territorial waters' extensive archipelago and fjords, which makes the maintenance of fairways challenging in harsh conditions of true four seasons. The conditions vary from gentle white summer nights to freezing cold, dark, stormy conditions on shallow and rocky waters with winding fairways. Despite the varying conditions the fairway infrastructure must be maintained, and piloting services must be available all year long and occasionally be supported with ice-breaking and towing services for commercial traffic fastest on high priority fairways.

5. Need for efficiency, environmental and safety improvements

The view of experts was almost unanimous: the first priority of the smarter fairway and navigation is safety (Figure 2).

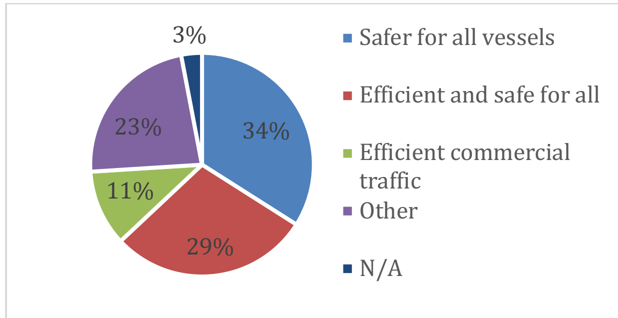

Figure 2. Which vessels Smart Fairway serves and what is the main purpose: more efficient commercial traffic or safer fairway for all vessels?

The opinions on prioritising merchant traffic divided opinions. However, making fairways smarter is seminal for environmental and safety improvements, not to mention fairways increasing role in securing supplies and passenger traffic.

Efficiency of commercial sea traffic is vital for shipping companies and major cost driver for trade. Hence, commercial sea traffic is crucial to the Finnish economy both in terms of efficiency and security of supplies. Digitalization provides additional means to improve logistics by reducing the coordination costs of reaching destinations on time, connecting intermodal logistics, and by adding ancillary services such as cargo insuring and financing to maritime transports. Improved planning and optimization of routing can improve carbon footprint minimization, and vessels can gather environmental information enroute.

Today a relatively high level of safety has been achieved through the use of vessels with Electronic Chart Display and Information Systems (ECDIS), improved navigational aids, quality pilotage, coordinated ice-breaking, and 24/7 remote Vessel Traffic Services (VTS). With well-trained seafarers and service providers it is possible to keep schedules in cargo and passenger traffic even when facing most demanding conditions.

But according to the expert interviews there are some recent trends counteracting the goal of safety: a) an increasing amount of commercial traffic[1] is handled by vessels with varying levels of digitalization and by crew with varying levels of experience and b) The recreational use of sea area is estimated to have grown even more than merchant traffic (Haaga-Helia, 2021); Territorial water area is increasingly used for yachting, motor boating, fishing, as well as expanding outdoors activities like skating, skiing, canoeing/kayaking, and jet skiing (see table 1). Often, these recreational vessels are not as well equipped and a mobile phone may be the only interface to access the fairway services.

Table 1. Watercrafts in Finland (Statistics Finland (2022); FMC (2022)).

Vessels	2021	2020	2019	Total tonnage
Ships	669	680	687	1 740 000
Small ships	283	285	284	4 742
Barges	283	278	275	130 000
Boat register	**2021**	**2020**	**2019**	Growth 2019-2021
Motorboats	203001	198066	193580	5 %
Sailboats	14368	14331	14243	1 %
Personal water crafts	9349	7982	6350	47 %
Motorsailers	1234	1229	1223	1 %
Inflatables and RIBs	661	534	450	47 %
Hydrocopters	133	116	112	19 %
Hovercraft	57	43	33	73 %
Other	1323	1280	1245	6 %
All boats registered	**230126**	**223581**	**217236**	**6 %**
+ Rowing boats, canoes, kayaks (estimated)	*750000*	*750000*	*750000*	*N/A*

Despite the growth, the safety on Finnish seas has improved: fatal accidents have diminished by a third from 57/a to 40/a during 2007-2015, and accidents overall have remained nearly constant (Traficom, 2021). But, at the same time there has been evidence of increasing near misses of various kinds. These are due to the abovementioned qualitative changes in using territorial waters.

In addition, there is a growing concern over environmental issues demanding marine traffic to reduce carbon, methane, and sulfur emissions; to limit eroding waves formation; to minimize both bilgewater and sewage loading to the sea as well as cut underwater noise and artificial lights emissions to reduce the strain on marine ecosystem.

We can safely conclude that the number of vessels, boats and other vehicles on territorial waters have grown, the traffic is denser and other emerging uses of regional and local water areas has grown all year round demanding more digital services.

5. Elements of future fairway

The Delphi study was able to pin down the elements necessary for enhancing the infrastructure for safer, more efficient and environmentally friendly seafaring towards autonomous maritime traffic within next 5-10 years timeframe. These are depicted in figure 3.

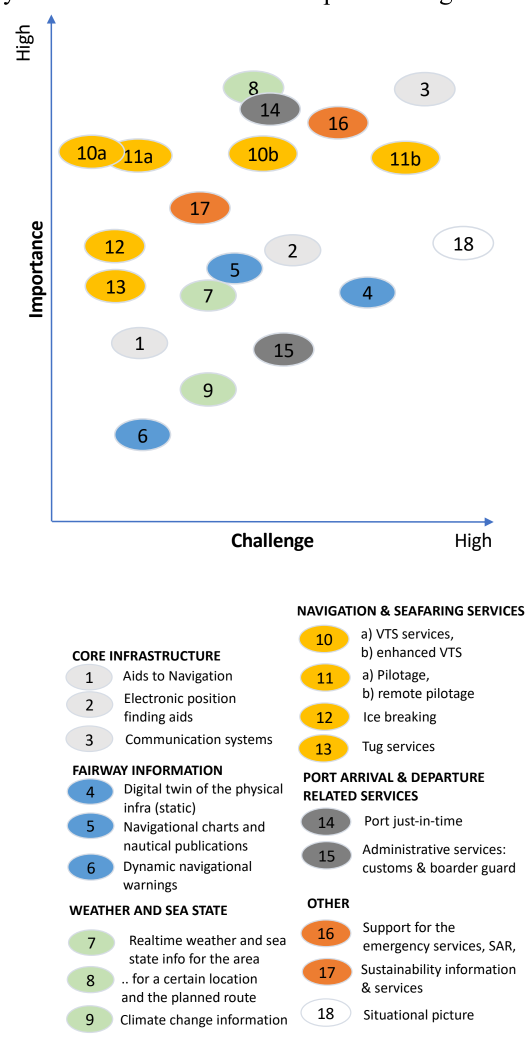

Figure 3. The elements for safer and more efficient maritime traffic within next 5-10 year.

[1] Long term statistics on vessel traffic shows that in 50 years inbound international cargo has more than doubled from 20Mtn/a to 46Mtn/a; outbound international cargo has quadrupled from 18Mtn/a to 50Mtn/a; domestic freight has grown a fifth since 1980 to today; number of passengers have grown sixfold from 3M/a to 19M/a.

Many of the elements are already available for merchant vessels and some high-end yachts (sailing and motor boats). On top of the grid the experts listed those areas, which have to be improved in order to facilitate safer and more efficient traffic.

The easy improvements include elements such as:

#14 Port just-in-time: information on berthing times and places, weather, real-time data on estimated time of arrival (ETA) of vessels. This would help several parties to coordinate their work and improve efficiency through shorter waiting and faster turn-around time. The on-going initiatives of EMSW and UNCTAD (2020) accelerate the development.

#17 Sustainability services would utilize sensors on buoys, on-board of vessels etc, for measuring and optimising emissions and erosion caused by maritime traffic. The gathering and meshing of information would require substantial effort, but could, for example crowdsource gathering of near-real-time observations for more sustainable routing and timing of traffic.

#10a/b VTS services and communication are currently compulsory for vessels over 24m of length. Extending the requirement to private traffic (e.g., cruisers and yachts), and multichannel broadcasting announcement for all seafarers can increase situational awareness. In addition to current services, VTS could provide active navigation assistance, including confirmed and more accurate position and movement of ships, oncoming and intersecting traffic, time information and anomalies on seas.

#8 More local, real-time weather information for the planned route of the ship and a specific location including observations and forecasts of winds, water-level, currents etc. Improved local weather information with local sensors, recording and meshing observations from seafarers and vessels to foresee surprising and unanticipated local circumstances and traffic patterns. Local design for automated censoring and meshing data is needed.

The following areas are of high importance, but according to the experts are **more challenging to improve** than the previous set of elements:

#3 Communication systems: Dedicated channels for maritime communication: MF-, HF- and VHF-radio enhanced with digital communication and navigation infrastructure (R-Mode) and digital services calling and IP-networks (e.g., Inmarsat) and devices (emergency beacons) connected with Maritime Rescue Coordination Centres (MRCC). Increases communication capacity for better coordination and managing exceptional/ hazardous situations.

#16 Support for Search and Rescue (SAR) requires exchange of information between MRCC, first line responders, emergency services, and authorities.

#11b Remote pilotage to ensure navigational safety in all conditions. The new remote service would be provided without pilot entering the ship. For the vessel this allows time savings and more flexibility in timetables. Remote pilotage requires reliable ship-shore communication and on-board automation.

#18 Situational picture is an element that would collect and present all relevant information of the conditions, traffic and vessel in an understandable format for the user. At best it could include predictive measures for avoiding collisions, hazards, and exceptional situations. However, after lengthy discussion in the workshop and also in group email conversation afterwards, the experts came into conclusion that the situational picture is user and context dependent; for instance, the sets of information and services forming the situational picture are different for a navy vessel, or an oil tanker or a sailing boat.

If the first priority elements are to be implemented in real within the given time window (5-10 years), one should start improving the infrastructure on most critical places. We identified the critical spots being (from observing official accident reports, discussing with the experts and from secondary sources, e.g., Vaimala, 2020). These are:

- Fairway crossings (with dense traffic, or obstacles of vision)
- Narrow places (e.g., straits with currents, areas limited by shallows and/or rocks)
- Points of handover of responsibility (at pilot entry points, or at the harbours)
- Areas without, or with insufficient SAR-services.

Starting from the reduced set of places, it is more feasible to reach for autonomous traffic on territorial waters in 5 to 10 years. This would require careful consideration on creating an open platform for meshing information from various sources to let emerging user segments develop their own services.

6. Fairway infrastructure as a platform

If we look the design of the current infrastructure, the priority has been to safeguard merchant and passenger traffic all year round, and only secondarily, the other uses. However, increasingly mobile and digital navigational aids, increased awareness and services could be – and has been - developed also to the other user groups. The incentives for designing systems for global, regional and local use differ - ocean going vessels are to follow global IMO, SOLAS[2] procedures and IALA[3] standards, whereas national and (not to mention) local requirements are considered extra, incompatible burden for the shipping lines.

The growing utilization of water area at large especially with increasing recreational activities would need further development and investments to fairway infrastructure and services to guarantee safe and sustainable use of territorial waters.

We suggest looking into digital platforms, which have been able to overcome dilemmas of inappropriateness and underinvestment. Similar to our context, they require upfront investments, but they regulate the participation to maximize positive externalities, whilst mitigating negative ones. Also, different strategies in regard to the allocation of control are frequently discussed, to find different approaches for successful inclusion of various parties. These principles of attracting communities to contribute to the governance and development of common resources have been recently applied successfully for creating multisided platforms. This has culminated in the discussion of control over platform vs. openness to parties as key factors towards innovation on multi-sided markets (Hagiu, 2013). Deciding on the degree of control (vs openness) is seen crucial on the motivation of the participants, increasing the reach on useful resources and boosting innovative capacity of the participating contributors.

Building on our analysis and theory base, we propose the main responsible party of the Finnish fairways, i.e., the authorities, should ensure the correct functioning of core elements and provide access to them in an organized manner. In parallel, they could allow more open, local development in selected non-core elements. This way private enterprises and user communities could create additional services to cater the needs of varied user groups, expanding the fairway services beyond merchant traffic.

Hence, a large network of actors is needed to achieve the Finnish objective to build smarter fairway, which could offer novel services, increase safety, enable more fluent, economically, and environmentally sound sea traffic. This is especially true, as the use of territorial waters has changed both in qualitatively and quantitatively. The central parameters of design are its openness in terms of its strategic orientation towards growth and organizational structure, to some extent also facilitating the inclusion of local communities of interest.

[2] International Convention for the Safety of Life at Sea

[3] International Association of Marine Aids to Navigation and Lighthouse Authorities

7. Conclusion

Enhancing the fairway to facilitate automated traffic requires complex and costly infrastructure. Investments on physical infrastructure can be supplemented with digital infrastructure and services, but so far, they are only haphazardly integrated to serve various needs of water area users when mobile on different seacrafts.

Against the backdrop of increased traffic on Finnish territorial sea and increased digital navigational aids for mobility, there is an obvious need to rethink the fairway infrastructure and related services for safe, efficient and sustainable navigation for all seafarers.

The increased automation and pursuit for autonomous maritime traffic require additional sensors and mobile services on the go. This paper presents the most important elements identified by experts during the iterative Delphi study. Our findings show that the critical cargo and passenger traffic is the conventional starting point for intelligent fairway design, and it should be compatible with international standardization requirements and processes, which are tedious and time-consuming efforts, not always sensitive to the local needs. Even though, the elements are designed primarily for merchant traffic (of cargo and passengers), most of the extra functionalities can be utilized by emergent users of the sea, if designed from the beginning.

In order to meet the near future targets on time (i.e., 5-10 years), it is feasible to start from the safety critical sections of the fairway: Pilot entry/exit points, straits & shallows, fairway crossings and handovers to harbour area interfacing the international traffic. These are points where the infrastructure investments could be shown to augment safety, and help avoiding escalation of risks. This also enhances the information for SAR, customs, guarding, policing, learning from accidents and near misses for better safety, efficiency and environmentally sustainable cargo and passenger traffic to ensure supplies for the economy.

However, the authorities' budget is limited in investing and developing new services for the emerging, less important, but more vulnerable farers and recreational users on sea. We cannot avoid the conclusion that the authorities' main interest is to ensure the quality of services for merchant users. For all users the lowest common denominator of the elements is to guarantee timely and correct data for all seafarers.

Therefore, as the answer to our second question, who should be responsible for the investment and provision of the services, we propose that authorities

(=public sector) should make initial investments to ensure the integrity of data and services of merchant traffic first, and thereafter establish jointly with other members of the maritime ecosystem an open platform where diverse user groups can design, try, implement, and test services to their specific needs. The platform can also crowdsource and share improved information for better situational awareness for safe, efficient and sustainable seafaring, even for autonomous traffic. Sharing data and standardized, open interfaces have boosted the development of mobile services to the local needs and we are proposing essentially the same for creating fairway services especially on territorial waters adapted to the local circumstances and needs.

The proposition also avoids the problem of investing in common resource: The new groups can reap the benefits from sharing data and attracting new users to join multi-sided markets on a common platform, but only if the existing data and service elements are open for them to set their own enforceable rules in line with the automated traffic and enhanced fairway infrastructure. One can easily figure out that critical elements for safety is different for jet ski riders in the summertime, or Nordic skaters on Spring ice.

This would also call for recognizing emerging standard procedures for autonomous marine vessels in the case malfunctions, or rule-violations, but these considerations are beyond the scope of this paper. So is also the increased need for accumulating information for education for operating on an enhanced fairway. Finally, we do not have a such platform available at the moment, but its elements. They have to be meshed with the already existing information under standardized APIs and ancillary mobile services.

The service platform provides an opportunity to divide responsibilities of the authorities, users and connect service providers in a loosely coupled way to serve growing user base and emerging uses of public infrastructure investments.

Although this research focused specifically on fairways, it could also be applied to other areas of society with similar needs regarding questions such as who should make the necessary infrastructure investments, how to define what are important and effective infrastructure services, and how the data created in public infrastructure services could be made available to mobile and other digital service providers and users.

8. Acknowledgements

We are grateful to the reviewers for their valuable comments.

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