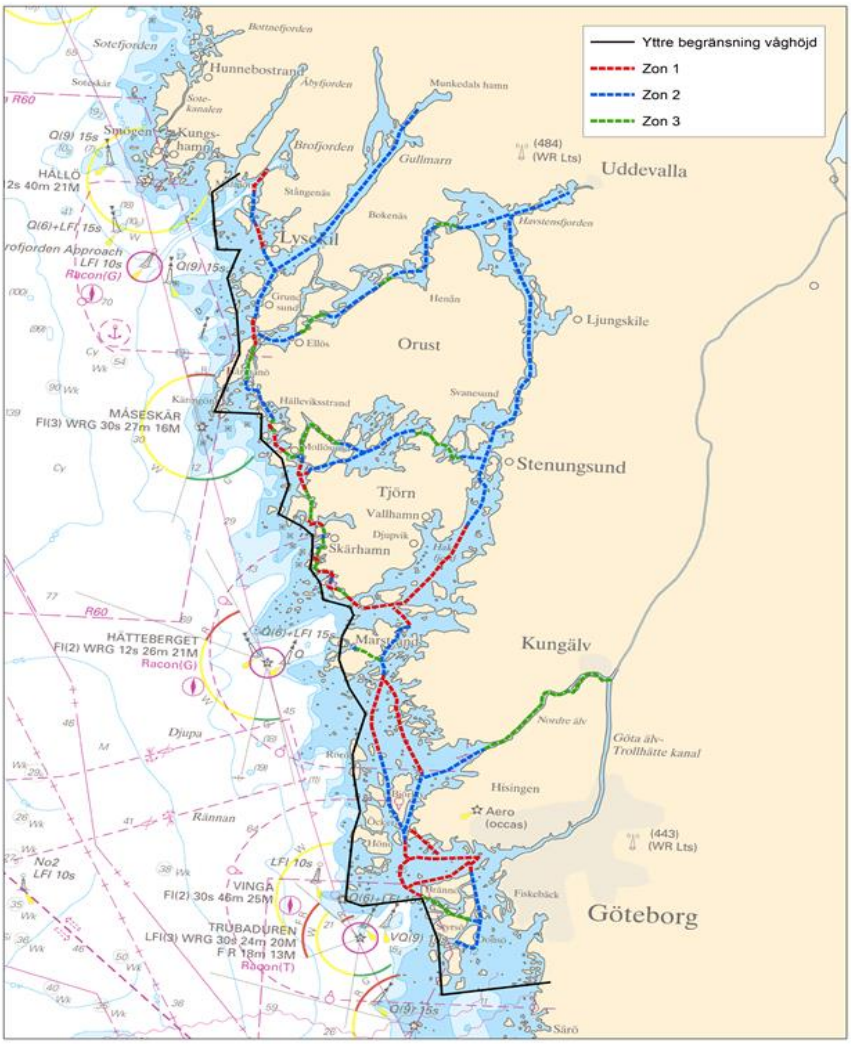
Simulation of new inland waterway fairways

Simulation and risk assessment of maritime passages in narrow fairway sections between Gothenburg and Brofjorden on the West coast of Sweden (Stånge Huvud, Malö Strömmar, Såten, Nötesund and Instö Ränna).

Project EMMA EXTENSION (INTERREG Baltic Sea Region)

ACTIVITY: WP 3, Group of Activity 3.1
VERSION: **FINAL**
DATE: 28th June 2021



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EMMA Extension Project is funded by the Interreg Baltic Sea Region Programme 2014-2020.

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The Programme is an agreement between EU member states Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Sweden and the northern parts of Germany as well as partner countries Norway, Belarus and the northwest regions of Russia. The Programme is funded by the European Union and approved by the European Commission.

The Programme funds come from the European Regional Development Fund (ERDF), the European Neighbourhood Instrument (ENI) and Norwegian national funding. Project partners co-finance activities with their own resources.

The Programme offers funding for four thematic priorities: (1) Capacity for Growth (2) Management of Natural Resources, (3) Sustainable Transport and (4) EU Strategy Support.

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INHALT

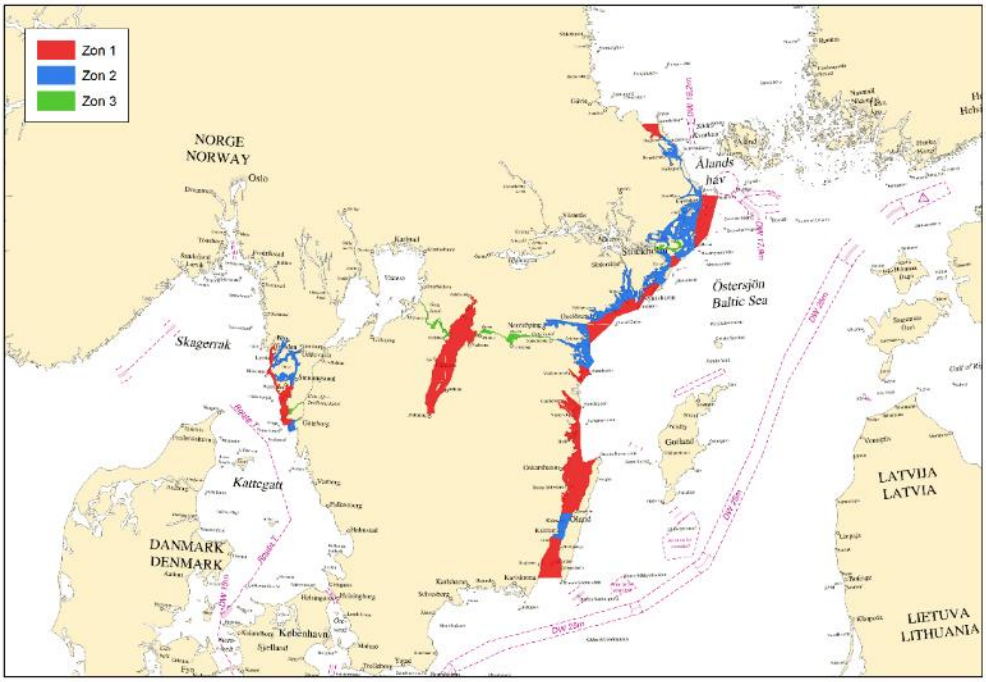
1 INTRODUCTION

This simulation aims to evaluate what infrastructure measurements that needs to be taken to make the inland waterways route between the Preem AB petroleum refinery in Brofjorden and the port of Gothenburg safely navigable for EU-classed inland waterway vessels.

In the freight transport strategy "Efficient, high-capacity and sustainable freight transports - The Swedish national freight transport strategy", the Government has stated that more goods should be transferred from road to rail and waterway transportation. As part of this, Avatar Logistics within the frame of the EMMA Extension Project, has together with Preem Sverige AB expressed an interest in being able to transport petroleum products from the PREEM petroleum refinery in Brofjorden to port of Karlstad in Lake Vänern. Transport should be executed with a tank vessel classified in accordance with the EU-regulations for inland navigation.
Transport with vessels classified for inland navigation is based on the Swedish Transport Agency's technical regulations for vessels in inland shipping (TSFS 2014: 96). The technical regulations are based on four different classes related to geographical zones. The zones for inland navigation are classified according to the significant wave height.

- Zone 1: The significant wave height is a maximum of 2.0 meters.
- Zone 2: The significant wave height is a maximum of 1.2 meters.
- Zone 3: The significant wave height is a maximum of 0.6 meters.
- Zone 4: Waves do not occur.

At present, only Lake Mälaren, Lake Vänern and the Göta älv river are classified for inland navigation by the Swedish Transport Agency. The EU-classed zones for inland waterway transportation are planned to be extended as shown in below map, whereof Gothenburg-Brofjorden is one of the appointed areas.



The Swedish Transport Administration, who are the holder of all Swedish infrastructure, has appointed the Swedish Maritime Administration to investigate the present conditions and what infrastructure improvements that needs to be taken to be able to offer a safe operation in the waterway section between Brofjorden and Gothenburg with cargo vessels. The Swedish Maritime Administration must also produce a rough cost indication for the measures that are needed to make the new routes navigable.
To evaluate which measures that needs to be taken and which vessel size that can operate in the inland waterway section, a preliminary fairway design and marking plan have been developed by the Maritime Administration. Before the simulation different fairway design options have been developed depending on the stretch and the size of the vessel. A draught survey has been executed by the Swedish Maritime Administration as a base for the simulation.
The fairway that has been developed follows the existing inland archway fairway as follows:
Brofjorden - Stånge Huvud - Islandsberg – Malö strömmar - Havstensfjorden - Instö ränna – Källö fjord – Dana fjord.
The areas that have been chosen to be simulated are the most critical and challenging passages at *Stånge Huvud, Malö Strömmar and Instö ränna.*
At *Instö ränna*, there is an eastern alternative where there will be a completely new fairway route down to the *Sälö fjord*. The western alternative is available with different stretches when crossing the mark Brandholmsrevet.
The vessels for which the fairway surfaces are dimensioned are *Mts Veendam* which is an EU-classed tanker vessel as an inland shipping model and the fictitious vessel *M/V Höljan* which is dimensioned for the future planned lock dimension in the *Trollhätte canal* in Göta älv.

2 PURPOSE AND GOALS

The purpose of the simulations has been to:

- Assess which fairway will be the best alternative from a nautical point of view.
- Assess the max size of the vessels that can operate the route.
- Assess the preliminary plan for navigation marks.
- Assess wind and current impact in critical passages.

The goals of the simulations have been to:

- Evaluate the maximum size of ship
- Documentation for an indicative cost estimation

2.1 Method

The method has been to:

- Design of new fairway surfaces for the dimensioning passages.
- Test the fairway layout with the two vessels models under different weather and current (water speed) conditions.
- Evaluate the test runs and assess the risks and suitability of the chosen vessels.
- Evaluation takes place based on participating pilots' evaluation and experience of the test runs and measurement of passage distance to the grounds and marking, including the selected engine power.
- Simulate sailing with the different models for evaluation and correction of the appointed fairway surfaces.
- Suggest and try adjustments/additions based on the outcome of the initial test runs.

The simulations have been carried out in the Swedish Maritime Administration's full-mission simulator in Gothenburg 2020-10-12 - 2020-10-14

3 THE SETUP OF THE SIMULATIONS

The following people participated in the simulation in Gothenburg:

- Niklas Hammarkvist project leader, Swedish Maritime Administration
- Henrik Göthberg and Peter Andersson, pilots from *Lysekil* pilot station
- Pilot masters from the Marstrand pilot station
- Nicklas Liljegren and Andreas Edvall, Swedish Maritime Administration
- Michel van Gent, Vigilia Shipping B.V.

Pilot and Simulator Instructor, responsible for the simulation:

- Jonas Sundin and Niklas Hammarkvist, Swedish Maritime Administration

Infrastructure coordinator and responsible for EMMA Extension report compilation

- Johan Lantz, Avatar Logistics AB

3.1 Scope and conditions

- Areas

The dimensioning passages for the waterway section Brofjorden - Gothenburg are the following geographical passages:

- Stånge Huvud
Relatively narrow but with high draught. Relatively straight navigation but exposed for wind from the west.

- Malö strömmar
Partly narrow with blasted rock profile. Moderate gears in the fairway. Wind protected but current water.

- Såten
Relatively wide navigation. Heavy gears without straight lines in between. Wind protected.

- Nötesund
Narrow passage under the bridge, heavy gears, wind protected.

- *Instö ränna*, west and east directions
Relatively narrow, heavy gears, narrow bridge passage. By history a dredged canal. Relatively wind protected. From time to time exposed for strong winds from the south.

Lighting conditions
The simulations have been carried out in daylight and darkness. as the goal has been to verify the fairway areas' support for day and night.
Unforeseen events
Unforeseen events have not been studied during the simulations.

3.2 Sizing vessels

In the simulator runs, a ship models were used of the future *Trollhätte canal* locks max size with the vessel's m/v *Höljan* and *Mts Veendam*. They have the following dimensions:

m/v Höljan	***Mts Veendam***
Length: 110.0 meters Width: 16.5 meters Load condition: Full load Depth for / aft: 5.4 / 5.4 meters Deadweight: 6300 tons Power machine: 4,000 kW Power book: 350 kW Rudder: 1 x Becker Propeller: 1 x CPP (pitch) (acting right handed)	Length: 85.95m Width: 11.44m Load condition: Full load / light Depth for / aft: load 3.25 Max displacement: 1916,618 m3 Power machine: 1014 Kw Power book: 357Kw Rudder: 2 x Vd Velden Propeller: 1 x fixed

Mts Veendam by VT Group B.V. (EU-classed inland tanker vessel 86m)

3.3 Simulator runs

Five reference runs are made to verify that the ship model as far as possible corresponds to reality. Each run is run simultaneously from three different ship simulators.

4 RISK ASSESSMENT AND RISK LEVELS

The term risk describes the combined value of the probability that a certain event will occur and the consequences of its occurrence (for humans, property, and the environment).
During the simulator runs, no risk analysis is performed with an assessment of the probability and consequence for different situations. Instead, overall assessments are made by pilots and other participants about risks in the various test runs.

4.1 Risk levels

In the simulations, the risks are assessed based on two different approaches:

- Measured risk
- Assessed risk

4.1.1 Measured risk

The measured risk is based on simulations on data from the simulator where the following three sub-areas are affected:

Power utilization
The power utilization describes the extent to which the vessels machinery and manoeuvring equipment are used in relation to maximum capacity.
The risks of high resource utilization are partly linked to the time the resource is used and do not necessarily involve any risk. On the contrary, it can be safety-enhancing to initially use the resources to 100 percent, to, for example, get a desired manoeuvre started quickly.

Safety distance in open water areas
Safety distances describe the distances to fairway edges, markings, and other physical obstacles. An accepted way to assess what is safe passage is to look at the margins sideways. A division into risk levels used in outer fairways is:

Distance: > One ship-width = Green, acceptable distance
Distance: > Half ship-width = Yellow, acceptable but doubtful
Distance: ≤ Half ship-width = Red, unacceptable distance

Safety distance in canal areas
However, these levels are doubtful to apply in areas where the fairway width is minimized according to *PIANC* recommendations. In the current location at *Björnsund/Malö strömmar*, the calculation according to *PIANC MarCon 121-2014* gives a required fairway width of about 77 meters, while the current fairway width in the Björnsund Canal is about 40m. With a 16-meter-wide vessel, it is then not possible to achieve one vessel width in the margin to both sides of the fairway, i.e., green level as above (for outer fairways) cannot be achieved. Other risk levels should be used in canals and narrow fairways.

Assuming a 40-meter fairway width and if the vessel (16.0 meters wide) is in the middle of the fairway, 12 meters are obtained on each side of the vessel. Based on this, risk levels for safety distances in this simulation are set to:

- Green> 12 meters. Low risk, acceptable distance
- Yellow 6-12 meters. Increased risk but acceptable, consider appropriate actions
- Red <6 meters. High risk, not acceptable, take appropriate actions

Green level is in practice impossible to achieve on both sides of the ship even at these levels as it means that the ship must be located exactly in the middle of the fairway, without lateral movement. These levels are intended to illuminate margins to fairway edges where the fairway is narrowest at e.g., the *Björnsund* canal.
Some structures, such as pile fenderings at bridges, are seen as protection devices for bridges and can be used when crossing. If necessary, it is accepted to fully oppose such constructions and thus consider them as aids instead of obstacles. As a result, it is misleading to generally consider that a small distance to a pile fendering means a high risk. It is an overall assessment of distance, speed and power utilization that gives the risk level.

Speed
Speed when crossing *Björnsund* and *Malö strömmar* is noted as an indication of how safe and controlled the passage is.
The vessel's speed when passing the area is directly decisive for the suction effect that occurs. Speed between 6-8 knots is considered as appropriate.

4.1.2 Assessed risk

- The assessed risks are based on the pilots' own experiences and assessments. The assessments are made individually after each test run in a special evaluation form and they are based on the following risk levels:

- Risk level 1-3
  Green = Low risk. Approved value from a risk point of view

- Risk level 4-5
  Yellow = Medium risk. Requires further analysis

- Risk level 6-9
  Red = High risk. From a risk point of view, not acceptable value

5 RESULTS

This chapter presents the results of the test runs carried out in the simulators.

Photo from Swedish Maritime Administration simulator in Gothenburg

5.1.1 Malö strömmar – draught 5.5m

This surface is without dredging measures. During the simulation, three test runs were performed in each direction with the *Mts Veendam* in loaded condition. There was one run eastwards in ballast condition (without cargo onboard) and three runs' westwards. Winds between zero and seventeen meters per second from northeast or southwest. The current (water speed) was with or in the opposite direction 0.5-3.5 knots. This fairway is due to Swedish regulation for mandatory pilotage, the largest allowed vessel size is 90x15m.

The critical sections are the *Björnsund* Canal and the passage of *Tärneskär*.

When sailing in ballast conditions, it was it was perceived as if the ship was too sensitive for the wind and to compensate for the wind factor, a lot of rudder angle had to be used. The participants and instructors in the simulation considered that the model did not reflect the actual vessel. The vessel model was corrected, which reduced the rudder angle, and it became more in line with reality. According to *Michel van Gent*, an inland waterway vessel does not turn to the wind in strong crosswinds, due to its shallow depth in the bow, at ballast condition about 0.6 m, but it falls away from the wind whereby you must compensate with the rudder against the wind. After the correction, the model was still sensitive but much less sensitive for wind exposure.

In loaded condition, the fairway surface is sufficient in the narrowest passage by the *Björnsund* Canal. (in summertime). The turn at *Tärneskär* considers working out in an acceptable safe way. The overall risk assessment is set to 3-4.

In ballast condition, the safety margins shrink especially in strong crosswinds. To compensate for wind drift, the commander must keep up about 2 ° to the wind and drive faster to reduce drift and avoid getting a large sweep area in the water. It's possible to pass the *Björnsund* Canal, but the safety margin will not be enough. The width of the fairway surface at *Tärneskär* for the turn cannot be managed with a sufficient safety margin. Here, the fairway needs to be widened to get sufficient width and safety margins. The overall risk assessment is set to 5-6.

With a strong current from the aft in the *Björnsund* Canal, it becomes difficult to keep the today's speed limit at 5 knots.

Proposals for safety-enhancing measures are illuminated pile fenderings along both channel sides. To be able to utilize the entire width of the fairway at Tärneskär, a supporting structure should also be placed in the inner curve. Today's floating marking needs to be adjusted and supplemented. Considering current and sway effects, some markings should be solid standing on rocks or bottom. Bottom-mounted illuminated screens are recommended. The important navigation line at *Tärneskär* needs to be checked as the line in the simulation does not correspond to reality. The navigation line at *Hallen* needs to be adjusted to match better with the direction of the fairway. It's proposed that the pile fenderings should be illuminated indirectly with some type of LED-strips or illuminated screens.

5.1.2 Malö strömmar draught 7.5m

This surface is without dredging measures. During the simulation, one run was performed in each direction with the *ms Höljan* in loaded condition. Wind 7-9 m/s from North East or South West and current from the aft with 2 knots.

The critical sections are the *Björnsund* Canal and the passage of *Tärneskär*.

The fairway area at 7.5 m is marginally smaller through the *Björnsund* Canal and at the passage of Tärneskär. However, the increased width and length of the vessel *mv Höljan* compared to the *Mts Veendam* means that margins in crosswinds become very small after compensating for the drift. The *ms Höljan* has a significantly larger wind area which increases drift. The overall risk assessment is set to 6-7.

No simulations were performed in ballast condition because the risk level does not improve and therefore does not add anything to the results of the simulations.

5.1.3 Malö strömmar with proposed dredging draught 7.5 m

This fairway surface was not tested as the difference compared to the not dredged surface at *Tärneskär* is neglectable. This means that the proposed dredged fairway surface does not improve the passage. A new dredged waterway surface will be produced, and it should be equal to the 5.5 m surface.

5.1.4 Instö ränna west 5.0m

The fairway surface is without dredging and basically follows today's route except at *Bockarna* where it goes west of today's fairway. A test run south was carried out. Wind from the north 2 m/s current from north east 1 knot. Pile fendering as safety arrangement at the Instö bridge. This fairway is not undertaken the Swedish pilotage regulations.

The test run shows that the critical passage is at the Instö bridge. Just north of the *Instö* bridge there are two smaller skerries where you must pass in-between before the bridge passage. It will be very difficult to manage the turn up towards the fendering structure at the bridge passing when going south. Large rudder angle and full engine power are required to complete the bridge passage. The weather conditions can be considered very favourable. The pilots in the simulation did not consider the fendering construction necessary but instead an aggravating factor. The pilots also remarked on that there were too many beacons and lighthouses placed out in the simulation chart. The risk assessment is set to 5-6.

The recommendation is to dredge the passage between the rocks and angle the passage in a way, so it corresponds better in line with the bridge passage. It should be investigated whether a lower air draught clearance should be measured and marked on the bridge, with aim to widen the fairway under the bridge. In the last test run, the fendering structure was removed at the *Instö* bridge.

5.1.5 Instö ränna west with proposed dredging 5.5m

This surface is dredged at the passage between the skerries before Instö bridge, *West Bockarna* and *Brandholmen*. There were four test runs with *Mts Veendam* in loaded condition. Three southbound and one run northbound. Wind from the north 2 m/s and the west 12 m/s. Current from north east 1-1.5 knots. No runs were made in ballast partly due to the overly unstable ballast model and that it was sufficiently challenging in the loaded condition. At the last run, the pile fendering was removed.

The passage between the inserts is widened and slightly more angled towards the bridge compared to the 5.0 m surface. The runs show that the surface is not sufficiently angled towards the bridge, especially in strong winds from the west when the rudder and machine may be used full. North of the two skerries the runs with less wind show that this surface is better than the 5.0m surface. During the last drive past Instö bridge, the fendering was removed with the result that it became much easier and safer to manage the passage under the bridge. The passages west *Bockarna* and east *Brandholmen* worked well. The overall risk assessment falls between 4 and 5.

The fairway surface between the islands north of the bridge needs to be angled more towards the bridge so that the bridge passage ends up more in line with the passage of the skerries. Eventually needs the ground (4.3 m drought) north of the skerries also need to be blast away, as well as the tip of the rock foundation west of *Tjällholmen.* This makes it possible to take the turn more eastwards to be able to position the vessel better for the passage between the skerries when one must cross the bridge going southbound.

The proposed marking also needs to be reduced in number and some lighthouses will be removed or replaced with illuminated screens. When passing between the skerries, it is appropriate to have fixed lighthouses since it’s a narrow area and to avoid problems with swaying of the vessel.

5.1.6 Instö ränna west with proposed dredging 7.5m

The surface is dredged at the passage between the skerries before the Instö bridge, west of Bockarna and Brandholmen. Two test runs were carried out with *ms Höljan* in loaded condition, one in each direction. Wind from the north 2m/s and from the west 9 m/s. Current from the aft 1 knot in both runs. The runs were carried out without a pile fendering in the bridge passage.

The fairway surface is perceived as very narrow when crossing the Instö bridge and the two skerries north of it. With light winds it is possible to get through, but with a relatively large rudder angle. The risk assessment is 4-5 in light winds. In stronger winds, margins decrease, and the risk assessment becomes 7.

The fairway surface between the skerries north of the bridge needs to be angled more towards the bridge so that the bridge passage ends up more in line with the passage of the skerries. Eventually needs the ground (4.3 m draught) north of the skerries also need to be blast away, as well as the tip of the rock foundation west of *Tjällholmen.* This makes it possible to take the turn more eastwards to be able to position the vessel better for the passage between the skerries when one must cross the bridge going southbound.

The proposed markings also need to be reduced in number and some lighthouses will be removed or replaced with illuminated screens. When passing between the skerries, it is appropriate to have fixed lighthouses since it's a narrow area and to avoid problems with swaying of the vessel.

5.1.7 Instö ränna east 5.5m

This area was not simulated as it was considered impossible based on the proposed route. The turns north of the bridge to get into the eastern bridge span, become too difficult to cope with in a safe way.

5.1.8 Instö ränna east with proposed dredging 5.5m

The fairway surface is a completely new stretch that runs through the eastern span of the Instö bridge. The surface requires dredging on both sides of the bridge. The surface is quite straight from the two skerries north of the bridge to a bit south of the bridge. This stretches joins today's fairway south of *Stora Holmen Grå*. Three runs were made with *Mts Veendam* in ballast condition, two northbound and one southbound. Wind from the west and the south 4-12 m/s. Current from the northeast 1.5 knots. Fendering are placed under the bridge.

The test runs show that the straighter fairway provides good margins in the simulated weather conditions. The fairway was experienced as easy to handle. The risk assessment will be 3. The proposed marking also needs to be reduced in number and some lighthouses will be removed or replaced with illuminated screens. When passing between the skerries, it is appropriate to have fixed lighthouses since it's a narrow area and to avoid problems with swaying of the vessel.

5.1.9 Stånge huvud

No simulation of the proposed waterway surface was performed. The fairway right next to *Stånge huvud* was judged to be too risky in overtime weather by the pilots. The water bounces in the rocks and this gives very irregular and rough waves. It's was therefore proposed that the fairway to be drawn between *Gulskären* and *Svartskären*. According to the pilots' experience, the waters is not as rough

and irregular in that area. The route via *Gulskären* remains within the EU-zones for inland waterways that have been approved by the Swedish Transport Agency.

5.1.10 Såten

The fairway surface follows present fairway. The existing navigation markings has been supplemented with additional navigation marks. Two test runs were made with the ship *mv Alice* in loaded condition, one in each direction. *mv Alice* is a ship that goes through today's locks in *Trollhätte canal* in Göta älv. *mv Alice* was chosen because she is closer to today's maximum size of ships in the today's line. Alice's manoeuvrability better reflects the traffic that can be expected today in these fairways. The *mv Höljan* is larger and wider, but it was judged that it's also possible to pass with her without any problems. The test run was to test the proposed completion of the marking. Wind from the north 9 m/s without any current. The performed runs show that it is easy to pass, and that no supplementation of today's marking is needed. The proposed additions were perceived to make it more complicated to navigate.

5.1.11 Nötesund

The fairway surface follows today's fairway. The existing navigation markings has been supplemented with an additional marking. Two test runs were made with the ship *mv Alice* in loaded condition, one in each direction. A proposed pile fendering with a fairway width of 50m under the *Nötesund* bridge. This run was to test the proposed completion of the marking. Wind from the north 9 m/s and a current from the west 0.5 knots. The test runs show that it is easy to pass and that no major change in today's marking is needed. It was discussed within the simulation group whether the 4m foundation west of the bridge needed to be dredged away. It was judged that this is not needed from a safety perspective. The safety margins when crossing the ground is sufficient today.

> Proposed measures are that the at the navigation mark (4m draught) on the ground west of *Nötesund* bridge is changed to a bottom-fixed screen. Some of the lighthouses can also be changed to illuminated screens.

6 SWOT ANALYSIS

SWOT Implementation of new inland waterway fairways

Strengths	Weaknesses
• *Positive outcome of the simulations* • *Proved that an EU-classed inland vessel can navigate in the area* • *The data-model for vessels and fairways was solid made*	• *High costs for dredging* • *High cost for new navigation marks* • *High cost for pile fendering* • *High investments for a modest traffic flow* • *Low traffic flow initially*
Opportunities	**Threats**
• *The new fairways have a high potential to achieve a modal shift from road transportation* • *Sweden can implement the full EU-regulations for IWW* • *Digitalisation is a possible way to implement land-based traffic control*	• *Swedish IWW regulations does yet not correspond to other EU-member states* • *High pilot and fairway dues* • *Other investments in new land infrastructure might be prioritised by the politicians*

7 CONCLUSIONS

By history the fairways in the simulation have by history been important trading routes for the domestic sea traffic, carrying products for the Swedish industry; however, the waterway alternative lost its competitiveness against road transport during the sixties and seventies. From that time until today this routes mainly has been used by yacht and navy ships. Of that reason there has been no commercial focus on this coastal area and hence the maintenance and sea chart documentation and updates has been neglected.

A growing demand of more sustainable logistics has increased the interest among the stakeholders using inland navigation to relieve traffic on the roads. This simulation was the first made in Sweden for EU-classed inland vessels and the outcome of the test runs in the simulator were positive. I can be established that the alternative with an EU-classed inland vessel can operate within the appointed test area however needs a high amount for investments in dredging, new marking, and pile fendering. The preliminary cost indication from the Swedish Maritime Administration indicates EUR 10.000 Million for these investments. Looking at the initially few numbers of vessel in this trade it will initially be difficult to get the financial calculation together. At this moment it is not set if the investments in the test area will become reality. The Swedish Maritime Administration will hand over the cost estimation to the Swedish Transport Administration that is in charge for all investments in the Swedish infra structure.

Their decision will follow and if it's positive more detailed simulation by the Swedish Maritime Administration is needed.

The executed simulation in Gothenburg October 12-14th 2020, for new inland fairway is a success story of how a private enterprise and an official authority, in this example Avatar Logistics and the Maritime Administration, can cooperate in a transparent way with a joint target to enhance inland navigation in Sweden and the BSR. The EMMA Extension project has been an important joint platform and a facilitator for the involved parties to handle the simulation case study. This form of cooperation will hopefully become a guideline for future projects.