EMMA EXTENSION SMART FAIRWAY IMPLEMENTATION REPORT

Implementing Smart Fairway Solutions

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Content

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The Interreg Baltic Sea Region Programme 2014-2020 supports integrated territorial development and cooperation for a more innovative, better accessible and sustainable Baltic Sea region.

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More information on aims of the programme, funding possibilities and how to get involved: https://www.interreg-baltic.eu/home.html

1 ABBREVIATION LIST

Abbreviation	
BSR	Baltic Sea Region
BSRP	Baltic Sea Region Programme
IWT	Inland Waterway Transport
MS	Member State
RIS	River Information Services
TEU	Twenty Foot Equivalent Unit
VTS	Vessel Traffic Services
ROC	Remote Operating Center
PP	Project Partner
AO	Associated Organisation
VTMIS	Vessel Traffic Management Information System
AIS	Automatic Identification System
SOLAS	Safety of Lives at Sea
FTIA	Finnish Transport Infrastructure Agency
LIS	Lake Information System

2 BACKGROUND TO THE REPORT

The Interreg Baltic Sea Region Programme's EMMA project (2016-2019) clearly showed that central European RIS applications will not be the solution for Finnish IWT. Finnish systems used are VTS and smart fairway solutions. Another system is not feasible to install. However, EMMA proved that functional extensions could support the increase of safety in navigation and simplify transport management solutions. The overall aim in this GoA is to support the further harmonisation of River Information and Vessel Traffic Services (RIS/VTS) in the BSR, based on the recommendation given in the EMMA policy paper (chapter 4.3 "Digitalisation"). Thus, smart fairway technology will be developed and implemented. The focus is put on aids to navigation by digitalised buoys being part of a smart fairway solution.

The benefit of smart buoys has already been analysed in EMMA, but at the stage of EMMA the implementation was not possible. Now, considering describes RIS/VTS developments, a further developed buoy system is beneficial and meaningful for IWT.

The buoys will deliver adjustable light intensity in signal lights. In bad weather conditions light intensity can be set to higher level by pilots on board or ship captains (via an existing app) to better support navigational aids. This brings more safety to shipping. When weather is clear, signal intensity can be lowered again, resulting in longer battery operational lifetime. Further, this technology results in reduced maintenance costs for waterway authorities, which can be better planned in advance and consider specific conditions such as water levels, weather conditions etc.

The implementation will take place in class 2 fairway number 6795 in Haukivesi-Joensuu deep-water fairway section which is fairway used for commercial shipping purposes and is connecting North Karelia to other inland waterway sections in Saimaa area and to Saimaa Canal which is the only link to the Baltic Sea area and Motorways of the Seas (MoS). Pilot action is supported by AO11 Finnish Transport Infrastructure Agency FTIA which is the responsible authority for public waterways in Finland. PP2 will advise how to best create further interfaces to link data to other systems such as ELIAS developed in EMMA project.

This implementation report can be understood as implementation guidance towards any waterway management authority in the BSR showcasing a cost-benefit assessment and sourcing.

By supporting the roll-out of smart fairway technology in the BSR, this GoA implements EMMA recommendation given in the policy paper. Smart fairway technology increases the safety in coastal shipping and inland navigation. It also lowers the risk for accidents by faulty fairway marking, as buoys' positions will be tracked by GPS and their actual position compared to targeted position can be monitored in real-time.

The activity is not state aid relevant. All data, which will be created by smart fairway instruments, is available (open access) on waterway management servers (AO11). As such it can be used by any ship crew (pilots, captains) operating in the waterways has a free access for the benefit of safety and logistic planning in shipping that smart fairway solutions might bring.

3 INTRODUCTION

Year-round marine transportation is essential for Finnish economy and foreign trade. 90 percent of Finnish export and 70 percent of import takes place by sea. The amount of transported goods going through Finnish ports is projected to increase from 100 million tons of 2006 to 150 million tons in 2030. 23 Finnish ports are in use year-round. There has been a need for icebreakers approximately half of the year in the ports of the Gulf of Bothnia and three months a year on the ports of the Gulf of Finland (Ilmasto-opas.fi. 2020).

In Finland, there are altogether approximately 16 300 km of state-administered fairways, approximately half of which are coastal fairways and half inland fairways. There are nearly 4 000 km of commercial shipping fairways. Overall, Finland has approximately 20 000 km of public water lanes. In total, there are over 34 000 navigational aids to navigation (such as lighthouses, buoys, beacons and leading marks) on Finnish fairways. Out of these, the Finnish Transport Infrastructure Agency administrates about two-thirds, or 27 500 devices. The fairway network includes the Saimaa Canal leading from the Saimaa lake area to the sea and 31 other locks. The canals are situated in Vuoksi, Kymijoki and Kokemäenjoki water systems. Most locks have been automated for self-service use.

Figure 1: Freight vessel Lindeborg in Saimaa Canal

(Source: Tulkki, P., Robodrones Ltd. 2020)

The cost-efficiency of commercial shipping has been improved by deepening the commercial shipping fairways in recent decades. The most meaningful factor for the cost-efficiency of transportation in the development of the fairway conditions is the improvement of the condition of the fairways, which in part has enabled the use of planned vessel and cargo sizes in transportation. The amount of trade fairways in poor shape has decreased by approximately 70 % in the 21st. century. The amount of navigational aids in poor shape has also been managed to be decreased and currently they consist of 8,8 % of all aids to navigation. Most significant shortcomings in the condition of the aids to navigation are on the Saimaa deep-water fairway.

The current service level on the fairways matches fairly well with the needs of businesses. There is, however, need for improvement in the case of individual ports and the Saimaa canal. There are numerous locations along the fairway system, which could be improved inexpensively, but still improve the reliability and efficiency of transportation. The systematic implementation of these one to five million euros projects is not possible with the current level of funding, so the conditions for vessel transportation cannot be improved cost-efficiently to match the transportation needs. On the commercial shipping fairways there is a significant amount of aging structures, on which the investments for repair will take place in the coming years.

In September 2929, the Finnish decided to proposed a funding of 90 million euros for 2021 for the extensions of Saimaa Canal locks by 11 meters and five million euros for the raising of water level (Finnish Ministry of Transport and Communications 2020). This gives a clear signal of the importance of inland water traffic in Finland and allows the navigation of larger vessels in Saimaa area, which highlights the importance of investing into tue safety of navigation.

The updated Finnish Water Traffic Act came into force in the beginning of June 2020. One of the goals of the revision is to enable the automatization of water traffic. The new act also aims to clarify the roles and duties of water traffic authorities (Traficom 2020).

3.1. State-of-the-Art in Finnish Fairways and the history behind

The earliest seamarks in Finland were built in the middle ages. They served almost exclusively daytime traffic. Even though there were lighthouses in use in the Baltic Sea region, in Finland they didn’t yet exist at the time. Typical seamarks used in Finland were heaps of wooden poles or 1,5 to 2,5 meters high cairns made of stones, which were often whitewashed with chalk. Barrels and broom beacons placed on water were also used. The first lighthouse in Finland was completed in the island on Utö on the Gulf of Finland in 1753. Until the 1870s the principal lighthouse building material was brick, but in the 1880s iron became the principal material. The arrival of automatic small lighthouses in the early 20th. century lead to a rapid decline in the use of cairns and wooden heaps. First fully automatically functioning lighthouses were introduced in Finland in the 1920s (Nyman, H. 2009. p.6-8, 11-12).

Lighthouses enabled the navigation in the dark winding fairways. Early automatic lighthouses required a lot of maintenance and the employment of at least a part-time lighthouse maintenance person due to their operational unreliability. The early automatic lighthouse apparatus was placed inside a protective booth. At first the automatic small lighthouses were situated near the fairways e.g. on rocks, but later they were placed on higher concrete of iron bases, so they could be seen further away. Petrol as a fuel was replaced by acetylene gas on the lighthouses during the first decade of the 20th. century. The reliability of the lights improved significantly with the arrival of gas, and full-time lighthouse maintenance personnel was no longer needed (Nyman, H. 2009, p. 9).

Figure 2: A sniffer buoy with a Finnish cruise ship in the background

(Source: Kine Robot Solutions Ltd. 2020)

Maritime industry has long been a so-called traditional industry. Roles in the value chain have been specific and the industry has relied on technical inventions restricted within the industry. Data transmission in maritime industry was slow and expensive for a long time. This has changed as satellites, radio systems and different sensors have become cheaper. A large ship can utilize smart technology in many ways, as it can been simultaneously seen as a power plant, hotel and a vehicle. The first change has been the utilization of large quantities of data for example in navigation. Data on ocean currents and weather can be utilized in optimization of traffic routes. Energy is also saved through new inventions such as wind rotors. Vessels now have more than one source of energy. (Kukkonen, 2017).

On the other hand, the digitalization has changed the service models. Ownership and the providing of services are becoming separated. For example, Amazon China has announced it is starting ocean transportations. New kinds of actors are combining data on cargo and free vessels and operating without their own ships. This is comparable to the arrival of discount airlines, Uber, or Airbnb and the deployment of empty capacity. However, there is still demand for special transportation even in the future, partly as a matter of trust. Other actors don't require the same level of service, which creates variation to the markets. A third change is the utilization of research and innovations in other industries. New influences can be taken for example from auto industry or the hotel business. Open information systems and start-up companies offer agile solutions, which can help survive through the digital revolution in maritime industry. Autonomous vessels are not yet in everyday use, but autonomous ports already exist, and Finnish companies such as Cargotec and Konecranes have taken part in that development (Kukkonen 2017).

Figure 3 A vessel transporting timber on lake Saimaa

(Source: Hakulinen, T. 2020)

First experiences of digitalization in Finnish maritime traffic came when automatic navigation systems and electronic navigation charts were deployed on ferries operating between Sweden and Finland in the 1980's. Due to the limited capacity of the computers of the time, one system was not able to process all of the necessary information (Tompuri 2016).

At the end of 2019, Finnish Transport Infrastructure Agency (FTIA) maintained 25 435 fairway aids to navigation. Out of these, 2 303 were on commercial inland fairways, 1 273 of the commercial inland fairway navigational aids were illuminated and 1 030 were "dark". In comparison, there were 3 948 aids to navigation on commercial coastal fairways, out of which 2 174 were illuminated. In addition to the navigational aids maintained by FTIA, there were 9 404 navigational aids maintained by municipalities and private actors, out of which 107 were on commercial inland fairways (Väylävirasto 2020. Väyläviraston ylläpitämät turvalaitteet 31.12.2019).

4 ADMINISTRATIVE PROCESS

The implementation of new fairways and fairway navigational aids requires a decision from the Finnish Transport and Communications Agency Traficom. The decision is required also when fairways and aids to navigation are taken out of use, as well as when certain “navigation-technical” changes to waterways or navigational aids need to be confirmed. The data about the fairways and navigational aids confirmed in the decision are added to the Finnish Transport Infrastructure Agency’s fairway database. After this the information can be published in navigational charts and other navigational publications. The decision can be directed to a single aid to navigation, a group of navigational aids, a section of a fairway, or the entire fairway (Traficom 2019, Väyläpäätösten valmistelu ja käsittely, p. 4).

When the decision on the building of a fairway has been given, the next steps are procurement, tendering of the supplier and contractor and placing orders. After procurement decision, the contractor acquires the materials and plans the implementation. The contractors use its own equipment in building the fairway. During the building process the old buoys are removed and replaced with new devices, which in the case of a smart fairway are connected to the remote monitoring system and can be monitored through a network connection. The reception and survey of the fairway are done when the fairway is ready (Kotisalo 2020).

4.1 Planning

As a rule, smart buoys are installed in the place of traditional navigational aids. The navigational aids are usually already placed in rocky places on the fairway. The pilots using the fairways usually make requests on adding rather than moving navigational marks. For example, on the pilot destination presented in this report, one or two new navigational marks have been added on the request of pilots. (Sikiö 2020).

4.2 Tendering process

So far there has not been a shortage of available contractors for the installation of smart buoys in the destinations tendered by the Finnish Transport Infrastructure Agency. The light devices for the Finnish Transport Infrastructure Agency are provided by Sabik Ltd. Currently the light supplier is not being tendered. In the case of remote controlling there is framework agreement in effect. The supplier for remotely controlled devices has been tendered for all the fairways maintained by the Finnish Transport Infrastructure Agency at once (Kotisalo 2020).

4.3 Implementation

The fairway is officially in use, when the contractor announces that the fairway is ready. At this point, separate test use is no longer performed. In the pilot case presented in the report, there is no need to get a confirmation for an altered fairway, as there has been no change in the location, light signal, etc. (Kotisalo 2020).

The components of the light and safety equipment of the fairways must be approved by the Finnish Transport Infrastructure Agency. For example, the beacon, chain, light device and weight of a floating device all must fulfill the standards set by the Finnish Transport Infrastructure Agency. The Agency also sets the requirements for the data the smart device must gather and the interface through which the information is transmitted for the use of the VTS center. The Finnish Transport Infrastructure Agency tenders the software developers and providers according to the EU Dynamic Purchasing System. Each of the seven jurisdictional areas are being tendered separately (Tuominen 2020).

The fairway administrator is responsible for drawing up and compiling the documents for fairway proposal. Information on the proposal must be accurate enough to examine and establish the purposefulness of the destination in terms of maritime and the adequateness of the implementation as well as to mark the destination and information to maps and other publications. A comprehensive version of fairway proposal includes the documents described in the following chapter.

4.4 Proposal

The Following information must be filled into the proposal form for a fairway decision:

- essential information about the proposed destination
- naming of a new fairway must follow the principles and practices according to the instructions of the Finnish Transport Infrastructure Agency

Description of the proposed fairway

- basic information about the fairway/project
- changes resulting from the project
- mention of the procedures causing a change in the depth of water
- mention of the changes made to nautical chart

A general map (excerpt from a nautical chart)

- detailed information on fairways, navigational aids as well as mapping and depth data
- information on dredging, verification measuring and stacking areas for sand, silt and debris from dredging operations

Special maps and more detailed maps of the area (if needed)

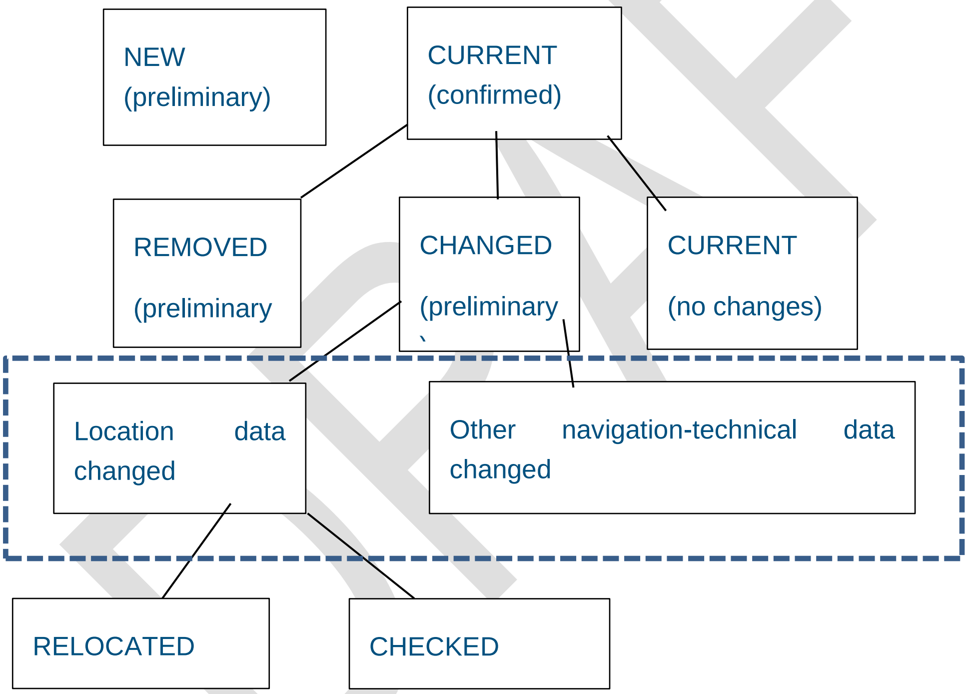
- large scale maps which include information that is difficult to present on the fairway proposal map

Co-ordinate and destination lists

- coordinates for fairway lines
- coordinates for the fairway area (border lines for the fairway)
- list of navigational aids (current, changed, new, removed)
- other additional reports and information (if needed)

(Traficom 2019. Väyläpäätösten valmistelu ja käsittely, p.8.).

4.5 Decision process



These changes can be in effect simultaneously

Explanation texts and their interpretations used in fairway decision documents:

RELOCATED	Navigational aid has been relocated in the terrain
CHECKED	Location coordinates have been looked over, device hasn't been physically relocated

CHANGED	Navigation-technical properties have been changed
REMOVED	Device has been removed
NEW	New device
CURRENT	Existing device, no changes to the current situation

Figure 4: Fairway navigational aid decisions in a fairway decision process.

(Traficom 2019).

FAIRWAY DECISION PROCESS IN A FAIRWAY PROJECT

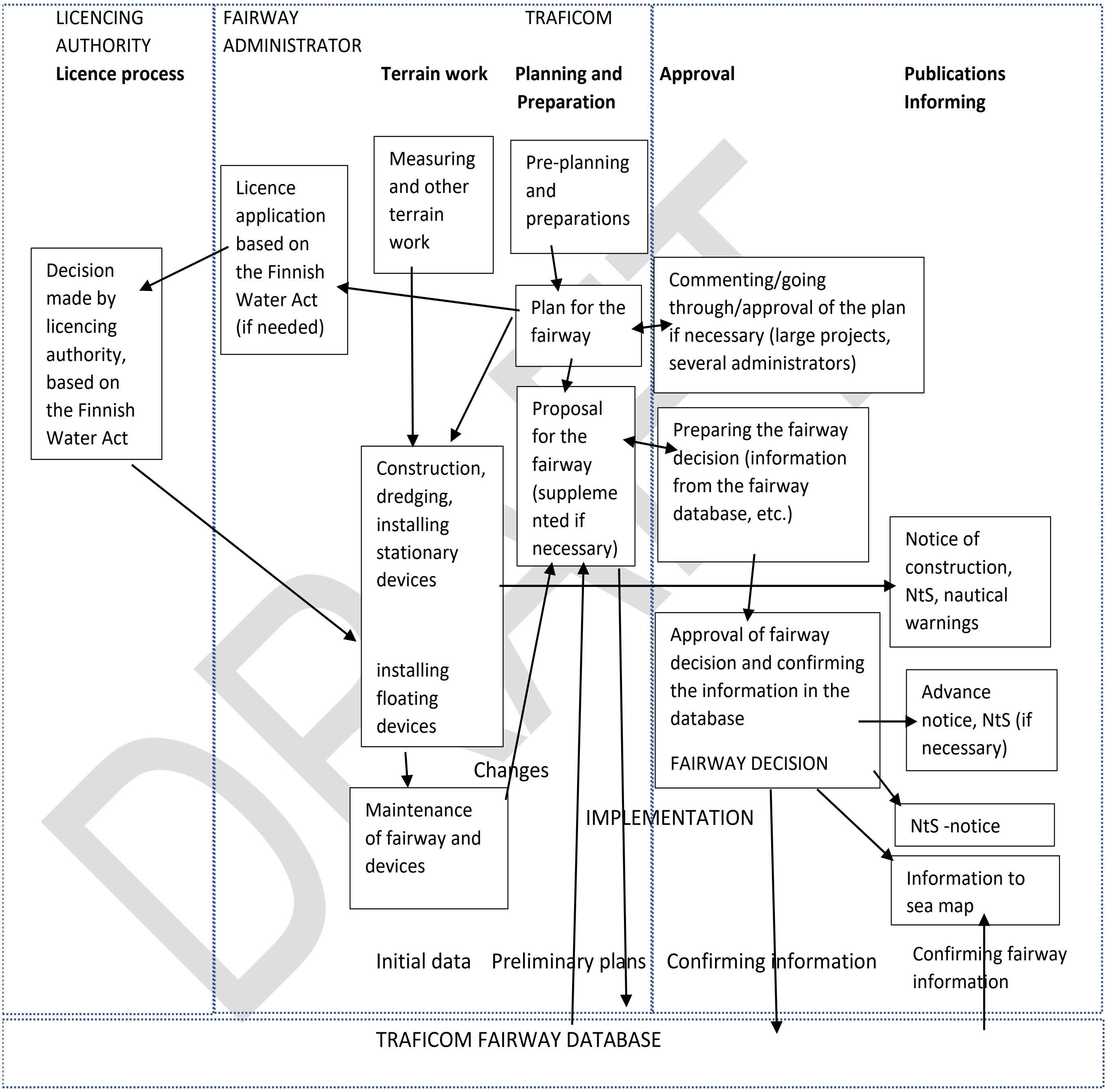


Figure 5: Fairway decision process in a fairway project.

(Traficom 2019).

4.6 Installation

Figure 6 A weight being lowered in the water, pulling the buoy with it

(Source: Hakulinen, T. 2020)

Figure 7: A Smart buoy being installed on the pilot fairway

(Source: Hakulinen, T. 2020)

Figure 8 A smart buoy with the Emma Extension sticker

(Source: Tolvanen, S. 2020)

An “installation ferry” equipped with a crane is used in the installation of a buoy. A weight and the buoy are attached to the crane with a chain. The weight is lowered in the water, pulling the buoy in the water with it (see figure 5).

On the pilot fairway, a weight of 1 200 kg and a buoy weighing 300 kg (almost 400 kg with a counterweight) were used. Each aid to navigation has a GPS-location. This location marks the center of a “dartboard view” with nested circles that shows on a computer screen. This view is used to place the buoy in the exact right spot when lowering and installing the device. Each navigational aid location is checked by June 20th. every year and the installation is logged into the SeaDatics log. If the water is shallow enough (at most five meters deep), a supportive structure can be used to help install the device in the correct spot. The installation requires a crew of three persons, with one person operating as the captain of the vessel. The contract schedule for the Haukivesi-Joensuu pilot smart fairway was calculated based on installing four smart buoys in a day. On a normal day in good conditions, seven buoys could be installed. Maximum amount for buoys installed on one day was nine, which required working overtime (Hottinen 2020). Although navigational aids can be also installed on land, all the smart buoys in the pilot fairway are located in water.

The synchronization of buoy lights enables the lights to blink simultaneously, so that the fairway can be perceived better, which is a clear improvement in vessel traffic safety. GPS satellite provides the time for the synchronization (Sikiö 2020.) Lanterns that use a remotely monitored SLC blinker device the synchronization can be done by changing the setting, With older LedFlasher blinker devices the synchronization is done with an additional synchronization card (Liikennevirasto 2014).

4.7 Maintenance

Ice buoys and other floating seamarks are usually in the water year-round and may be damaged for example by moving ice or due to floating timber rafts. Therefore, they must be regularly monitored and maintained to ensure reliable functioning. Light device maintenance visit procedures include checking the functionality of daylight switch, light signal, LED-lights, lanterns and lenses. Data from lanterns equipped with a SMC flasher device can be read with a programming device through the lense by an IR-link. Changing the light, lantern, battery or the flasher device, or reading the flasher device error code are done if necessary. The Finnish Transport Infrastructure has published a maintenance guide for the light devices in waterway buoys and beacons (Lasma, S., Liikennevirasto 2014, p. 6, 13-16). The location of each aid to navigation is measured every spring (Hottinen 8.18.2020.)

Figure 9 Timber rafting can cause damage and dislocate smart devices

(Source: Tolvanen, S. 2020)

Figure 10 Ice can also move and damage smart devices

(Source: Kotilainen, J. 2020)

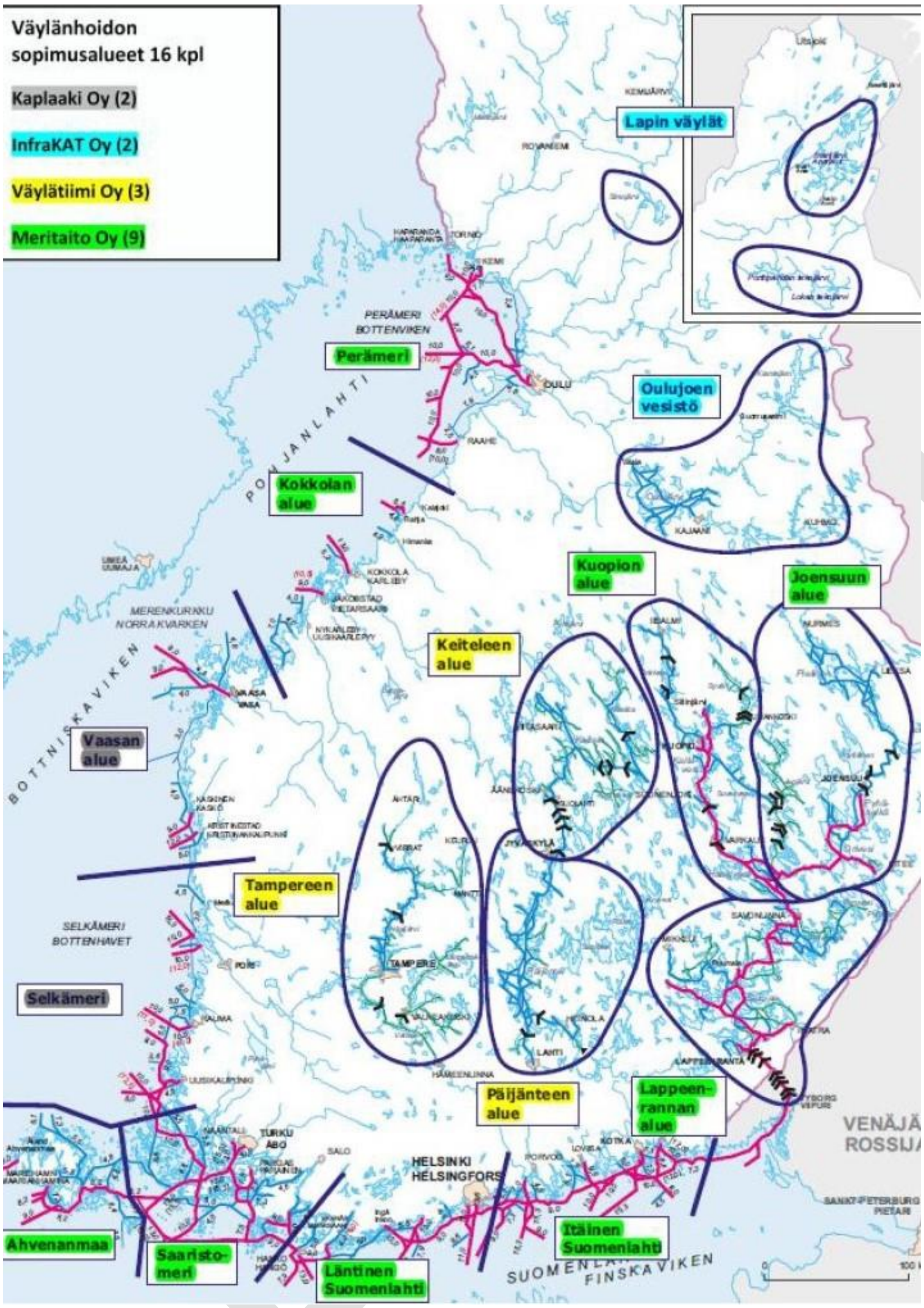


Figure 11: Finnish Transport Infrastructure Agency's fairway maintenance contract areas in 2016.

(Liikennevirasto 2016. Väylänhoidon kilpailutusohjelma ja -aikataulu 2016).

5 SMART FAIRWAY

In a smart fairway, traditional fairway aids to navigation have been replaced with smart devices, which enable their remote controlling as well as gathering data on circumstances and transmitting it to the vessel traffic. A smart fairway transmits real-time circumstantial data to the users, which for example enables the optimization of loading cargo to the vessels, which in turn improves energy-efficiency of vessel transportation. Smart buoys also enable the remote adjustment of the illuminance of the buoys, which minimizes the energy use of the lights. There are currently 800 aids to navigation in Finland on remote monitoring. A new experimentation has been started on the remote monitoring of “dark” buoys. These navigational aids help improve the possibilities of automatization in vessel traffic, but their first costs are about a third higher than those of traditional aids to navigation. Therefore such renewals of navigational aids can be done only in limited amounts on the most important fairway destinations.

Rauma smart fairway uses a SeaDatics -system developed by Nodeon and Meritaito Ltd., which enables remote monitoring of the status and remote adjusting of the light luminosity on a navigational aid. All adjustment changes, person making the adjustment, time and date of adjustment and the adjusted luminosity are recorded (Repo 2017). Each user signed in the SeaDatics -portal is able to adjust and monitor only his/her own navigational aid – for example, a pilot working in the Åland district is not able to adjust the lights on the devices on the Rauma fairway (Tuominen 2020). Any navigational aid (buoys, lanterns, line marks, beacons, spurs, etc.) with a lantern manufactured by Sabik Ltd. can be connected to the SeaDatics system. (Arctia 2020. SeaDatics – Remote management of navigational aids). In the future, maritime cloud service, third party users (such as pilots and ports), SeaDatics customers and the VTS system could all be connected to the SeaDatics cloud service and receive data sent by the navigational aids. Waterway users could benefit from the data through VTS AIS messages (Tuominen 2016).

Figure 12: Cross-section of a smart buoy

(Source: Meritaito Ltd. 2020).

Figure 13 Two smart buoys installed on the pilot fairway, with a battery and light device

(Source: Pohjola, Kari, Meritaito Ltd. 2020)

5.1 Pilot description

Due to the difficulty of navigation and the regular freight traffic towards and from the port of Joensuu, there is a need for turning the fairway 6795 in Haukivesi-Joensuu into a smart fairway. Therefore this particular section has been chosen as the pilot destination (Sikiö 2020.) There are several challenging spots to navigate and tight 90 degree turns along the section. In such places the smart devices are especially useful (Kotisalo 2020). Saimaa fairway is at places very shallow and grounding can take place in a matter of seconds (Koivisto 2015.) For example, a vessel operating in Saimaa was ordered to use a pilot after it had grounded twice in less than a month's time (YLE 2011.)

The deep-water fairway section chosen as the pilot destination is approximately 38 kilometers long. There are 34 traditional buoys on the fairway, all of which will be replaced with smart buoys. Few buoys are already being remotely monitored, but these buoys will also be replaced with remotely controlled buoys. There will be no new locations for buoys on the fairway (Kotisalo 2020).

Figure 14: Location of the smart fairway in Baltic Sea area

(Source: Project EMMA 2020, Cartography David Edwards 2017, European Waterways Map and Directory, Transmache Consultants SARL)

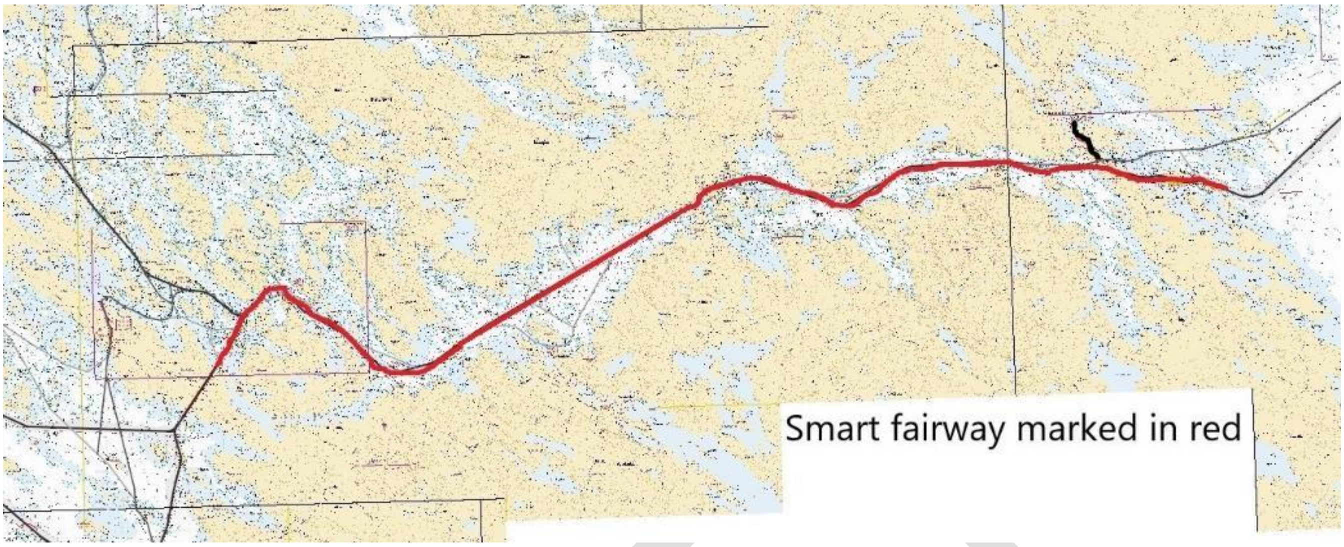


Figure 15: Approximate location of the smart fairway

(Source: Finnish Transport Infrastructure Agency (FTIA), 2020, link to FTIA’s Oskari database: https://julkinen.vayla.fi/oskari/?lang=en)

5.1.1 Project schedule and phases

The first ideas on the original smart fairway pilot destination took place in early 2019. The planning and purchase were done in the fall of 2019. The project was slightly postponed, when the plan to build the smart fairway pilot to the Puhos fairway was relocated to the current destination. This was due to the sawmill company StoraEnso’s decision to shut down the Puhos sawmill and the inevitable major decrease in the volume of freight traffic on that fairway. The installation work on the new destination took place during the summer and early autumn of 2020, with the last buoys installed in August. That way the smart fairway will be in use, as the nights begin to get darker at the end of the summer and there is a bigger need for navigation lights (Sikiö 2020).

5.1.2 Desired benefits

In short, the desired benefits of building a smart fairway are the improvement of navigation safety and, hopefully at some point, the decrease of maintenance costs. Less frequent maintenance visits also lead to decreased emissions (Sikiö 2020).

5.2 Evaluation

5.2.1 Cost benefit analysis smart fairway versus traditional fairway marking

Based on historical data, cost effect evaluation consists mainly of the cost difference of one smart floating aid to navigation compared to a traditional one, which is about 1 500 euros per floating aid to navigation. The addition of smart fairway equipment on a buoy accounts for the main addition in smart fairway costs when compared to a traditional fairway. There are also additional costs from transmission of data, but in Finland these do not account for a major addition in costs.

The cost effects comparison for maintenance cost is hard to evaluate because the implementation of smart fairways has not been factored or tailor-made into the contracts and therefore the cost benefits have not been realized for the fairway administration side. The utilization of information is still in early stages, which also affects the cost efficiency. In the future, the information will be utilized in contract tendering, to also benefit the fairway administrator's side. In the current tendering model, where each individual contract area is individually tendered, the benefits are not visible in the beginning, but if smart fairways are built in the entire contract area, the cost benefits will become much more likely. The current tendering model does not fully motivate the maintenance operator to optimize the fairway maintenance.

On the other hand, placing new technology in challenging circumstances can also add to total costs. This issue has been addressed by the development of more durable buoys and protective structures (see Figure 17), but breakdown of devices can not be completely avoided, which adds to total costs.

Only one study related to the cost-benefits of smart devices was found. The Finnish Transport Infrastructure Agency studied the cost benefits of remote monitoring of maritime aid to navigation in 2011. According to the study report, remote monitoring is economically beneficial in case of illuminated aids to navigation, assuming that remote monitoring is deployed only when a device is replaced according to the "normal" schedule of replacing navigational aids, so that calculated costs come only from adding remote monitoring to the device, not from replacement of the navigational aid. The net savings (savings in device operation minus annuity of the investment and the usage fee) per navigational aid are 40 euros per year for illuminated beacons, 100 € / year for illuminated buoys and 170 € / year for illuminated fixed aids to navigation. In case of unilluminated aids to navigation, remote monitoring was not calculated to be cost-effective (Liikennevirasto 2011, p. 33).

The effect of remote controlling on maintenance visits was calculated using the Bothnian Sea area (west of Finland) as an example area. According to the calculations, remote monitoring could save one maintenance visit to the navigational aids in a year in case of all other types of aids to navigation except unilluminated beacons, where the decrease was on average half (0.5) visits a year. In case of illuminated beacons the average amount of visits would drop from 2,75 to 1,75 visits in a year, with unilluminated beacons from 1,06 visits to 0,56, with illuminated buoys from 2,88 to 1,88 visits, with unilluminated buoys from 1,89 visits to 0,89 visits and with fixed aids to navigation from 2,66 visits to 1,66 visits (Liikennevirasto 2011, p. 20,).

The report gave the following recommendations based on the study of cost-effectiveness:

1. Only illuminated aids to navigation should be taken under remote controlling
2. Remote controlling should be deployed gradually simultaneously with the replacement with the normal renewal of light devices
3. The available investment money should be directed to the contract areas with the most difficult circumstances, not necessarily every area
4. In the contract areas, remote controlling should be deployed primarily to:
   - most difficultly accessible navigational aids
   - navigational aids located near difficulty accessible ones
   - fairway entities.
5. The sufficient accuracy of location data provided by remote monitoring should be ensured

(Liikennevirasto 2011, p. 34).

Location measuring for the traditional buoys on Haponlahti-Vuokala -fairway has been done once a year by boat. The aim is that with smart buoys these visits can be avoided, resulting in at least one less visit in a year. Additional maintenance visits depend very much on the need and are irregular, so they are not as easily countable. The approximately 10 hour measuring trip requires two persons, with estimated personnel costs of 30 euros per person. One trip consumes approximately 1 000 litres of fuel (Hottinen 9.14.2020).

In addition, savings can result form the decrease in the amount of "irregular" maintenance visits and decrease in electricity consumption due to remote adjustment of lights. CO_2 emissions per litre for diesel have been calculated to be 2 640 grammes of CO_2 per litre (Ecoscore 2020.) Therefore, the CO_2 emissions could be decreased by at least 2 640 kilograms per year.

As the addition of smart fairway equipment per buoy is roughly 1 500 €. The Regional Council of North Karelia is responsible for the expenses of the pilot fairway "smartification". When the fairway is in use, costs also come from maintenance visits (which can hopefully be better timed), repairs and replacements of broken equipment, data transmission, etc.

However, the most important benefits of a smart fairway compared to a traditional fairway are improved safety and smoothness of navigation, which are difficult to assess and represent numerically. The investment costs of a smart fairway can be theoretically compensated if one large accident can be avoided with the help of a smart fairway. A fairway is essentially a place or work for vessel captains and pilots and a smart fairway helps create better working environment for them by improving safety and smoothness of navigation. Accidents are a sum of several factors, but maintenance costs can also be lowered as by avoiding "unnecessary" maintenance visits, also resulting in decreased amount of emissions. To fully realize the economic benefits from smaller amount of maintenance visits, smart buoys would have to be installed on an entire contracting area, so that there would be no traditional buoys, which would require maintenance visits that can be avoided with the help of smart devices. Smart fairways also improve the service level of a waterway, which may motivate actors to pay for the better service, thus resulting in economic gain.

Below is an estimation on the expected impacts of the properties and maintenance of smart fairways have on various factors related to the use of the fairway:

Impact analysis of the properties of smart fairway on various factors related to navigation (++ = large positive impact, -- = large negative impact, 0 = no considerable impact)

	Safety	Costs	Environment	Accessibility	Data for fairway users and authorities	Enhancing working environment
Data transmission	+	-	0	+	+	+
Remote adjustment of lights	++	-	0	+	0	++
Synchronization of lights	++	-	0	+	0	++
Smart fairway maintenance	+	-	0	+	0	+

Table 1 Impact analysis of the properties of smart fairway on factors related to navigation

Data transmission impacts the safety of navigation by improving and advancing the awareness of misplaced or malfunctioning smart buoys and safety of maintenance through better timed maintenance. This indirectly improves the working environment for pilots and vessel chiefs. We expect the addition of new technology to add to costs through replacements, repairs, license fees and software updates, even though the desired omission of location measuring visits would impact fuel and personnel costs as well. There are also expenses from smart fairway data transmission, but these costs are relatively low in Finland. The desired omission or location measuring visits would mean less emissions, but on the other hand repaired and updated technology is expected to cause visits and therefore emissions. Correct location and status data on the buoys is expected to have indirect positive impact on the accessibility of the fairway.

Remote adjustment should improve navigational safety especially on bad weather. Adjustable lights can also reduce the strain on the eyes and light pollution caused by excessively bright lights, thus improving fairway accessibility, enhancing working environment for fairway users and reducing distraction to people living near the fairway. The synchronization of lights is also expected to improve navigational safety and accessibility, as well as enhance working environment, as the fairway can be perceived more easily when several lights blink simultaneously. As mentioned with location measuring, new technology is expected to add to costs. This applies to remote controlling and synchronization of lights as well.

Regular maintenance of smart fairway is obviously essential to ensure that the smart fairway has the desired impact on safety and working environment. As mentioned earlier, added technology is expected to increase the maintenance costs despite the expected reduction of location measuring and better timing of maintenance.

5.3 Technical specifications

5.3.1 Illumination

The light of a floating aid to navigation consists of the frame, light source (light bulb or a led), optical hardware, a photoelectric cell (with a daylight switch) and the signaling device. A battery is used as a power source (Lasma, S. Liikennevirasto 2014, p. 7).

Finnish Transportation Infrastructure Agency's seamarks generally use Sabik Ltd.'s VP LED or MVP-LED lights, depending on the diameter of the mark. There are also older VP-3 and MVP-3 versions available for light bulbs. The signaling device enables the light to be turned on and off in certain lighting and the brightness to stay constant even if the voltage fluctuates. In addition, the signaling device provides the specific light signal. Modern signaling devices can be programmed with different settings and they provide statistical information on the functioning of the light. Signaling devices are made both for bulb and led lights (Lasma, S. / Liikennevirasto. 2014. p.7-9).

The margin of adjustment on a remotely adjustable light device is significant. For example, on the Färjsund fairway in Åland the luminosity is set at five percent, which equals a light range of approximately two nautical miles. If needed, the luminosity can be raised to 100 percent, equalling a light range of over ten nautical miles (Tuominen 2020).

5.3.2 Battery life of devices

Constant gathering of data consumes battery power to the degree that the aids to navigation maintained by Meritaito Ltd. send their location only once a day. At the moment the capacity of batteries does not allow the constant measuring activity of several sensors on one navigational aid. With the progress of battery technology, however, the company has managed to cut down the frequency of battery replacement on their devices from once a year to once every two years (Tuominen 2020). The battery voltage of a light device is 10 to 20 volts. The voltage of a new battery is 20 volts. When the voltage decreases to 11 volts, the device sends a warning. The warning enables the battery to be proactively changed along other maintenance work and doesn't yet equal a fault notification (Tuominen 2020).

The capacity of a smart buoy battery is a little over 200 amperes. A fixed aid to navigation generally has a 50 to 250 ampere battery and one to three solar panels, which generally produce 50 to 150 amperes per panel. The power of a LED light is between 0,1 and 15 watts (Lehtola 2020). The capacity of batteries sets limits on what can be measured with one navigational aid. Currently it is not practically possible to have several constantly measuring sensors on one buoy, for example, the status data (location, etc.) is sent once a day. However, notifications on malfunctions are sent in real time. Vessel traffic authorities have relatively simple needs in terms of what needs to be measured, limited to the safety of vessel traffic (Tuominen 2020).

Development work is done to solve the issues with smart device power and battery life. Meritaito Ltd.'s and Kine Robot Solutions' air quality Sniffer Buoy has been covered with solar cells, which provides backup power to the 8 kWh battery. However, solar power works much better in locations such as Southern Europe or the UK, where the winter nights are not as long and there is no risk of ice covering the cells, as is the case in Finnish archipelago in the winter. Therefore, a PEM fuel cell, which is powered by methanol, is under development. This fuel cell would be activated when the charge of the battery drops below a certain level. However, solutions such as watertight lock and air filtering are essential to as salt is harmful to the PEM fuel cell. Meritaito's polyethylene buoysinsulate cold quite well, which is why the company is looking into creating a moonpool free of ice inside the buoy (Knight 2020).

5.3.3 Component requirements

Finnish Transport Infrastructure Agency has a list of approved components, that should be primarily used in fairway navigational aids. If components not listed are to be used, a permission from the commissioner is needed beforehand (Väylävirasto 2019, p. 2). The list is attached to all contract enquiries when contractors are tendered (Sikiö 2020.) The component list is for the most part compatible with the component list in fairway maintenance application Reimari (Väylävirasto 2019, p. 2.)

Figure 16: Battery and light device of one smart buoy installed on the pilot fairway

(Source: Tolvanen, S. 2020)

5.4 Stakeholders in smart fairway development in Finland

5.4.1 Users and authorities

Finnpilot Pilotage Ltd. has a statutory exclusive right to offer piloting services in Finland. (Finnpilot 2020. Finnpilot Pilotage Oy). In Finland it is mandatory to use a pilot when the hazardousness or harmfulness of the cargo, or the size of the vessel, requires the vessels to do this. Exception is made with vessels, whose captain has completed a fairway- and vessel- specific Pilotage Exemption Certificate, or vessels that have exemption from the use of a pilot granted by the Finnish Transport and Communications Agency Traficom. (Finnpilot 2020. Mitä luotsaus on?).

The Finnish Transport Infrastructure Agency (FTIA), in Finnish Väylä, is responsible for the development and maintenance, as well as the infrastructure, of state-owned fairways in Finland (Väylävirasto 2020. Väylä.)

Traffic Management Finland controls and manages traffic on the land, in the air and at sea. VTS Finland, a subsidiary of Traffic Management Finland, provides traffic information that helps companies to create new traffic and smart mobility solutions for people and goods and is responsible for monitoring the safety and smoothness of marine traffic in Finland. VTS Finland is in contact with the vessels and provides them with information about other traffic, weather condition and other circumstances, as well as faulty navigational aids and other safety factors. VTS Finland also directs traffic and, when needed, assists in navigation. In addition, VTS Finland maintains radio service for vessel safety. There are three VTS centers in Finland, which enable the monitoring of all commercial shipping routes on the Finnish coast and in the inland deep-water fairways of Saimaa. In addition, Helsinki Traffic collaborates with Estonian and Russian authorities in monitoring the international waters on the Gulf of Finland. (Traffic Management Finland 2020. VTS Finland lyhyesti). Saimaa VTS center, which is responsible for monitoring the Saimaa deep-water fairway, is located in the town of Lappeenranta in southeast Finland. The Saimaa Canal traffic is not part of its jurisdiction. The operation of Saimaa VTS center operates during the vessel traffic season, which is largely compatible with the operating season of the Saimaa Canal. However, the beginning and ending of the vessel traffic season is announced separatively by VTS Finland. (Traffic Management Finland 2020. Keskukset).

5.4.2 Software and hardware developers

Sabik Ltd. offers solutions for maritime navigation and lighting. The company manufactures remotely monitored and remotely adjusted maritime signals (Sabik 2020. About Sabik Marine) and LED lights, as well as power supplies and structures for the signals. (Sabik 2020. About Sabik Marine). Sabik supplies lights for Finnish Transport Infrastructure Agency's smart fairways (Kotisalo 2020.) For example, Sabik Ltd. developed lights that measure the magnitude of waves by following the movement of the buoys through sensors and geographic information system (GIS). The lights were installed on the Gulf of Finland by the Finnish Transport Infrastructure Agency (Väylävirasto 2018. Meritilannekuvan mittaukseen apua Aaltopoijuista).

Figure 17 A smart buoy lantern manufactured by Sabik Ltd., with a special cover to prevent damage caused by timber rafting

(Source: Tolvanen, S. 2020)

Rotations Plast is a Swedish-based company manufacturing different kinds of buoys, pontoons and maritime signals and their components. The product catalogue includes e.g. light buoys, seamark floats, signal lights and batteries for lights (RotationsPlast 2020).

Telia, formerly known as Sonera, is a Finnish teleoperator that has provided sim cards used for enabling the transmission of the information on the status of hundreds of buoys owned by the Finnish Transport Infrastructure Agency and maintained by Meritaito Ltd (MeriTaito 2017. Jo yli 600 merimerkissä on Soneran sim-kortti).

Elisa, Finnish teleoperator, offers mobile subscriptions and 4G network that has been used in the implementation of the Taival fairway navigational aid location solution designed by Emergence Ltd. Taival -solution has also utilized Elisa's IoT platform and ecosystem (Elisa. 2017. Digitalisaatio parantaa merenkulun turvallisuutta).

Kine Robot Solutions Ltd. is a Finnish company that has developed a software called AirNow, which is used in analyzing sulphur dioxide emission measurement results provided by a „sniffer buoy" (MeriTaito. 2019. Meritaidon ja Kine Robot Solutions Oy yhteistyössä kehittämän "Snifferipoijun" prototyyppi pian pilotointivaiheessa).

Nodeon is a technology provider company that has developed SeaDatics -control system for Meritaito Ltd. The system connects navigational aids and buoys online and compiles data gathered by the devices. With the help of SeaDatics Meritaito can monitor the functionality and status of the navigational aids (for example the location and battery charge), as well as gather information about the sea conditions. The data helps to reduce maintenance costs and improve navigational safety. The SeaDatics -system is cloud-based, using global Microsoft Azure platform solution. The platform allows the system to be efficiently scaled and the platform is given almost 100 percent availability guarantee. The data-collection and communication system is mobile-based and has been customized specifically for navigational aids to navigation. All the navigational aidss are gathered in a map view and can be individually or regionally reviewed (Nodeon 2020).

5.4.3 Solution providers

Meritaito Ltd. is the most experienced contractor in building fairways and installing fairway aids to navigation. The company was previously the manufacturing department of the Finnish Maritime Administration, but currently it is a limited company owned exclusively by Arctia Ltd (Sikiö 2020), which in turn is owned by the state of Finland (Arctia Ltd. 2020. Expert in Arctic conditions). Meritaito Ltd. offers products and services in e.g. fairway maintenance, measuring, maritime safety, fairway planning and construction (Meritaito 2020. Osaavin kumppani vesialueiden palveluiden hankintaan.)

Meritaito Ltd. also manufactures polyethylene buoys designed to endure wintry conditions. There are 27 000 buoys in use in Finnish fairways. Meritaito Ltd.'s buoys are designed to endure ice (MeriTaito 2020. Viitat ja poijut). In addition, the company designs and manufactures smart buoys, in which the polyethylene buoys is equipped with sensors and data transfer technology, enabling the gathering and real-time transmission of water data, such as the height of water and waves, current, location of the device and the status of a light device (MeriTaito 2020. Älypoijut). In 2019, The Finnish Transport Infrastructure Agency Väylä was Arctia Ltd's main customer, with fairway maintenance playing a major role among services provided for Väylä. In addition to domestic markets, in 2019 navigational aids and buoys were sold to Estonia, Norway, Russia and Latvia (Arctia Ltd. 2020. Year 2019).

Luode Consulting specializes in water modelling services and physical and chemical measurements carried out in challenging conditions. The company also manufactures and sells measurement stations used in measuring the quality and level of water (Luode Consulting 2020). As an example, Luode consulting was a sub-contractor co-operating with Meritaito Ltd. in the development of a smart buoy for oil spill detection, which was installed outside Porvoo, Finland in October 2016 (Finnish Environment Institute 2016.)

5.5 Potential additional functionalities for aids to navigation

5.5.1 Vessel emission detection

During the year 2020, Meritaito Ltd. and Kine Robot Solutions Ltd. are testing a prototype of a “sniffer buoy“ in Naantali, southwest Finland. A Sniffer buoy is a smart buoy that is capable of measuring, in this case, the sulphur dioxide content in the air, which helps in the assessment of the sulphur dioxide emissions of a passing ship. In Finland, the Finnish Transport and Communications Agency Traficom is responsible for monitoring the sulphur dioxide emissions. Basically the sniffer buoy can be installed along any fairway. The sniffer buoy is constantly active, producing measurement results online. Ideally, a sniffer buoy can operate several years without maintenance. The sniffer buoy uses a combination of solar panels and chargeable batteries as a power source (MeriTaito 2019. Meritaidon ja Kine Robot Solutions Oy yhteistyössä kehittämän ”Snifferipoijun” prototyyppi pian pilotointivaiheessa). The first sniffer buoy was put in use at the end of May 2020 for a pilot period which will last until autumn 2020. The functionality of the device and the reliability of the measurements are to be verified by the first pilots (Arctia Ltd. 2020. First Sniffer Buoy pilot started).

Figure 18 A sniffer buoy measeures buoy measures vessel emissions

(Source: Virtanen, S. Arctia Ltd. 2020)

To process, analyze and share the vessel emission data gathered by sniffer stations, Kine Ltd. has created a cloud-based emission monitoring service called AirNow. Authorities and ports can follow the data, which is processed through algorithms, from the web-based user interface. In addition tot he information gathered by the emission detection equipment, other data such as wind, humidity, temperature, AIS and ambient pressure, is used in data analyzation. AirNow shows the fuel sulfur content of the passing vessel, which, together with database records helps the authorities decide if an on-board check or other actions are necessary. Measuring stations operate automatically 24 hours a day and can store data for several days in case they are out of range of mobile networks (Kine Ltd. What is AirNow?. 2020). The amount of sniffer stations that can be added to AirNow system is unlimited. The raw data collected by the sniffer stations can be transferred through 4G or 3G routers (Kine Ltd. Monitoring System. 2020).

5.5.2 Wave height measurement

Smart buoys can also be used to measure the magnitude of waves. In November 2013 Finnish Transport Infrastructure Agency installed lights measuring the movement of the buoys by sensors and geographic information into buoys located on the Gulf of Finland. The lights were manufactured by Sabik Ltd. In addition to the wave data, the lights provide approximate information on the magnitude of winds. The data provided by the buoys has been utilized more comprehensively since 2017, when a software was developed, which compiles the information into a sea state. In June 2018, there were 13 “wave buoys“ in use in Finland (Väylävirasto 2018. Meritilannekuvan mittaukseen apua Aaltopoijusta).

In their permanent measuring stations, the Finnish Meteorological Institute uses anchored buoys with a diameter of either 0,7 or 0,9 meters so that the movement of the buoys freely follows the movement of the waves. These Directional Waverider -buoys measure the waves with the help of three acceleration sensors and a compass. One sensor measures the acceleration of the buoy in vertical dimension and the other two in horizontal dimension. This way, the height, frequency and direction can be measured. In addition, the buoy measures the temperature of the surface water. The data is sent to land through a HF-radio link or Argos satellite system. The Finnish Meteorological Institute also has smaller DWR-G4 wave buoys that can be used in temporary measurements and are floating freely or are briefly anchored (Ilmatieteen laitos 2020).

5.5.3 Oil spill detection

A smart buoy measuring the oil concentration of the water and manufactured by Meritaito Ltd. was put into use in October 2018 south of Helsinki on the Gulf of Finland as part of the Finnish Environment Institute’s co-operation in the GRACE project, which aims to develop the smart buoy technology used in monitoring oil spills. The project is coordinated by the Finnish Environment Institute and funded by European Union’s Horizon -program. The buoy uses a mobile connection to transmit more accurate information online about the concentration of oil, which enables a faster identification of oil spills and implementation of oil destruction measures. The information can be utilized by not only authorities responsible for oil destruction measures, but port authorities monitoring their territories and environment protection authorities as well (Suomen ympäristökeskus 2018). Tests for “oil buoys” developed by Meritaito Lrd. and sub-contractor Luode Consulting took place in October 2016 outside Porvoo, southern Finland. A smart buoy with an oil detecting sensor was installed near an oil refinery in Porvoo, to be used for data transmission during the winter of 2016-2017 (Finnish Environment Institute 2016).

Figure 19 An oil spill detection buoy

(Source: Luode Consulting 2020)

5.5.4 Water quality measurement

The measurement of water quality and the concentration of blue-green alga may become more common as objects of measurement for smart buoys. This would provide useful information for the administrators and users of beaches. Smart buoys can also be used in measuring the emissions and effects of agriculture to water. At the same time, information can be gathered for navigation on attributes such as depth of water, height of waves and current. Smart navigational aids gathering new information can be added when aging devices are being replaced with new ones. Constant observation can provide more reliable information for example on the water conditions compared to sporadic sampling (Pohjoisranta

BCW Oy. 2011). A buoy measuring water quality was installed in Pyhäjärvi, Säkylä, Finland, in May 2019. The buoy functions continuously and transmits almost real-time data which is utilized in water protection as well as in the monitoring and research of lake condition. The measuring buoy is used to observe the temperature, opacity and humus concentration of water, as well as phycocyanin indicating the amount of blue-green alga, and chlorophyll, which indicates the level eutrophication (Suomen ympäristökeskus 2019).

5.5.5 Location detection

With the help of a smart device, the buoys on the fairways can notify their location, which prevents them from disappearing. There were 17 000 floating buoys on the fairways maintained by the Finnish Transportation Infrastructure Agency, out of which is more than 700 disappeared annually. The number of disappeared buoys was especially high in the winter as moving ice moved and broke buoys. A disappeared or displaced buoy increases the risk of the vessel running aground and thus presents a major safety risk. With the location information available, the amount of arduous inspection visits has decreased (Väylävirasto 2017).

5.5.6 Ice movement detection

The so-called ice detection buoys enable the monitoring of the moving of ice fields. With the help of buoys installed on the Bothnian Bay in February 2018 by the icebreaker Urho, information can be also gathered on air pressure and the temperature of surface water. The Finnish Meteorological Institute receives a GPS location every hour, which helps to assess the movement of ice fields, which in turn is useful in drawing up the daily ice chart. (Ilmatieteen laitos. 2018. Jääpoijuja perämerelle). SIMB (SAMS Ice mass balance) ice buoys, which were primarily used by the Finnish Meteorological Institute in Baltic Sea in early 2013 to observe the vertical temperature profile of air, ice, snow and water, also provided information on movement of ice by recording the place of measurement. This data served the vessels operating in the Baltic Sea, among others. SIMB ice buoys were first used on lake ice in Sodankylä, Finnish Lappland during the winter 2009-2010 (Ilmatieteen laitos 2013).

6 LEARNING EXPERIENCES FROM STAKEHOLDER INTERVIEWS

Experiences and views from stakeholders on smart fairways were gathered by conducting interviews in February 2020. The results were gathered and composed into the form of a SWOT-analysis and are presented later in this report. The interviewees represented the following organisations:

- Finnish Transport Infrastructure Agency (responsible authority for fairways)
- Meritaito Ltd. (Smart buoy manufacturer and maintenance operator)
- Vessel Traffic Service Center / Traffic Management Finland (vessel traffic monitor)
- Pilots from Finnpilot Pilotage Ltd (pilotage company)

6.1 Users

In the interviews conducted, the users of smart fairways found the remote controlling of lights as the major benefit of smart fairways compared to a traditional fairway. Especially when the weather is foggy or the visibility is otherwise poor, the ability to adjust the lights clearly improves visual navigation, thus improving navigation safety.

Figure 20: Rauma smart fairway

(Source: Meritaito Ltd. 2020)

6.2 Service providers

Fairway service providers also brought up the possibility of remotely adjusting the lights as a benefit. However, the benefits of remote monitoring of the navigational aids stood out in the safety providers' interviews. Real-time data on the status of the smart device helps in the anticipation of maintenance and greatly reduces the need for avoidable maintenance and repair visits, as well as location check-up trips, saving money, time and fuel. For example, it was calculated that in Rauma and other fairways, 6 000 liters of fuel has been saved annually when location check-ups trips have been left out. Another estimate including all remotely operated aids to navigation Finland placed the amount of fuel saved to 8 000 liters, resulting in lower emissions and carbon footprint (Palta 2020.) Maintenance personnel can also see if there are other navigational aids nearby in need of repair or maintenance, which also helps to save fuel and time. In the past, information on faulty or displaced aids to navigation came from the fairway users who saw the faulty or displaced device and reported the information forward. The location data on the navigational aid reduces the number of devices going missing and helps the maintenance personnel look for the device in the correct area. Service providers also mentioned to cost-efficient way to gather data and forward it to not only the fairway administrators and maintenance personnel, but fairway users and possibly third parties as well. The data gathered on smart devices can be used in the development of remote navigation and automatic vessel traffic.

While the use of plastic buoys is not limited to smart fairways, a service provider brought up benefits of replacing steel buoys with plastic buoys. According to research, life cycle costs of a plastic buoy are significantly lower than those of a steel buoy (even up to 50 percent), resulting from the lack of need for regular raising up, sand blowing and painting. There is no practical difference in the operability of the buoys as navigational aids. Plastic buoys are lighter and cause less strain on anchoring equipment. Also, the plastic buoy has less need for inspecting and renewing the anchoring, which can lower the cost of fairway maintenance. The transportation, handling and installation also requires lighter maintenance equipment, which results in lower necessary equipment investments.

One service provider brought up challenges related to the alignment of different operators. A smart fairway in Finland consists of technical solutions and services provided by various authorities and service providers. This can cause challenges with costs, schedules and the compatibility and operability of the services. There can also be conflicts of interest between different operators. For example, research and development of smart fairway hardware and solutions can serve to gather funding for the service provider, with little or no actual benefits for the fairway administrator or to the user. The cost structure and market situation in fairway maintenance can also change in a way that it may serve an operator's interests to slow down the development of smart fairways. Also, a service provider felt that the overall costs of building and maintaining a smart fairway may not be lower than on a traditional fairway, even though smart fairways can improve the operability and production of current services as well as generate new services.

Another representative felt that it is only a matter of time that the amount of circumstantial data gathered from seas and inland waterways with the help of smart buoys increases. The Finnish Transport Infrastructure Agency, municipalities and ports do not have an obligation to gather such data, neither do they have the financial resources to invest on smart buoys that will produce new data. A "missing piece in the puzzle" might be an actor that understands how to profit from the data produced by the smart buoys. This actor could utilize the buoys as a platform for its own data collection, sharing the buoy maintenance and renewal costs with the owner of the buoy, and make profit by selling or sharing the produced data to/with users.

A service provider representative viewed the navigational aid (buoy, cairn, lighthouse, etc.) in itself is as a platform and an existing infrastructure with an energy conservation and remote connection solutions. This infrastructure could be harnessed to produced desired additional information. Sensoring includes a wide array of possibilities, such as water current, water level, water quality (e.g. oil or alga concentration) and air quality, which are currently measured with smart buoys. It can also open new possibilities, for which there will be a need in the future, such as weather stations, video image, strengthening network connections, or transmitting vessel data. This kind of infrastructure has a maintenance and service operator, which can be harnessed to service and maintain the data collection, saving investment costs for the actor collecting the data and making that company more agile. The idea of a smart fairway equipment adjusting the lighting by itself based on the weather conditions might be implemented by connecting a weather station to the smart fairway control system. However, this might increase battery consumption as the lights would be switched on more "just in case", even if there was no traffic. In the future, smart buoy energy sources may be connected to solar panels, which will load them full during the summer, so they can provide lighting during the winter.

6.3 Fairway administrator authorities

Authorities responsible for the administration of fairways brought up benefits for both the navigation as well as the administration and maintenance of the fairways. Real-time information for example on malfunctioning devices, batteries running low, displaced buoys enables the maintenance to be performed on time, batteries to be replaced before the device stops functioning and the displayed buoys to be located easily. Administrators felt that rightly timed maintenance and the decrease in avoidable maintenance visits reduces costs, time and the risk of accidents on difficultly accessible destinations. The decrease in maintenance traffic also decreases the carbon footprint. Accurate location data also helps to avoid separate visits to check up on the location of the buoys. Real-time information helps the authorities transmit the information on weather conditions, vessel traffic or faulty devices to the fairway users more quickly, thus improving the navigation safety.

The benefits for fairway users mentioned by the administrator authorities were largely similar with those mentioned by the users themselves: the ability to adjust the lights enables the fairway to be perceived more easily even on challenging conditions. In addition, the administrator authorities mentioned benefits for third parties as well. The adjustment of lights causes less distraction to people living by the fairways as the lights can be kept dimmer when there is no vessel traffic on the fairway. Also, various kind of information on weather conditions and other circumstances (current, water level, wave magnitude, temperature, opacity of water, etc.) can be provided to third parties if needed.

Administrative fairway authorities brought up various future possibilities with smart fairways. Various kinds of sensors are constantly being developed for smart buoys, providing data for not only maritime, but for example environmental authorities or authorities responsible for oil damage control as well. In this regard, the data needs of a fairway administrator are relatively simple. In the future, adjustments of the lights could become automatic and happen according to weather conditions and traffic. The data provided by the smart devices could also be transmitted to the vessels automatically. The general development appears to be heading towards automatic vessel traffic. Smart fairways are seen as a crucial part of this development, providing data for the vessels. In the future, the communication and data transmission between smart devices and vessels could become more and more automatic. In the future, regular aids to navigation could be harnessed to provide approximate data at lower on conditions such as wave movement and magnitude, which is currently provided by more accurate, but more expensive, buoys built specifically for measuring wave movement and magnitude. With a wider network of measuring devices and better algorithms the accuracy of data could likely be improved. A pilot project on the subject has provided promising results.

6.4 Development suggestions from users

One development suggestion from the fairway users was the integration of the smart fairway user interface into the navigation software. At the present, user of the smart fairway user interface needs to sign into a portal with a mobile device, which can be difficult during navigation (comparable to checking the traffic situation from a phone while driving a car). In relation, the information should be presented in a more user-friendly way, basically on the same screen that is used for navigation. The use of mobile devices can also be problematic due to poor or unstable network connections, especially on open sea.

Users navigating the fairways also expressed the need for “true intelligence”, meaning that the smart fairway system itself can automatically read the conditions and circumstances and react to them by adjusting the lights even during daytime or improve the lighting when a vessel arrives to the fairway. Users navigating the fairway also felt that users of the fairway should be better informed about the smart fairway applications and services. For example, currently there is no mention in ECDIS (electronic map display) of the smart fairway applications of each fairway. In addition, pilots also expressed the need for more information on conditions affecting navigation, such as visibility and wind, which were viewed as more relevant in terms of navigation as data on current, for example. Data on water level combined with reliable forecasts would be useful concerning the draft of the vessel.

The need to improve the reliability of the smart fairway devices came up repeatedly as a need for improvement among the administrative authorities. For example, false notifications on malfunctions cause unnecessary maintenance visits. Fortunately, the amount of false notifications has been managed to be reduced. The frequent updates and new software can cause problems with the functionality of the devices. Sometimes the only option is to replace the entire device with a new model, as the old one is too laborious or even impossible to update. The arrival of constant new device models causes problems with the updating of the software as the old models need to be taken into account as well. Naturally, this increases the equipment costs. Poor network connections on the open sea came up in administrator interviews. This causes problems with data transmission and remote controlling. Administrative authorities also repeatedly brought up the need to develop and improve the software used in smart fairways, which hopefully would result, among other things, in more accurate positioning and better recognition of malfunctioning devices.

Figure 21: A Smart buoy at Helsinki Port

(Source: Meritaito Ltd. 2020)

Fairway administrators mentioned the need to improve the data analyzation software. An automatic analyzation software has been developed to analyze the large amounts of data provided by the 1400 remotely monitored smart buoys, but the software needs to be improved and its utilization expanded. Improvement in the operability of the analyzation software would also lead to improved anticipation of maintenance needs. Automatized analyzation software could pick up anomalies in the data provided by smart devices and thereby significantly ease the administrative and maintenance work.

Fairway administration authorities also noted that even though smart buoys transmit information for the anticipation of maintenance needs, adding more technical equipment into often rough conditions can lead into more maintenance and repairs. As smart navigational aids are more expensive than traditional devices, the cost difference needs to be compensated in lower maintenance costs. Therefore the proper functioning of smart devices is crucial in terms of cost benefits. Currently, smart fairways are been taken into account insufficiently in fairway maintenance contracts, partly due to aforementioned unreliability, difficulty in utilizing information and location accuracy. This could be improved by decreased maintenance visits resulting in lower costs.

Fairway users have expressed hopes for data on conditions, such as current and the height of waves. Data concerning the state of environment does not particularly concern fairway users, but overall solutions like the “sniffer buoy”, which measures the sulphur dioxide concentration in the air, present a major opportunity for development. The possibilities and constant new inventions in different sensors and measuring equipment came up repeatedly in the service providers’ interviews. The natural development of smart fairways progresses as separate small streams of different factors. The changing standards and requirements of international maritime, development of commercial services and vessel support services create a solid base for controlled planning and construction of smart fairways. The goal should be that these streams of development are combined and together enable the smart fairway of the future.

7 SWOT ANALYSIS

7.1 Strengths

Improved anticipation and prevention of malfunctions

- less traffic and emissions from inspections and maintenance
- improved safety as fairway users get information on malfunctions sooner
- improvement and better timing of maintenance
- due to proper timing of maintenance, lower risk of occupational accidents in destinations that are difficult to access.

Historical information on the function of the device (time and date of light being switched on, energy consumption, location history)

Remote adjustment of lights

- saving energy as lights can be kept dimmer when not needed
- less disturbance to the surroundings from constant bright lights
- better durability of batteries
- better detectability of the navigation aid/buoy

Automatic information on the location of the device/buoy

- less devices going missing
- instant notification of a changed device location

Information on signal codes

Data on circumstances (waves, temperature, height of water, current)

- hopes for circumstantial information becoming more common
- information can be distributed to clients and third parties when needed

The accuracy, reliability, quickness and cost-efficiency of gathered data

Smooth distribution of gathered data to all users

Improved operational reliability of the devices

Digital supplementation of fairway markings

Data for the development of remote piloting, controlling and autonomous vessel traffic

7.2 Weaknesses

The need for maintenance

Deficient contract bookkeeping and how contractors utilize the information

The limited amount of specific company expertise

Limited life cycle of the devices

More vulnerable equipment placed into difficult circumstances

Expensive equipment

- must be compensated by maintenance savings

Poor network connections (especially on open sea)

- device not communicating/operating due to network operator's base station not working

Remote controlling not always working

The impact of circumstances on the devices

False notifications on malfunctions

- amount of false notifications has been reduced

Problems and procedures from updated software

- quickening speed of development
- need to update technology
- increased cost in equipment

7.3 Opportunities

Development in the supply of circumstantial data

- approximate information from sensors installed into traditional devices as well

Automatized analyzation of and reaction to circumstantial and traffic data

- possibility of device adjusting the lighting itself according to the weather and traffic

The development of environmental technology

Improvement possibilities for automatic vessel traffic

Lower maintenance costs and more efficient maintenance

Improved operational reliability and safety

Development in analyzation methods and utilization of data

- better anticipation of maintenance needs
- improved perception of anomalies by automatic analyzation tools

Development in the reliability of predictions

The possibilities related to location data

Improved cost-efficiency and quickness of data

7.4 Threats

The utilization and adaptation of new technology in practice

- decrease in malfunctions?
- the realization of cost benefits?

The need to improve and broaden the use of analyzation tools and software

Separate/disconnected applications and the integration of user interface

The functioning of network connections

Positioning of malfunctioning devices

Challenges in power supply

Insufficient information to the fairway users about the smart fairway applications

Operational reliability

- false alarms and subsequent unnecessary maintenance traffic
- higher costs due to unnecessary traffic

Availability of proper circumstantial information

The effect of many separate actors on the costs, schedules, compatibility and operability

The risk of increased total costs and the need for isolated investments

Research and development serving operator's own interests instead of fairway users and owners

A change in the markets and cost structure of fairway use and maintenance

- a collision of interests?
- a motivation for an operator to prevent or slow down the development of smart fairways?

Location accuracy in floating devices

User interface not integrated into the navigational software

Unrealistic goals and presumptions in respect of the resources and actual need

Lack of coordination

- personal interest leading to research positions that involve significant weaknesses
- lack of cooperation between the operators and overlapping projects

Tendering and contracting of smart fairways

- crucial to reap benefits from smart fairways from economic sense, if the aim is to save fairway owner's money

8 HARMONISATION OF RIVER INFORMATION- AND VESSEL TRAFFIC SERVICES (RIS/VTS)

8.1 Finnish Transport Infrastructure Agency's Digitalization Program

Since the implementation of the Finnish Transport Infrastructure Agency's (FTIA) Digitalization Program, which took place in 2016-2018, open data and interfaces have been provided to be used in for example transportation, solution development, construction and communication. The openly shared data, which is obtained from users, enables the digitalization of specific construction and maintenance processes. Transport route users get real-time, updated information on conditions and attributes on the routes. The open data also significantly improves interoperability between different ICT systems (Liikennevirasto 2016. Digitalization Program 2016-2018).

Smart marine fairways were specified by FTIA as one area of development to benefit from open data. Smart marine fairways benefit from the availability of open data through improved services and maritime safety, optimized cargo volumes and transport efficiency, and facilitated navigation reducing the risk of grounding and collision. In addition to studying and developing conditions, forecasts and models, studying the data products in fairway testing surroundings help enable the improvement of navigation and pilotage. Measures for improving safety and services include developing route planning and navigational digital database, as well as providing unified height system and remote-controlled aids to improve navigation. The aim of the program was for the information and data transfer necessary for navigation to be based on internationally recognized standards. Another aim related to improved safety was to make the utilization of information considerably easier. Another aspect of safety is to make navigation in varying routes and conditions safer. Measures improving the optimization of cargo volumes and transport efficiency include creating new methods for more comprehensive, reliable and multi-faceted data collection on sea routes, fairways, port depths, water levels and depth data models. Studying and developing sea condition and forecasts, as well as remote controlling of security devices, reduce the risk of groundings and collisions (Liikennevirasto 2016. Digitalization Program 2016-2018).

Several projects related to smart marine fairways were started in the digitalization program. These include projects on water level information, nautical depth chart models, dynamic calculation of gross underkeel clearance, transferring to the BSCD 2000 height system, marine condition information, remote control of aids to navigation and digitalized Saimaa Canal (Liikennevirasto 2016. Digitalization Program 2016-2018).

8.2 RIS service levels in Finnish context

Finnish vessel traffic legislation is based on seafaring instead of river networks, but the systems can be compared on some level by the coverage level of services. Three different Corridor Management service levels were defined in the CoRISMa project. In Finland, Saimaa Canal and lake area constitute a major part of commercial inland vessel traffic and largely cannot be directly compared with a river fairway system. However, some examples on how the service levels requirements are met in Finland, are discussed below:

”Level 1 Corridor Management is a service to enable reliable route planning by supplying dynamic and static infrastructural information (Fairway Information)

This is the basic level. It deals with the hard infrastructure information and provides the fundamental fairway information required for route planning. On this level, questions such as: “How many locks are on the way?” “Are they open?” “How are the actual water levels?” “Where can that information be obtained?” are answered.

The main task here is to provide fairway information from the point of origin to the final point of destination.” (RIS Comex 2020).

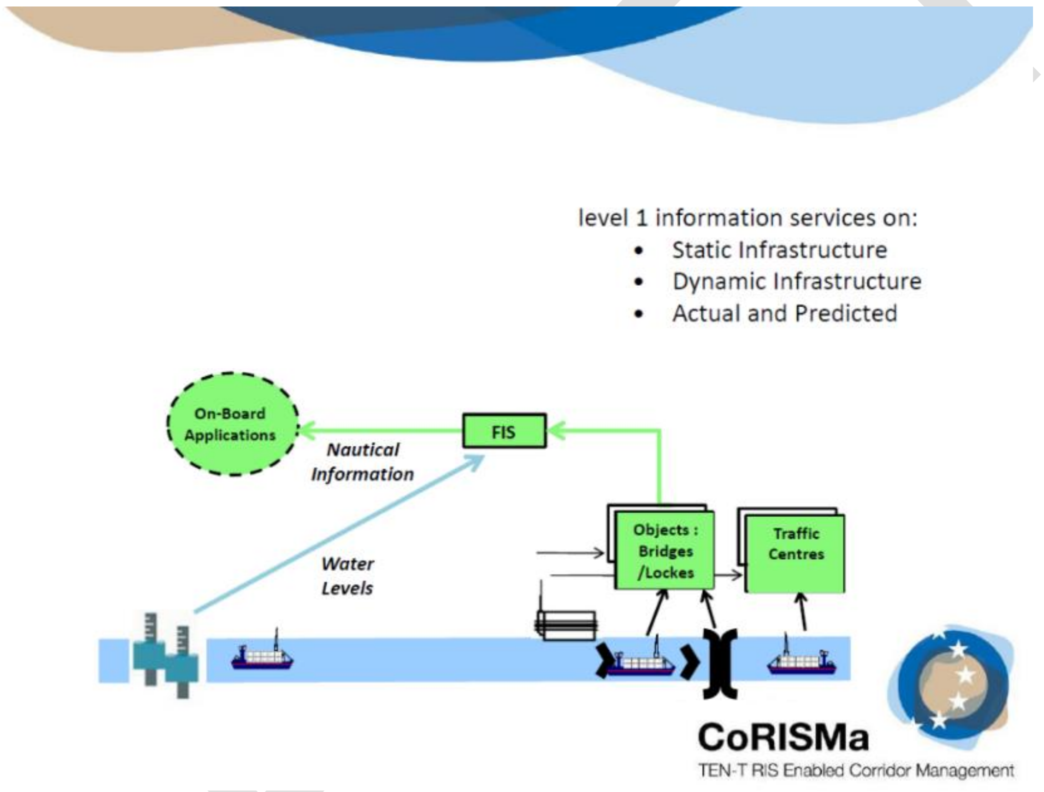


Figure 22: Corridor Management Service Level 1 (RIS Comex)

(Source: RIS Comex 2020).

Information on fairway infrastructure and navigational circumstances is sufficiently available in Finland but dispersed between many sources. The Finnish Transport Infrastructure Agency gives basic information (head height, contact phone number, basic specified features) on the locks of Saimaa Canal on its website. During the traffic season, the canal is open 24 hours a day. (Väylä 2015.) Basic information on bridges can be found elsewhere on FTIA webpages, along with information on other canals in Finland other than Saimaa Canal (Väylä 2018.) The Finnish Environment Institute maintains a website on water levels across Finland (Suomen ympäristökeskus 2020.) Navigational charts also give information on the amount of locks and the height of bridges on the fairways.

”Level 2 Corridor Management is a service to enable reliable travelling times for voyage planning and for traffic management, by providing traffic information

This level builds on the previous one, adding traffic information to Corridor Management. It's logical: Once you have the infrastructure information you need the actual traffic image. You are looking for information such as: How many vessels are on the fairway? What is my estimated time of arrival?

To know the traffic situation on a Corridor allows the stakeholders to plan their voyage better, or to know the position of specific vessels on the waterway network

Level 2 is further sub-divided into:
– Level 2a: Taking into account the actual traffic situation (e.g. actual traffic density, actual waiting times)
– Level 2b: Also taking in account predictions during a voyage (e.g. predicted traffic density, predicted waiting times) where considered reasonable” (RIS Comex 2020).

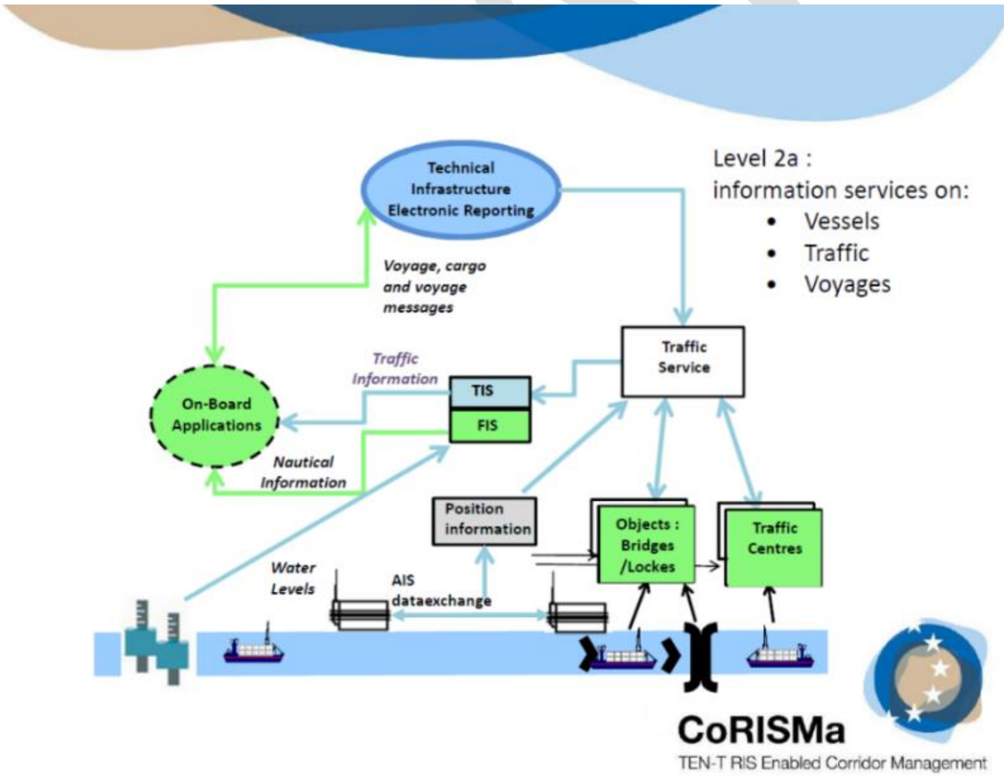


Figure 23: Corridor Management Service Level 2 (RIS Comex)

(Source: RIS Comex 2020).

In Finland, information on vessel traffic situation and other vessels is provided to vessels by VTS centers. VTS informs vessels of the situation or dangers when the VTS center feels it's necessary to do so, on set intervals, when the vessels report to the VTS and when the vessels requests information. In addition, VTS informs the vessels of the current circumstances and the conditions of the fairway and navigational aids. Vessel traffic system has been organized to ensure safe and smooth traffic flow. There are designated areas within the VTS jurisdiction where vessels are permanently prohibited to meet or overtake each other. If the weather or traffic situation requires to do so, traffic can be separated in the aforementioned areas as well as in pilot boarding places. The notification duty is mutual, as the vessel master must inform the VTS center of the following incidents and circumstances:

- "any incidents or accidents affecting the safety of the vessel, such as collisions, grounding, damage, malfunction or breakdown, flooding or shifting of cargo, any defects in the hull or structural failure
- any incidents or casualties affecting the safety of the vessel, such as failures likely to affect the vessel's maneuverability or seaworthiness, or any defects affecting the propulsion system or steering gear, the electrical power generating system, navigation equipment or communications equipment
- any circumstances liable to cause pollution of the waters or shore, such as the discharge or threat of discharge of polluting materials into the sea
- "any slick of polluting materials and containers or packages seen drifting at sea" (VTS Finland 2020).

"Level 3 Corridor Management is a service to support transport management of the logistic partners (e.g. deviation management)

This is the last level, which thereforee builds on Levels 1 and 2, and introduces a new dimension: Third-party information for logistics and transport management purposes

Private stakeholders within the logistics chain can benefit from customized services providing specific relevant information (e.g. vessel position information or estimated times of arrival of specific vessels for authorized logistics users, voyage and cargo reports), enabling increased efficiency within the logistics processes" (RIS Comex 2020).

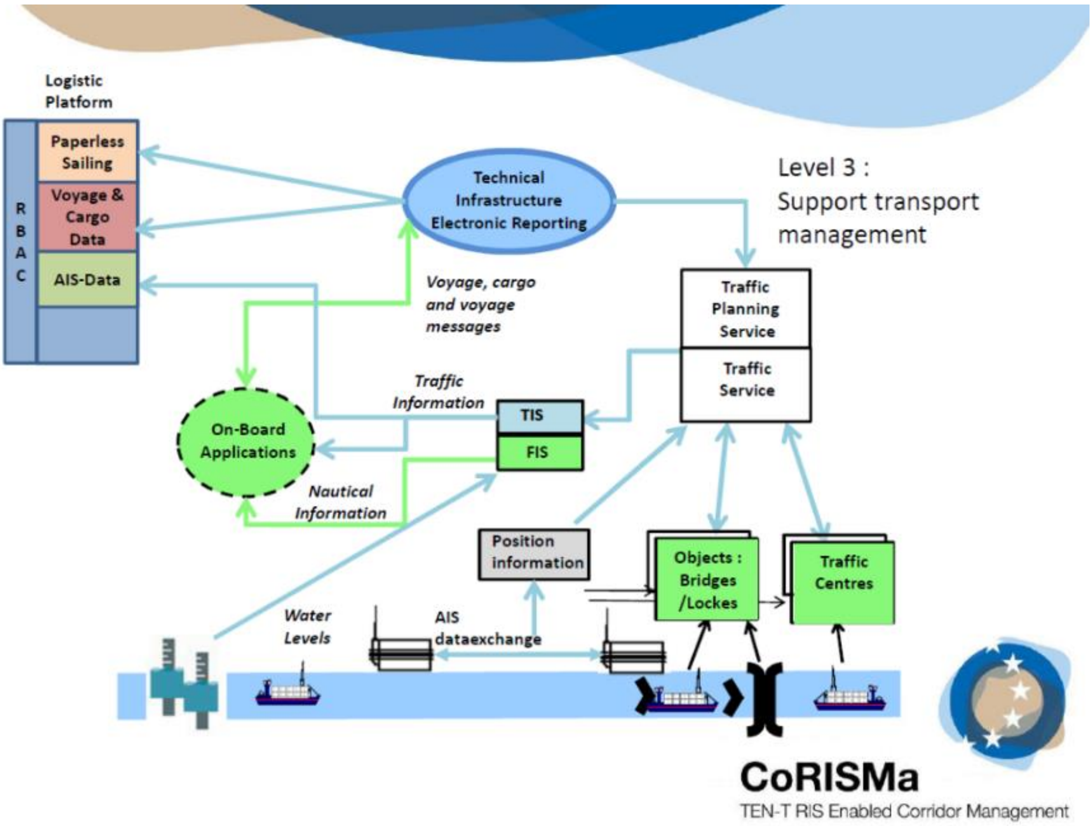


Figure 24: Corridor Management Service Level 3 (RIS Comex)

(Source: RIS Comex 2020).

Shipowner companies currently have a duty (through their vessel agents) to give out information on the movement of their vessels into the Portnet system. The Saimaa Portal project, which is discussed below, aimed to find ways to provide information in a more easily accessible and concentrated form (Ramboll 2018). PortNet is a data management system, which is maintained by the Finnish Transport Agency. When a vessel visits a port in Finland, information on the following is entered into the system:

- "Vessel (24 hours before arriving in the Finnish port)
- Cargo (within one hour from docking)
- Dangerous cargo (24 hours before arriving in the Finnish port)
- Vessel waste information"

PortNet has approximately 1 000 daily users. Main actors include ports, customs, brokers, maritime authorities, coast guard and chartering companies (Utriainen, Lahtinen, Hasu 2018).

8.3 Automatic Identification System (AIS) and Digitraffic service

SOLAS regulations require all vessels larger than 300 GRT to have Automatic Identification System AIS, practically meaning that all commercial vessels have to have AIS. Uses for AIS include the following:

- Collision avoidance
- Fishing fleet monitoring and controlling
- Vessel traffic services
- Maritime security
- Aids to navigation
- Search and rescue
- Accident investigation
- Ocean currents estimates
- Infrastructure Protection
- Fleet and cargo tracking
- Statistical analyses of traffic

(Utriainen, Lahtinen 2018).

In Finland, A class position and metadata messages are provided by the Digitraffic service operated by Traffic Management Finland. Some of the AIS messages, such as vessel types and cargo descriptions, are filtered and modified (Traffic Management Finland. 2020. Digitraffic).

8.4 Traffic Management Finland's Traffic Situation -service

Traffic Management Finland operates a Traffic Situation -service, which presents data gathered by Traffic Management Finland, Finnish Transport Infrastructure Agency and Finnish Transport and Communications Agency on an illustrative map view. The service shows information gathered by the aforementioned organisations on road-, marine and railway traffic. The service allows the user to different kinds of data simultaneously by choosing visible data on Show -menu and clicking on objects on the map. Data regarding vessel traffic includes navigational warnings and information on vessels arriving and currently in all ports. (Traffic Management Finland 2020. Liikennetilanne-palvelu). The service also provides data on faulty navigational aids (Traffic Management Finland 2020. Traffic Situation.)

8.5 Suggestion from Saimaa Portal workshop

Saimaa Portal project aimed to gather information and define the needs for a single window application. The project was part the Interreg Baltic Sea Region Program's project EMMA (2016-2019). However, the current status of the project is not clear, and the portal is currently not in operation. During the development project, an anticipatory e-mail enquiry was sent to Saimaa fairway stakeholders in December 2017 on their needs for data related to inland waterway traffic. The enquiry received 35 responses from representatives of industry (9 answers), port operators (8), freight traffic (5), authorities (4), passenger traffic (1), leisure traffic (1) and other stakeholder groups (7) (Ramboll 2018).

In the query, stakeholders expressed a large variety of data needs. Needs relating to navigation and transportation included data on conditions, traffic situations, the amount of traffic, incoming and leaving traffic (commercial and leisure), vessel situation on ports, vessel location data, allowed vessel size in ports and carrying capacity of docks for proper cranes and proper lifting. There was also need for data on traffic delays, stoppages, abnormal situations, events requiring permit of exception and faulty navigational aids. Data needs related to weather included wind, wave height, visibility, ice situation, water temperature (especially in late autumn before the arrival of ice) and data on the current in Saimaa water system. Wind forecasts and canal opening hours were specified as the most important data. Data needs on services included information on port services, contact information of port contact personnel, rope services, bridge operators, border authorities and customs‘ assignments, icebreaker services, unloading of ships and agents. Other information needs on the Saimaa Canal included need for information on the progress and schedule of lock renovations, changes in pricing and permissions on the transportation of liquefied natural gas (LNG) (Ramboll 2018).

Stakeholders wished to have more accurate and real-time data of vessel traffic in one portal instead of comparing the data on Portnet system to the information on websites or apps such as AISLive or MarineTraffic. In principle, the data was available, but gathering the necessary data was arduous, as one had to visit several websites to get a comprehensive picture of the conditions and situation. Most commonly used sources for data in addition to the aforementioned AISLive, Marine Traffic and Portnet included VTS centers, the Finnish Transport Agency (now FTIA) website, weather forecast websites, water level data websites, website for the Centre for Economic Development, Transport and the Environment, Finnish customs website, e-mails, port and municipal websites, personal connections, agents, shipowner companies, Finnpilot website, etc. (Ramboll 2018).

Roughly half of those who responded found the necessary data on most common sources. Frequently mentioned data that could not be found included weather data on the visibility and water temperature, as well as data on currents, current velocity and the direction of current (common currents on straits could be found on websites, but more accurate current data could not be found). The names of contact persons were also difficult to find from common sources. Other information lacking from the most common sources included the amount of passengers, stoppages (for example related to Saimaa Canal lock renovations), port services/facilities, rope services, exceptional license events, bridge operators, border authority and customs assignments and the sufficiency of pilots. One in five of those who responded currently used a mobile app related to fairway traffic (including Finnpilot/AIS app, company's own apps, PortNet, Marine traffic and Foreca weather forecast app). More than half of the respondents felt that the availability data on mobile apps was necessary. 51 percent of the respondents did not care if the data was in Finnish or English, while 43 percent preferred sources in Finnish and six percent in English (Ramboll 2018).

The most common ways the stakeholders wanted to utilize the data included operational planning, risk and preparedness planning, digital shipping forms and graphical representation of vessel movement by clicking the picture of the vessel. Operational planning included the planning of the flow of goods and the management of changes (advancing smooth and cost-efficient vessel traffic by keeping freighters and pilots up to date), planning the operation of the vessels and utilizing data in decision making and, if required, forwarding it to other organisations. Included in operational planning was also the ability to utilize the data in forming new ideas and options, finding new actors and deepening and broadening cooperation, as well as increasing the amount of tendering (Ramboll 2018).

Figure 25: Freight vessel RMS Saimaa in Saimaa Canal

(Source: Tulkki, P., Robodrones Ltd. 2020)

Slightly less than one third of the respondents wished to produce data into the systems themselves. Stakeholders wanted to produce data on traffic situation, situation in ports, information and links to limitations and orders, for example by customs officials, information on marinas for leisure boating, oil damage spreading models to support the preparedness planning by authorities, data related to vessel movement and vessels staying in ports. Shipowners companies have the duty to produce data on vessel movement into the system. More than 90 percent of the stakeholders who answered the enquiry felt there is a need in the Saimaa / Vuoksi water area for centralized portal that contains the different data (Ramboll 2018).

In the conversation conducted after the anticipatory enquiry, some additional needs came up, including information on required documents that a vessel operating without an agent needs in order to pass through Saimaa Canal. Other issue were the frequently changing orders (different practices between countries in how notification on freight should be made). The conversation participants agreed that the information is already available quite well but is spread between several different sources. In this context, the participants felt there is a need for an encompassing and illustrative data portal. The portal is mainly about utilizing existing information. The participants felt that the information should be presented in Russian as well. A need to involve port operators to increase the efficiency of the service chain came up in the discussions as well. At the same time, some of the information could be only accessed by entering a password and there for not open for all portal users. The up-to-dateness of the data came up as a concern among the participants. There are a lot of factors in vessel traffic that are difficult to predict, so operations have to be often conducted based on the information currently available and the best possible estimate. The participants felt this needs to be taken into account in the portal data, which should show when the information has been updated (Ramboll 2018).

A workshop was also held on Saimaa Portal. The following needs were formulated:

1. Information on vessel movement
- Information is already sufficiently available (Portnet, AIS, baltice.org), it is more a matter of how to represent the information in the portal

2. Information on weather conditions
- Water level, mist, current, ice forming on the vessels
- An estimate on the development of weather conditions based on advance information / best available estimate
- Weather conditions in Russia and the ensuing stoppages in traffic - related integrally to need number 3.

3. Information on stoppages, faults and other exceptions
- This information mainly moves by e-mails
- Possibility for the lock operators to make a notification of the malfunction into existing systems, from where it is forwarded to the portal
- Possibility of representing the information on maps with symbols, so the user is able to detect exceptions quickly; for example the bridge heights: free height based on the currently available information

4. Information on port services
- Technical (basic) data of freight ports: number of vessel spots on docks, storage possibilities, is the port private or public, phone number and contact personnel information
- The aforementioned information would be presented in the portal on map by each port, with a link to the port website; the port being responsible for the information being up to date.

8.6 NaviSaimaa project and Lake Information System (LIS)

NaviSaimaa is EU-funded project, started in August 2019, that aims to improve the business environment for Saimaa Lake region water transportation and promote inland water transport as the environmentally friendly form of transport in the Saimaa area (NaviSaimaa. Welcome to naviSaimaa homepage!. 2020.) Funding also comes from the Regional Councils of North Karelia, South Karelia, North Savonia and South Savonia, as well as municipalities and cities located by the lake Saimaa, and companies using the inland waterways in their logistics. The increase of bioenergy and raw wood industry in Eastern Finland and the ensuing increase in transportation volumes increases the need for new practical solutions. The project aims to to help meet those needs by finding ways to increase the modal share of waterway transportation in the Saimaa Lake region and Saimaa Canal. The most important goals include information sharing between stakeholders, increasing co-operation between all parties, including Russia, as well as growing inland water transport, including transport of both people and goods (NaviSaimaa. What is naviSaimaa. 2020).

Based on conversations between ports, operators and naviSaimaa project representatives, a preliminary plan has been made on a Saimaa area freight traffic information system, called Lake Information System (LIS). LIS -system would be developed by supplementing Traffic Management Finland Ltd.'s AIS-system with the situational data from Finnpilot's Pilotline -system, which is the operative system for piloting and gives an accurate, real-time picture of vessel movements. The basic functions of LIS -system would be similar to those of the River Information System (RIS). The LIS -system would include the controlling of the Saimaa lake area vessel traffic as well as Saimaa Canal controlling and situtional picture of Saimaa Canal vessel traffic. Lake Information System could be a part of the services of Port of Saimaa Ltd. (Koskinen, Rinta-Keturi 2020).

The main functions of LIS-system would include the following:

- Situational picture of vessel traffic, arriving and leaving vessels, vessel location data
    - Including the Saimaa Canal area
    - The situational picture will be forwarded to operators, ship agents, administrative officials and vessels trough phone and a computer
- Berth administration
- Ordering port services
    - Resources for loading and unloading vessel cargo
    - Other port services
- LIS -situational picture could be supplemented with other services, such as:
    - Water level projections
    - Real-time data from waterway navigational marks

(Koskinen, Rinta-Keturi 2020).

Based on the preliminary plan, Lake Information System would include the following functions:

- The accurate time of vessels arriving in port
  - Based on the Finnpilot's piloting system reporting the time of arrival to port
- The accurate time of vessels leaving the port
  - Based on Finnpilot Pilot Order Service combined with the time of completion for the loading of vessel cargo
  - Time of completion of loading confirmed by the foreman of the stevedoring firm
  - Time of loading completion can also function as the order for the pilot
- Real-time vessel location data on a map
  - Based on the AIS data managed by Traffic Management Finland Ltd.
- Data on Saimaa area shipping berths
  - Pilot order system supplemented with berth data on each port
  - Can act as a reservation for a berth when needed
  - Gives data on the actual use and vacancy of a berth
- Ordering of stevedoring firm resources
  - Pilot ordering system supplemented with a function, which helps ship agents to order resources from the stevedoring firm
- Ordering port services
  - The system would be added with a function allowing the ship agent to order port services

(Koskinen, Rinta-Keturi, 2020).

There have been discussions about the plan during the June 2020 between naviSaimaa representatives, Meritaito Ltd., Finnpilot Ltd. and port representatives regarding the initial development costs, funding and utilization costs. Further discussions will take place during the fall of 2020 (Hirvonen K. 2020).

8.7 Saimaa area data transmission capacity survey

In August 2020 NaviSaimaa project and traffic analytics- and consulting company Flou Ltd. carried out a survey on the capacity of, data transmission and the demand for data transmisson in the Saimaa deepwater fairway area. For the most part, different actors (freight operators, port- and vessel agents, waterway maintenance operators, pilots and authorities) were satisfied with the capacity and coverage of data networks. According tot he survey, the smart navigational s in Saimaa deepwater fairway area currently have a very limited need for data transfe, as the devices can function even in 2G network. Bridges and locks in the area have fixed network connections for remote use. Due to a relatively low amount of waterway traffic, commercial investments in data transfer capacity in the area have been limited. Present investments have been directed to the needs of basic waterway maintenance and authorities, instead of services provided for freight traffic (Haapamäki, Kantala 2020).

The survey concluded that if the amount of smart navigational aids is increased, areal review of network coverage is necessary. Gaps in network coverage can occurr especially on sections leading towards Joensuu in North Karelia. Gaps identified in mobile phone network coverage were mostly situated in southern Saimaa. In addition to the aforementioned Lake Information System (LIS) project, a project focused on constructing backup data transfer connections for Vessel Traffic Services in underway. The project utilizes existing mobile networks. 5G networks are estimated to extend to deepwater fairways within approximately five years. Meritaito Ltd. has investigated the possibility of building 5G networks between aids to navigation. However, building a 5G network in the fairway with current technology is difficult due to size and demands for electricity as well as a wired frame network. (Haapamäki, Kantala 2020).

8.8 Seaguide map service and Finnish Marine Portal project

The Seaguide.fi (Finnish name Meriopas) is a browser-based map view service providing data on weather and sea conditions, various restricted areas, guest harbours, cyanobacteria volumes and places of interest for visitors. It's directed for boaters, and people residing in the coast. Seaguide is part of the Finnish Marine Portal project, which aims to improve the accessibility and usability of the generated marine data in Finland by crating a national service that combines the data and material produced by different organisations operating in the marine sector. The portal website and data service can be found was launched in late 2019 in the address itameri.fi. The focus on the project is on user-friendliness by making the portal visually clear, search paths and user interfaces functional and the data accessible for download. The portal is realized by the following Finnish organisations: the Finnish Environment Institute (SYKE), the Finnish Meteorological Institute, the Natural Resources Institute Finland, Metsähallitus, the Geological Institute of Finland, the Finnish Transport and Communications Agency Traficom, the Finnish Heritage Agency, the Brahea Centre at the University of Turku, the maritime spatial planning coordination and Government of Åland (Finnish Environment Insitute 2019).

8.9 VTMIS (Vessel Traffic Management Information System)

The Vessel Management Information System is „an extension of the Vessel Traffic Service (VTS), in the form of an Integrated Maritime Surveillance, which incorporates other telematics resources to allow allied services and other interested agencies in the direct sharing of VTS data or access to certain subsystems in order to increase the effectiveness of port or maritime activity operations as a whole, but that do not relate to the purpose of the VTS itself (Shelter Training Academy 2020).“

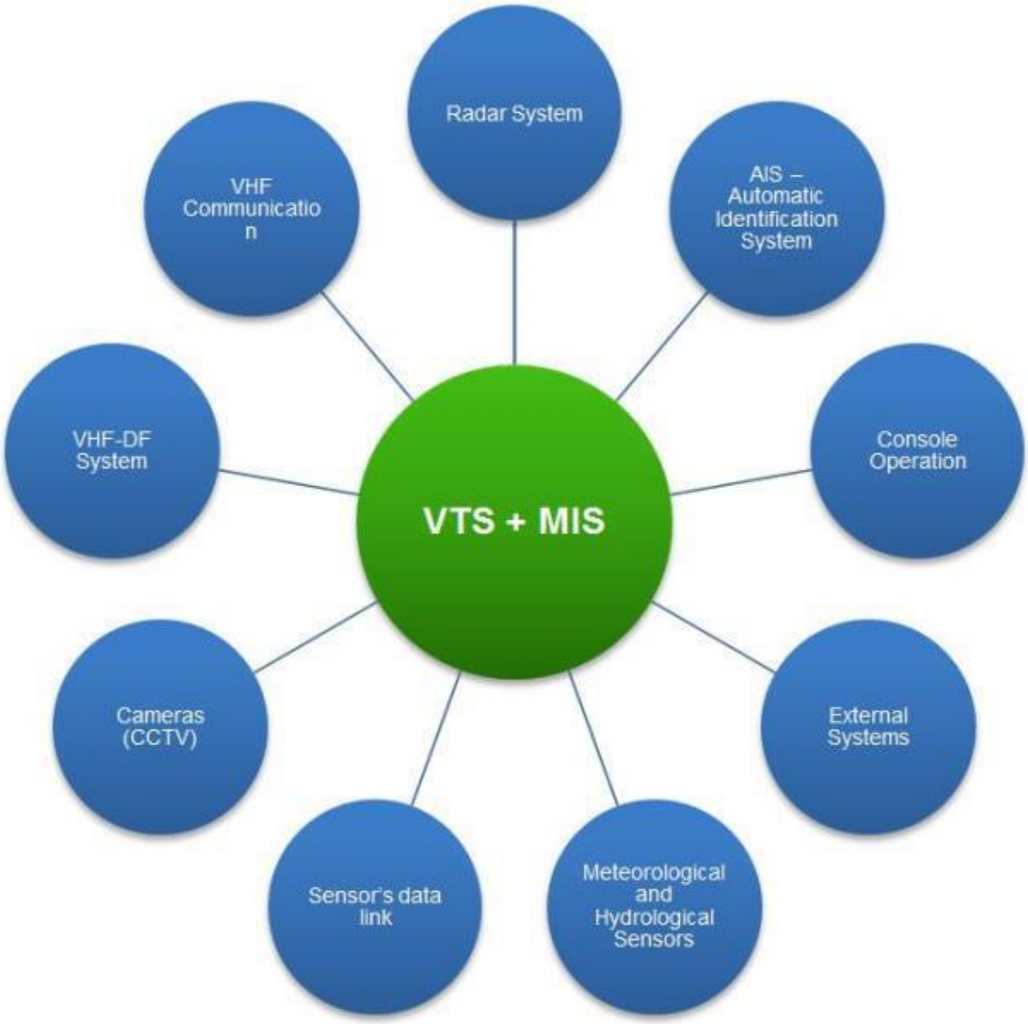


Figure 26: Diagram showing VTMIS input and output components and subsystems

(Source: Shelter Training Academy 2020, https://sheltermar.com.br/en/vts/vtmis/)

8.10 Open data on waterways

The Finnish Transport Infrastructure Agency Väylä publishes up-to-date waterway data as open data. Väylä maintains data on waterway locations, marine aids to navigation, waterway areas and dredging- and landfill areas on a waterway register. Data on waterways is available on download- and viewing service Oskari (https://julkinen.vayla.fi/oskari/?lang=en) and through open interfaces. Data for winter marine traffic on Baltic Sea, such as up-to-dute ice chart, ice thickness chart, ice reports, forecasts, traffic restrictions and icbreaker service areas, can be found on Baltice.org -service (Väylävirasto. Vesiväylien avoin data. 2020.)

8.11 Challenges related to the sharing of data

Johanna Heikkilä has studied the factors related to sharing data on vessel arrival and departure time in Finnish ports. Ports typically have several different organisations that share data with each other. However, currently the sharing of data is inefficient. The data is not in an unified, electric form that would be simultaniously accessible to all parties, but is instead spread between various sources and is often unreliable. Because marine industry is based on networks, this can cause problems throughout the logistic chain. As a result, consequences such as vessels waiting outside ports and challenges in organization of work increase costs, decrease the profitability of ports and even effect the environment as the vessels have to wait outside the port or cannot enter the port at optimal speed. Also, transmitting same information separately to different actors consumes resources, slows down the logistic chain and as a result impairs the competitiveness of the logistic chain (Heikkilä 2020, p. 11-12).

The attitude towards sharing of data varies from actor to actor. Building trust is seen as important factor in building a culture of data sharing and creating data sharing practices. Maritime industry and logistics actors and authorities interviewed in the study recognized many benefits in sharing vessel arrival and departure data. Most importantly anticipation, planning, controlling and operation of the logistic process would be improved by recognizing changes in the time data in the earliest possible state. Many actors determined vessel departure and arrival time data to be crucial for business. This kind of time data is constantly used by port companies, shipowner companies, port operators, mooring companies, pilots, crane operators, tugboats, authorities, etc. However, marine industry is cautious of making mistakes, which can undermine trust between the parties. Some actors feel that competition between actors can cause unwanted behaviour if open data is openly available, for example cutting in on other vessels when receiving a „notice for readiness“ of a free berth in a port (Heikkilä 2020, p. 33-35, 54).

In 2019 European Union and Council of Europe issued a decree to form a unified service environment for European maritime industry. The decree aims to create unified rules for providing data for port visits, so that the same data can be transmitted to each national centralized service point in the same way. In Finland, the decree requires changes in national statutes, renewal of systems and widespread co-operation between stakeholders (Heikkilä 2020, p. 11-12).

According to a 2019 report published by The Centre of Maritime Studies Brahea Centre at the University of Turku, Finnish port companies do not currently have a person solely responsible for the advancement and development of digital services. Instead, this kind of work is done alongside other tasks, depending on the backrgound and motivation of the person in question. As with vessel arrival and departure time data, information on on port infrastructure is often controlled by infrastructure companies, such as water companies, instead of the city officials or the port company. Also, know-how in port companies related to open data is often scarce. Therefore, there is need for training, starting from the basics (Saarikoski, Helminen 2019).

9 DISCUSSION AND LEARNING EXPERIENCES

Finland is in the forefront of maritime digitalization. Smart fairways are an example of this development. Contemporary smart fairways are one step in the digitalization process that aims to make shipping and navigation smoother, safer and more environmentally friendly.

Meritaito Ltd.has a great deal of know-how that could benefit many actors in the maritime industry both domestically and internationally. However, the marketing of this know-how has been challenging. Due to being a former department of Finnish Maritime Administration, for a long time Meritaito's assignments came almost exclusively from the Finnish Transport Infrastructure Agency (Väylä). Gradually, Meritaito has reached new markets and customers and expand markets. In general, the Finnish maritime infrastructure industry has been based on domestic markets and could open out more towards international markets. Due to its history, Meritaito has a fairly heavy cost structure, but is constantly working on lightening the cost structure. This may be necessary for Meritaito to be able to answer to the challenge presented by smaller, lightly structured and agile actors. There are about five contractors operating in the Finnish waterway contract and maintenance field. In recent years contractors for contract areas have changed and crossed on many occasions.

At the moment, the number of actors providing the technology and maintenance services is very low. Therefore the current actors do not have to lower the prizes to stay competitive. As mentioned previously on chapter 5.2.1, the cost benefits might not necessarily be directed to the buyer. However, the improved safety and lowered emissions can pay back the investments, even though this can be hard to define in exact numbers. In the Saimaa region, the margin for navigational error is small. A large accident could cause inland shipping in Saimaa to end completely. There is some pressure as well as political gain to end inland shipping in the region, the protection of Saimaa ringed seal being one factor that is brought up in the discussions.

Currently, the costs and benefits of smart fairways in Finland as a whole are hard to evaluate. The benefits clearly exist, but the exact benefits and benefactors need to be defined. The actors in the Finnish maritime industry need to find a mutual understanding about who benefits and how.

With the development of autonomous vessels, there are questions about the necessity of physical aids to navigation. This may increase the need to find additional uses for them. Theoretically, the smart buoys on the pilot fairway could also one day measure circumstantial data such as water quality or vessel sulfur emissions if the buoys are fitted with sensors. However, this would require improved battery capacity. As mentioned in chapter 8.7, the use of smart buoys as 5G base stations has already been looked into. As technology progresses, smart buoys could be deployed more and more in such additional and alternative uses. Smart buoy could also be equipped with cameras, providing weather and other circumstantial information for fairway users or authorities.

In the future, it would be beneficial to examine, which fuel would be most suitable for inland shipping in Finland. In addition to low emissions, there is a question of how large of a risk the fuel can cause in case of an accident. This question is especially relevant on a narrow waterway such as the fairway chosen as the pilot destination. Currently it is forbidden to transport fuels in Saimaa fairways. The possibility of transporting more environmentally friendly fuels such as LNG or natural gas in the future should be examined.

10 LIST OF TABLES AND FIGURES

Cover picture source: Tolvanen, S. 2020.

11 REFERENCES

11.1 The list of literature and sources

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