MOVING HAVENS
AN APPLICATION OF THE E-NAVIGATION SERVICE ROUTE EXCHANGE

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SUMMARY

e-Navigation is a concept launched by the IMO in 2006. The point is to share digital data to the benefit of safety, efficiency and the environment. Every ship must make a voyage plan before leaving berth. Sharing such voyage plans between ships and between ships and shore is called route exchange and such a feature would allow alarms to be triggered both onboard and ashore if a ship deviate from its planned route, or if two ships plan to be at the same place at the same time. To visualise correspondence or lack of correspondence between the planed position and the real position the concept of Moving Havens is suggested. It is a visualisation tool designed to intuitively show if a ship falls out of its safety checked position. In case of route exchange and Ship Traffic Management it will facilitate for land-based operators or automation to distinguish dangerous situations. The concept is presented in this paper.

1.   MAKASSAR HIGHWAY

In the early morning hours of 23 July 2018, the 139 meters long car carrier MAKASSAR HIGHWAY grounded on the Swedish east coast (see Figure 1). There were no fatalities, but the ship was badly damaged and had to be scrapped. The vessel had deviated from its planned and safety checked track in order to go closer to the coast to ensure cell phone and Internet coverage. At the time of the grounding the vessel was steaming at economy speed, somewhat less than 14 knots, in smooth sea and good visability on a straight course in among the small skerries, rocks and shallows on a remote part of the Swedish archipelago south of Stockholm (see Figure 2).

Figure 1: MAKASSAR HIGHWAY grounded on the Swedish east coast on 23 July 2018. [1]

As the ship was approaching the coast at 7 o'clock in the morning (local lime), the first officer who had the watch was either asleep or at the back of the bridge doing administrative work. The accident investigation failed to establish exactly what he was doing, only that he was not monitoring the progress of the ship. He had a blood alcohol content at the time of the grounding estimated to 1.15 permille, according to the police report [1]. The lookout was absent from the bridge on his fire watch round when the vessel grounded.

MAKASSAR HIGHWAY had the morning before left the Kiel canal for the final leg to Sodertalje, south of Stockholm, with 1325 cars and a crew of 20 onboard. The vessel had, in accordance with Chapter V, rule 34 of SOLAS [2] and Section A-VIII/2 of STCW [3], the stipulated voyage plan programmed into the Electronic Chart and Display Information System (ECDIS). In order to monitor the vessel's progress along this planned track, the track would have had to be safety checked for under-keel clearance in order to make sure the planned track was not passing into shallow water.
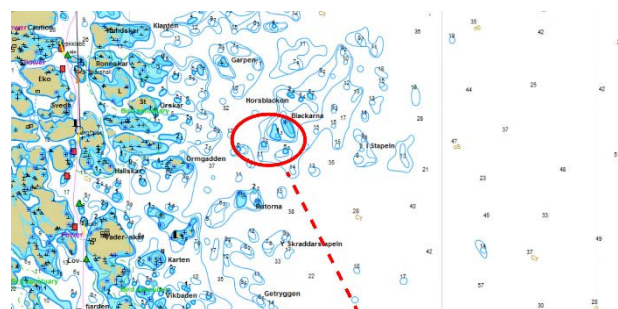

Figure 2: MAKASSAR HIGHWAY with a draft of 6.6 m grounded SE of the small port of Flatvarp on the Swedish east coast at 7:21, local time, the 23 July 2018. Derived from positions in [1].

However, during the afternoon on the day before, the vessel left the planned track and followed the coast line in the Bay of Hano (see Deviations from the track, in Figure 3). The aim was to reach the mobile telephone network and thereby having a chance to connect to the Internet at a reasonable cost in order to call family, etc. This course adjustment was accepted by the master. However, the vessel's voyage plan was not updated (which it should, according to the regulation referred to above).

During the evening of the 22nd another such deviation was made as MAKASSAR HIGHWAY went closer to the coast of the island of Oland, and later made the fatal coarse change that lead to the grounding. In Figure 3 the safety-checked voyage plan is showed in red, and the actual track the ship took is shown in blue.

Figure 3: The red line is the planned and validated route plan for MAKASSAR HIGHWAY's voyage between Kiel, Germany, towards Sodertalje, Sweden. The blue line is the actual AIS track sailed. Times here are in UTC, i.e. Swedish summer time +2H. Adapted from [1].

Swedish territorial waters in monitored by three different authorities: the Swedish Maritime Administration's coastal Vessel Traffic Service (VTS), the Coast Guard and the Defence. None of these entities raised any alarm when Makassar Highway deviated from its planned track (which is natural as voyage plans are presently not shared with external bodies). However, the VTS in Sodertalje notified the Swedish Jointed Rescue Coordination Centre (JRCC) in Gothenburg 12 minutes after the grounding that MAKASSAR HIGHWAY "had been observed being still outside of Vastervik" [1]. At around 07:45, the JRCC contacted the vessel via VHF radio. The person who answered on board stated that: "…since seven thirty we are aground…" [1].

During 2018 and 2019 two more similar groundings, with incapacitated watch officers, have occurred in Swedish waters.

1.2   OFF-TRACK ALARMS

If a watch officer falls asleep or is distracted and a ship deviates from its planed sailing route, should there not be an alarm? In the case of MAKASSAR HIGHWAY there was indeed a Bridge Navigation Watch Alarm System (BNWAS), much like a wake-up clock which sounded every 12 minutes if there was no activity on the bridge. The timer then had to be reset for another 12-minute period. This system was turned off.

However, the ECDIS also includes some automatic features designed to assist the watch officer for precisely this reason. One of them are based on the existence of a voyage plan.

The IMO regulation says: "On the basis of the fullest possible appraisal, a detailed voyage or passage plan should be prepared which should cover the entire voyage or passage from berth to berth," [4].

A voyage plan in an ECDIS is made by clicking out way points along the intended route. Some attributes need to be added to this track-line, one of them is *cross-track distance (XTD)*. Own vessels *safety depth* also needs to be set. The safety depth is the needed water depth considering draught, squat and a safety margin. When this is done the route can be automatically checked for under-keel clearance within a corridor limited by the port and starboard XTD (see Figure 4).
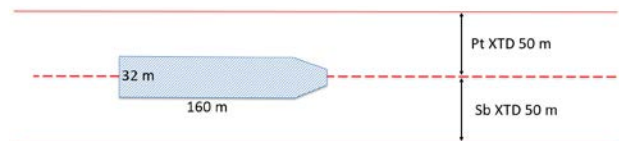

Figure 4: Cross-track distance (XTD), is set to a number of meters on the port and starboard side of the dotted track line. The corridor can then be automatically checked in ECDIS for under-keep clearance. An alarm can also be set to sound if the vessel leaves the corridor.

"When Cross Track Distances are properly set to each leg of a voyage plan then route checking assists in checking for potential obstructions, dangers and insufficient depths" [5], i.e. warnings are presented if a track line for instance passes over land, or over areas with a water depth less than the set Safety Depth.

A vessels autopilot can even be set to "path-following" mode, whereby the ship automatically can pass along a track. On one Hurtigruten ship (Norwegian coastal express) which I visited on the bridge, the captain said that they mostly sailed using track-following mode, with an off-track alarm set to 50 meters port and starboard. Manual steering was only used in very narrow passages and when going to and from mooring.

All ECDIS also have an off-track alarm for leaving the planned track. "It should be possible for the mariner to specify a cross track limit of deviation from the planned route at which an automatic off-track alarm should be activated" [6].

There is no mentioning of an off-track alarm in the accident report. And the captain states that he authorised a deviation from the planed track in the Bay of Hano the night before the grounding. This deviation was done without changing the voyage plan. However, he denies authorising the second deviation that eventually led to the grounding. It is therefore follows that this off-track alarm must have been turned off.

Many ECDIS also have a safety feature called "look-ahead sector" (or similarly). This feature warns if the

water depth within a set distance in front to the vessel is less than the set Safety Depth. This feature must also have been turned off (as it often is due to many false alarms in narrow waterways). But why was it not turned on as MAKKASAR HIGHWAY had been transiting open waters during the last 24 hours?

Had it been on, had the voyage plan been updated to reflect the new deviations and had the off-track alarm been on, and then the watch officer then fell asleep or became distracted, an alarm would call for his attention if he missed his turn. If he should he not react, such alarms can in many ships be set to promulgate to another officer onboard, the captain or to sound in the general crew's quarters. It is reasonable to believe that this could have prevented the accident.

One may wonder why such alarms can be turned off? On the other hand, experiences from interviewing bridge officers during many years show that the "alarm hysteria" on the bridge is a big problem. One may also wonder if it would not be useful if such an off-track alarm also was visible for the coastal VTS? This last question is addressed by *e-Navigation*.

2.   E-NAVIGTION

The basic technologies of electronic navigation (apart from radio and radar) came with the Global Positioning System (GPS) and electronic chart plotters in the 1980's and 90's. At about the same time in the maritime domain the Swedish pilot Benny Pettersson started experimenting with transmitting GPS positions through the Ship Position Exchange System (SPEX), later to be named Automatic Identification System (AIS). AIS became mandatory by the IMO in 2002.

In 2006 IMO approved a proposal by Japan, Marshall Islands, Netherlands, Norway, Singapore, United Kingdom and United States to develop an "e-Navigation strategy". The objective of the proposal was to "develop a broad strategic vision for incorporating the use of new technologies in a structured way and ensuring that their use is compliant with various navigational communication technologies and services that are already available, with the aim of developing an overarching accurate, secure and cost-effective system with the potential to provide global coverage for ships of all sizes" [7].

The point was to share digital data to the benefit of safety, efficiency and protection of the environment. As an example: if ships where to share voyage plans between between themselves and shore (such as VTS), "single points of failure" could be caught, such as a ship straying off its course, whether deliberate or because a watch officer was making an error or falling asleep. In many research projects since, possible e-Navigation features has been investigated. The feasibility to share routes has been called "route exchange" and could potentially allow alarms to be triggered, first onboard and later ashore, if a

ship deviated from its planned route. Addressing precisely the accident above. Route exchange in different forms has been researched by e.g. [8, 9]. However, there are also cases where alarm triggered by off-track, or shallow water cannot prevent accidents. Such cases are collisions and an example will follow.

3.   THE FU SHAN HAI-GDYNIA COLLISION

On a beautiful May day in 2003 the 225-meter-long Chinese bulk carrier FU SHAN HAI collided with the 100-meter-long Cyprus registered container ship GDYNIA about 3 nautical miles north of the island of Bornholm in the southern Baltic Sea. The ships had been on straight courses and in sight of each other for hours before the collision. According to Rule 15 of the International Regulations for Preventing Collisions at Sea 1972 [10] FU SHAN HAI was the stand-on vessel with right of way (see Figure 5).

Figure 5: FU SHAN HAI and GDYNIA collided in open sea and good visibility 31 May 2003 [Adapted from 11].

The Chinese vessel was by the rules compelled to keep her course and speed. GDYNIA, on the other hand, being the give-way vessel, should by the same rules either turn starboard and pass behind FU SHAN HAI, or slow down and let FU SHAN HAI pass in front of her. Neither was done. The reasons are unclear. There was an exchange of watches on the GDYNIA just before the collision. But it looks as the Chinese vessel was not at all observed from the GDYIA until it was too late. The subsequent collision ripped open a hole in the forward part of FU SHAN HAI which sank (see Figure 6). The crew of 27 were all rescued. [11].

Figure 6: FU SHAN HAI sinking after the collision, [11].

FU SHAN HAI had departed from Ventspils in Latvia on 30 May 2003 at 16:20 local time on a voyage to China. GDYNIA had departed from port of Gdynia in Poland the same evening at 23:25 on a voyage to Hull, England. This collision serves as an example of the about 10-15 vessels every year that are totally lost after a collision at sea. Although there is a lot to be said about the actions of the crews in relation to COLREGS, this paper will look if features made available by the e-Navigation development could be used to prevent this type of accidents.

3.1   TIME COORDINATIED VOYAGE PLANS

Both FU SHAN HAI and GDYNIA had onboard the required voyage plans, and were sailing in accordance with these plans, so no off-track alarm could warn then of the upcoming encounter ahead of time. But, if we assume that these two voyage plans had been transmitted to some sort of central coordination mechanism and superimposed on top of each other, then a warning might have been issued.

The IMO guidelines for voyage planning [4] also mentions the need to determine the estimated time of arrival (ETA) both at the destination and "at critical points for tide heights and flow". Until recently standard format for route exchange has not included speed settings and ETA at waypoints. However, in the MONALISA projects [12, 13] the author took part in work which resulted in the so called RTZ-format for route exchange, approved by the International Electrotechnical Commission in 2015 [14]. This format allows precisely that, and would allow time coordinated voyage plans to be compared for the existence of "loss of separation", i.e. if two ships planned to be in the same place at the same time.

In reality, a prediction made maybe days ahead will be inexact as speed might change due to weather, engine performance, sea state and many other parameters. But if the onboard ECDIS keeps comparing present and planned positions, safety checks and shares a constantly updated voyage plan with the central coordination mechanism the prediction will become better and better as the time to the predicted moment decreases. In the case of FU SHAN HAI and GDYNIA such a system could have alerted the bridge crew on both ships about the predicted close quarter's situation and might have recommended a minor speed change on one or both ships. Furthermore, information about the upcoming situation would have been available in the central coordination centre (maybe a "Baltic VTS") where yet another pair of eyes would be alerted and could intervene. However, to simplify for the navigator onboard and the operator in a VTS a visualisation tool is needed. This tool is called Moving Haven.

4.   MOVIG HAVENS

When submarines operate together in groups they cannot see or hear each other under water. To avoid collisions, they use coordinated voyage plans in three dimensions. Each submarine is designated to a "moving haven" visualized as a cube, moving in a 3D nautical chart. The own submarine's motions are tracked by an advanced inertial navigation system and the navigator's task is to keep the submarine within its own designated box. The other submarines' positions are visible through their havens, given that they all stay in their boxes [14].

The same principle can be applied to surface vessels. By visualizing the planned position of ship along its voyage plan with a box, a Moving Haven, the navigation officer onboard can have a quick and intuitive confirmation that he is on track and on time. If he or she strays out of the box there could be a warning.

4.1   THE WIDTH – CROSS TRACK DISTANCE

Cross-track distance (XTD) was discussed above in section 1.2. By attributing an XTD on each side of the track in the voyage plan, a corridor of safety checked water can be created for the ship. By tailoring this XTD for each leg, smaller in confined waters and larger in open sea, a dynamic precision in navigation can be acquired. In some cases, the XTD can be different on the port and starboard side, e.g. when the track passes close to a buoy. The corridor created by the port and starboard XTD can for each leg be used as the width of the Moving Haven. See Figure 7.

4.2   THE LENGTH – TEMPORAL PRECISION

The length of the Moving Haven has to do with the needed temporal precision and effective space management in a traffic coordinated system.

The length of a Moving Haven set for a precision of one hour with a ship moving at 15 knots would be 15 nautical miles long. This is not a "box", more like a long "snake". In a time-coordinated ship traffic management system where the Moving Haven was used as a "safe haven" which would be exclusive for only one ship, this would mean that the ship would block this whole area. This would be inefficient in congested waters. Some other concepts need to be considered.

Just in time arrival is a logistic concept used to make traffic flows more efficient and decrease greenhouse gas emissions. Traditionally ships would steam along their rout on their standard speed and arrive to their destination early to be able to anchor and issue a *notice of readiness*. Depending on the charter agreement they could then collect *demurrage* while waiting for the port to be ready to take them in. However, if the readiness of the port and the arrival of the ship is synchronised the ship might be able to *slow steam* to its destination and arrive just in time. And because fuel consumption (and accompanying emissions) depends exponentially on the speed, large savings can be made by slowing down.

A port is ready to take in a vessel when all assets are in place: the tide is right, pilots are ready, the required length of pier side is free, tugboats and linesmen are in place, etc. There might even be a booked time for a lock passage to reach the berth. In any of these cases a time precision for the estimated time of arrival (ETA) could be less than 5 minutes. An assumed precision of 1 minute for a 160 metres long ship moving in 15 knots is illustrated in Figure 6. That Moving Haven is 2.5 cables long (463 meters) and 100 meters wide, assuming a XTD of 50 meters port and starboard. There should be no problem to stay in such a box in nice weather for an autopilot in track-following-mode and a good *speed pilot* (autopilot for speed). Heavy wind, waves and currents would of course require different dimensions.
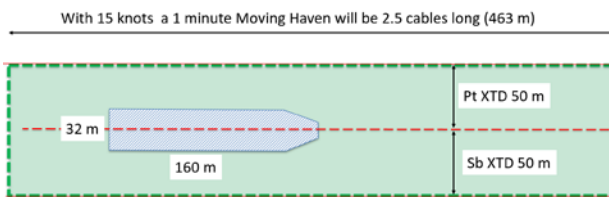

Figure 7: A 1-minute Moving Haven for a 160 meters long vessel at 15 knots will be 463 meters long. The width will be 100 meters with a XTD of 50 meters on either side of the track line. On the ECDIS the colour is green because own ship is in the haven, "on track and on time".

The time-precision could change dynamically during the voyage. Less stringent at the start and more precise closer to destination. If a ship slips out of its Moving Haven an alarm would be triggered. The ship should then either get back into the box, update the track or recalculate ETAs for the voyage.

4.3 ALARMS

Alarms could, as mentioned above, be given to the watch officer for the case the ship gets off track or loses its time slot. This could be done first visually with colours, as suggested in Figures 6, 7 and 8. If there is no response they could promulgate with alarms, first within the ship, and finally, in a STM regime, sent to a coordinating mechanism, e.g. a VTS, if one is in place for the waters.
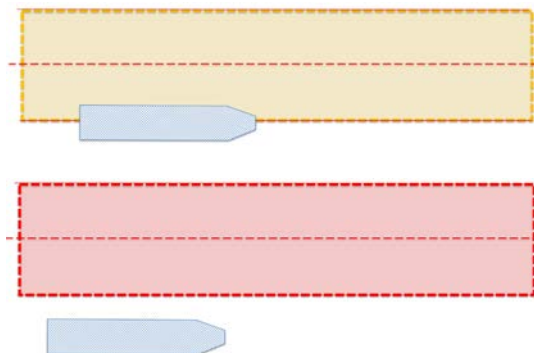

Figure 8: If a ship starts to slip out of its Moving Haven a colour warning could first alert the watch officer.

In case such a coordinating mechanism is in place and routes are shared the scenario for the example accident with FU SHAN HAI and GDYNIA, referred to above, could look like Figure 9, or 10.
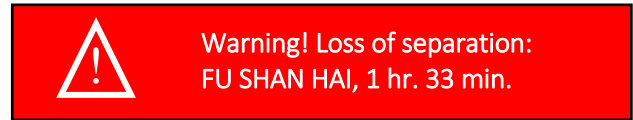

Figure 9: A central coordination system receiving voyage plans from all ships reacting to is two ships were to approach a point where they would be at the same place at the same time.

In the MONALISA project technical tests with the Moving Haven in the ECDIS-like "e-Navigation Prototype Display" were made onboard a Korean training vessel in the southern part of the Korean Republic. Figure 10 shows a screen dump from these tests. For safety reasons the ship was not allowed to navigate using the Moving Haven why the ship on this chart is outside and above the "box" in the red circle. On the "conning display", bottom right, the Haven is coloured red to warn for this fact [8].
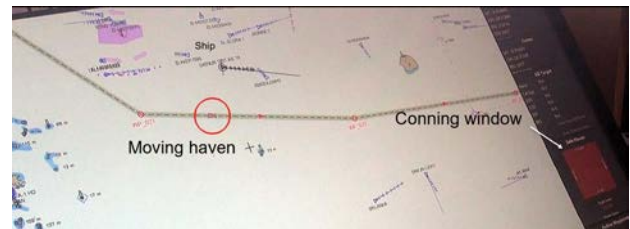

Figure 10: A screen photo from an ECDIS-like prototype display system using a Moving Haven in the sea outside, Wando in South Korea during a test in 2014. The own ship is outside ad north of the Moving Haven [8]. Photo by the author.

5. CONCLUSIONS

e-Navigation is about to deliver new infrastructure for sharing route information. This makes it possible to allow ship traffic management systems to survey and intervene in some type of accidents where bridge officers onboard have lost situation awareness (single point of failure).

Following a voyage plan for a set destination and ETA means turning up at specified waypoints at specified times, i.e. following a scheduled "virtual position" along a track on the ECDIS. This "virtual position" today often recides in the mind of the watch officer which makes it difficult to share with the outside world. Visualising this "virtual position" with a Moving Haven would make a deviation from the plan obvious for the outside world which then has a bigger chase of intervening.

While the AIS system will visualize the position of the real ship in the ECDIS, the Moving Haven will visualize the

planned (and possibly) coordinated position where the ship is supposed to be. If all ships stay in their Moving Havens, close quarter's situations and groundings can be avoided. At least in theory. In reality there are also fishing boats and leisure crafts that are not part of the system. But id at least all larger SOLAS vessels are included safety can be increased.

6. ACKNOWLEDGEMENTS

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