

Human Factor Aspects in Sea Traffic Management

Thomas Porathe, Norwegian University of Science and Technology (NTNU), Trondheim/Norway,
thomas.porathe@ntnu.no

Anders Brødje, Swedish Maritime Administration, Gothenburg/Sweden,
anders.brodje@sjofartsverket.se

Abstract

This paper presents a summary of human factor methods and results from the tests of the Ship Traffic Management (STM) system developed in the EU projects EfficienSea, MONALISA and ACCSEAS during the years 2009 to 2014. STM is a controversial concept with the possibility to move responsibility from the captain of the ship to the operator on land. However, the studies presented here showed a mostly positive and interested attitude towards the concept as it materialised in the prototype development. Focus for the studies presented have been on “professional acceptance” and safety and mostly qualitative data has been collected.

1. Introduction

On a beautiful day in May 2003 the 225 m long Chinese bulk carrier ‘Fu Shan Hai’ collided with the 100 m long Cyprus registered container ship ‘Gdynia’ about 3 nautical miles north of the island of Bornholm in the southern Baltic Sea. According to Rule 15 in the International Regulations for Preventing Collisions at Sea 1972 (COLREGS) it was ‘Fu Shan Hai’, which was coming from starboard, which was the “stand-on vessel” with right of way. According to the rules, the Chinese vessel was compelled to keep her course and speed. ‘Gdynia’, being the “give-way vessel”, should by the same rule either turn starboard and pass behind ‘Fu Shan Hai’, or slow down and let ‘Fu Shan Hai’ pass in front of her. At 12 o’clock noon there is normally a change of watch on bridges of ships. On the ‘Gdynia’ the captain was relieved by the second officer (the time 12.00 is annotated in the chart image in Fig. 1 (right) from the Danish accident investigation). The ships were at that time 18 minutes from collision. 10 minutes later the captain on ‘Fu Shan Hai’ gives a signal with the whistle and stops his propeller. However the speed only slowly starts to decrease. At 12:11 h, the second mate on the ‘Gdynia’ makes a small course change to starboard and 4 minutes later hard starboard rudder. The two ships collide 3 minutes later. The collision ripped open a hole in the forward part of ‘Fu Shan Hai’ which subsequently sank. The crew of 27 were all rescued, *DMA (2003)*.



Fig.1: Left: ‘Fu Shan Hai’ sinking after the collision, Middle: ‘Gdynia’ after the collision. Right: Chart reconstructing the ship movements for the final 18 minutes up to the collision, *DMA (2003)*

‘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. The ‘Fu Shan Hai’ and ‘Gdynia’ collision serves as an example of the 10-15 vessels every year that are lost after a collision at sea, *Graham (2012)*. Although there is a lot to be said about the actions of the ships in the final stages before the collision, this paper will focus on the fact that both ships happened to be at the same place at the same time, the question being: could this have been avoided?

All larger vessels are required to make a berth-to-berth voyage plan before leaving port according to regulations by the International Maritime Organization. Both ships here had such plans. If these two plans had been superimposed in a central coordination system, it would, knowing the service speed of both vessels, in a perfect world have been possible to predict the collision. Of course, in reality, a prediction made several days ahead will be inexact as speed might change due to weather, engine performance, sea state and many other parameters. But as the system keeps calculating the prediction will become better and better as the time to the predicted moment decreases. In the case of ‘Fu Shan Hai’ and ‘Gdynia’, the system would 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 coordination centre where yet another pair of eyes would be alerted and could intervene.

However, sharing one’s voyage plan with a coordination centre is a controversial issue challenging the captain’s ultimate control of the vessel. The presented studies here have been seeking to address the issue of professional acceptance of sharing future intended routes. The findings presented here result from work in three EU-projects:

- EfficienSea (2009-2012), <http://efficiensea.eu/>,
- MONALISA (2010-2014), <http://sjofartsverket.se/monalisa>, and
- ACCSEAS (2012-2015), <http://www.accseas.eu>.

1.2 A taxonomy of ships routes

One might think of a ship’s future voyage as consisting of different parts: first there is the voyage plan. This plan can be made many months ahead of the journey and must be in place before the ship leaves port. We call this the ship’s strategic route. Then, once the ship is underway and the strategic route is uploaded to the navigation system on-board, there are new parameters that need to be taken into consideration, like weather, other ships in the area, etc. These parameters may change parts of the strategic route on short range (maybe 30-90 minutes ahead). We call this tactical part the intended route. On a very short range (0-3 minutes) there is also a predicted route which is relatively well determined by inertial characteristics of ship and environment, Fig. 2.

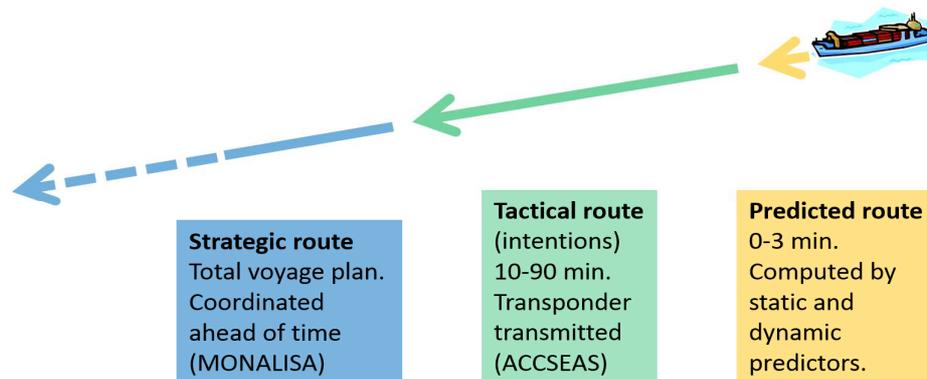


Fig. 2: A suggested taxonomy for ship routes (Inspired by Jan Hendrik Oltmann, WSV)

1.3. Ship Traffic Management (STM)

Vessel Traffic Service (VTS) has a coordinating role in many parts of the world where ship traffic is dense. The tasks of the VTS are divided into Information Service (INS), Navigational Assistant Service (NAS), and Traffic Organisation Service (TOS), *IALA (2008)*. The NAS and TOS to different extent have the ambition to coordinate ship traffic. However, VTS’s normally only manage a limited geographical area. The concept of Ship Traffic Management (STM) implies coordination of ship traffic in a much larger area, maybe as large as the North Sea or the Baltic Sea. The concept is investigated in projects like MONALISA and SESAME Straits, <http://straits-stms.com/index.html>.

The strategic route coordination process can be explained as follows, Fig. 3: The ship makes a voyage plan in its electronic chart system, just as today. (1) The route is then electronically sent to the coordination centre (2). While the centre looks at the route and checks it against close quarter's situations to other ships, violations of NoGo areas etc. the route is dashed in yellow on the chart screen (3). Next one of two things can happen: The coordination centre recommends some changes to the route (4), and sends a new route suggestion where the "not recommended" part is in red and the new suggestion is in dashed green. There can then be a negotiation back and forward until there finally is a "recommended route" dashed in green (5). The ship finally "agrees" to the route and it becomes an agreed, coordinated route with a green backdrop (6), *Porathe et al. (2014)*.

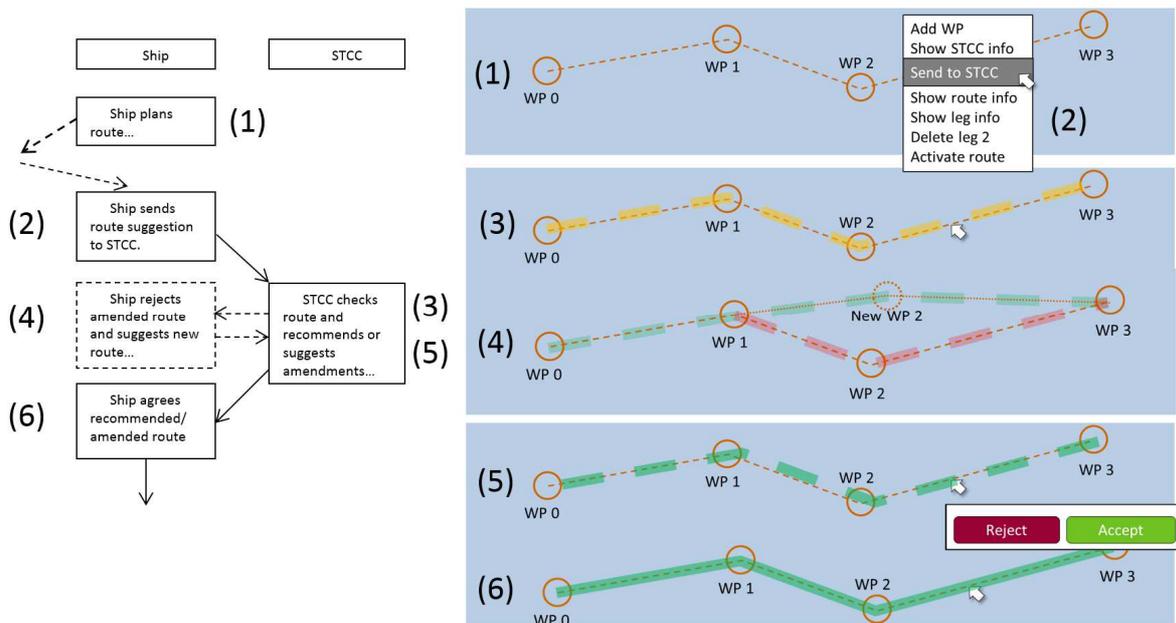


Fig. 3: Route exchange process between ship and the Ship Traffic Coordination Centre (STCC)

Strategic routes are not openly shared and only the coordination centre can see all ships strategic routes. Strategic routes can be planned years ahead as e.g. in the case of ferry companies. There will be priority issues here as well as there is with landing and start slots in the aviation industry. But these could be solved in a similar way.

The tactical, intended route process is different and much straighter. In this case, a number of waypoints ahead of the ship's present position is transmitted through AIS to all ships within radio range. They can then see other ships' "intended route" by right-clicking on the ships' AIS symbol in the electronic chart and select "show intended route", Fig. 4.

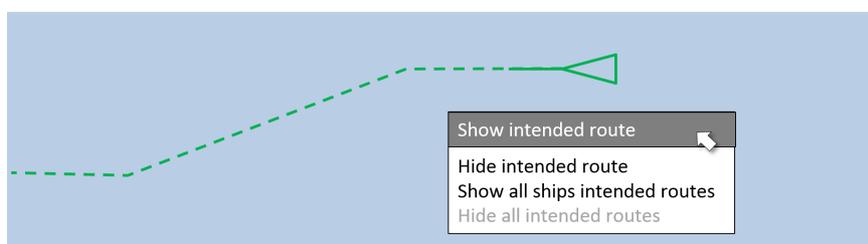


Fig. 4: A ship's intended (tactical) route is displayed by right-clicking on the AIS symbol and selecting "Show intended route".

Together the strategic and tactical route exchange forms the Human Machine Interaction basis for a proposed STM concept. This concept then has to be tested and evaluated. And in the very early phase we need to investigate professional acceptance: Is this concept acceptable for the stakeholders that

work in this process today? The captains onboard in the first instance, because they are the ones that will carry the final responsibility. And then to VTS operators which today do traffic management in local areas.

2. Method

The Human-centred design philosophy was developed in the 1980s by psychologists like *Norman (1988)*. The design process describes an iterative spiral of observation, idea generation, prototyping, and testing. The users are deeply involved in the whole process. This as a reaction to the usual process of an engineer making a specification that is then manufactured and sold, often with problems of usability as a result. One example is the Electronic Chart and Display Information Systems (ECDIS) mandatory on all vessels. It is most often a complex and difficult product with few standards and constant usability problems. The Chief Inspector of Marine Accidents wrote in the foreword of the 2013 ‘Ovit’ grounding in the Dover Strait: “This is the third grounding investigated by the MAIB where watch-keepers’ failure to use an ECDIS properly has been identified as one of the causal factors. As this report is published, there are over 30 manufacturers of ECDIS equipment, each with their own designs of user interface, and little evidence that a common approach is developing,” *MAIB (2014)*, p.9.

2.1. Prototyping

The starting point of the proposed STM solution has been the observation of real problems like the collision between ‘Fu Shan Hai’ and ‘Gdynia’. Many other accident reports have contributed to the realisation that there is a problem. Field studies have also been conducted as well as focus groups with mariners, pilots and VTS operators.

To be able to conduct user tests, the EPD (E-navigation Prototype Display) has been developed by the Danish Maritime Authority (DMA). The prototype system is able to mimic an ECDIS as well as shore-based VTS systems. The DMA software developers have been involved in the whole process and reprogrammed on the fly to improve functionality and HMI after user input. The strategic and tactic route services have all been implemented on the EPD, Fig. 5.

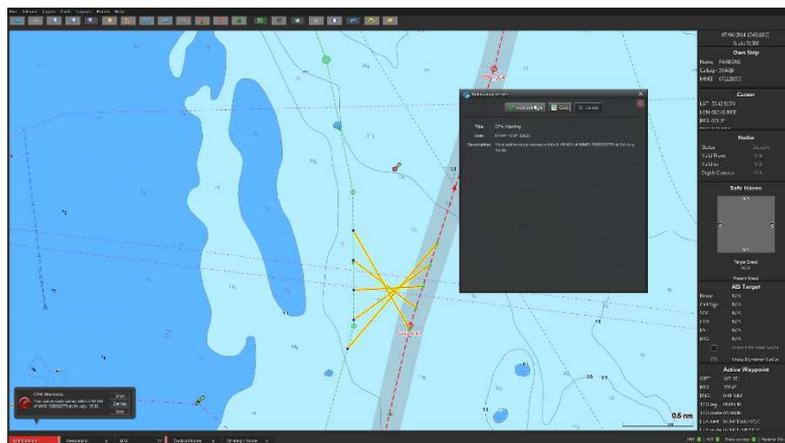


Fig. 5: Screen shot from the EPD prototype software developed by the Danish Maritime Authority as an experimental platform in order to be able to conduct simulator tests of the proposed STM

Although not a fully functioning ECDIS, the EPD had all the necessary functions to connect the necessary navigation information both in simulator and onboard ships. Once the first implementation of the STM was in place on the EPD, the testing started.

2.4. Testing

The testing was mostly done at the ship handling simulator at the Simulator Centre at Chalmers University of Technology in Gothenburg, Sweden. The simulator was a Transas 5000 with two bridges, each accommodating the bridge team in a bridge mock-up with 270° and 180° of surrounding visualization, respectively. The Transas' ECDIS was rewired to show the EPD which in turn was fed with real-time data and AIS from the simulator. The original Transas' radar screens were kept and could show AIS targets but not the new services or own ships planned route as it was made on the EPD. The benefits of using a simulator are many: compared to a real ship it is more cost and time effective, the scenarios can be repeated exactly and the realism is very high.

2.4.1. Scenarios

We will now give an overview of four studies conducted on the STM concept at different iterations during the years 2009-2014. The first study was conducted at the Simulator centre at Chalmers in 2009, *Porathe et al. (2013)*. The scenario was a passage through the Sound between Sweden and Denmark with two vessels, one passing from south to north, and one from north to south. The focus of this study was the tactical route exchange ship-to-ship.

The second study was conducted at Chalmers in 2013, *Porathe et al. (2014)*. The focus this time was the strategic route exchange ship-to-shore and shore-to-ship. The scenario was a ship entering a coordination area at Skaw sending its voyage plan to the coordination centre, and negotiating a green route. Later the route is changed, first initiated by the ship due to weather, and later by the shore due to port delays, and then drifting timber.

The second study was then repeated onboard two Korean training vessels in a Korean archipelago context in April 2014, *Porathe et al. (2014)*.

A final study focused again on the tactical route exchange and was conducted at Chalmers, *Porathe et al. (2015)*. The environment was the Humber Estuary and the approach to the ports of Immingham and Hull in the UK with several scenarios with high traffic density and congestion.

2.4.2. Participants

The participants in all these studies were professional bridge officers and pilots with long experience and cadets and in relevant cases, pilots and VTS operators with experience from the areas simulated. The scenarios lasted often several hours. Therefore the number of participants was in the range of 10-20 for each study, which inflicts somewhat on the validity.

Qualitative data was collected by video during the simulations. Here the participants were encouraged to think aloud and comment on their experience and during debriefings after the scenarios.

3. Results and discussion

3.1. The Sound simulator study, 2009

One of the most important aspects of testing new technical services such as the tactical and strategic route exchange is to look for unintended consequences of change, new behaviour that might lead to new types of accidents. One such new behaviour due to the presence of the new route intention was spotted during this test. The tanker was southbound in the Sound and was approaching the ferry crossing between Helsingborg and Helsingör. Several ferries cross the Sound here every hour and they might suddenly appear from the two ports on either side. According to COLREGS, ship should give way to other ships on their starboard side. But because of the narrow strait, the ferries normally give way for all passing traffic or delay their departure to fit an opening in the traffic flow. This is however a behaviour that has no support in COLREGS and may cause misunderstandings. When the tanker was approaching the ferry crossing from the north a ferry was departing from the Danish side on the tanker's starboard. As the ferry started she broadcasted her intended route, a straight line over

to Helsingborg. The intention of the ferry was noticed by the tanker some 6-7 minutes away. Being the give-way ship according to COLREGS rule 15, the tanker announced her intentions to go astern of the ferry by adding a waypoint and dragging it west to just outside the port entrance. She then made the route active and it was automatically broadcasted to all ships that had the “show intended routes” switched on. However, the ferry intended to give way according to practice and added two new waypoints to her route and dragged one of them behind the tanker showing her intentions to turn port outside the pier head and go astern of the tanker. The pilot onboard the tanker then acknowledged this by dragging her waypoint back to resume her previous route.

The behaviour of the bridge crew of the tanker and the ferry were quite surprising for us. The participants had not been instructed to use the intended route feature for anything else than take note of each other’s intentions. Today ships use the VHF radio to agree on counter COLREGS behaviour (for instance a meeting starboard to starboard). Such behaviour is not recommended but is still common practice. Using intended routes to negotiate a meeting situation between two ships could serve just the same purpose, only with less risk of misunderstanding because the route intentions of both ships are displayed graphically, not only for the upcoming manoeuvre but also for the following. Possibly this behaviour could lead to avoiding entering into a close quarter’s situation. This might give operators a second chance if the manoeuvre fails. However, there might be hidden traps that will need to be investigated carefully. Using intended route feature this way might lead to complicated situations in congested waters with many ships present. As one close quarter situation is resolved, others might be created. Also showing intentions and then not carry them out might be very dangerous comparable to flashing the turn lights on a car and then not turning.

An issue brought up by the participant was that there definitely was a limit when negotiations using the ECDIS had to be abandoned for old-fashioned collision avoidance looking out of the window.

A similar feature named “suggested routes” was also tested. This feature allows a stakeholder, here the VTS, to send out a route segment to a designated ship. The VTS used this feature to send new routes to one ship with too deep draught to pass the Sound altogether (which instead was rerouted via The Belt, and a ship with a planned course leading directly aground (these two scenarios were based on real situations). These tests went smoothly without surprises.

Findings from the test suggest that the intended route feature well serves its purpose. It may also serve as a less ambiguous ground for route negotiations, even if this behaviour was not intended from the start. Subjects were generally positive to the tool. But issues were raised as for instance on the cluttering of the chart in the VTS display and on that in very tight and time constrained collision situations none of the ships will have time to click intentions into the ECDIS. Another concern raised by the VTS operator was the question of responsibility for the route exchange. As an example, the VTS operator was contacted by one of the vessels asking him to send a suggested route to the other vessel to keep out of his way. Today, the Sound VTS is only entitled to give information services while the executive decisions on navigation remain the responsibility of a ship’s captain and the navigating crew. Sending routes from shore might eventually require to move some of this executive decision making power to shore to avoid unnecessary negotiations in critical situations.

Results from the simulation were promising and solutions for the problems encountered was to be found for the next iteration of the route exchange service.

3.2. The Kattegat simulator study 2013

The focus of the study was the strategic route exchange ship-to-shore and shore-to-ship. Observations, comments and statements made during the debriefings were classified into four levels: conceptual, procedural, functional and HMI. Results on the detailed levels of functions and HMI will not be presented here. In this study participated 12 captains, 12 cadets, 5 VTS operators and 1 pilot.

- Conceptual level - The hypothesis was that ship-board participants should be negative to the

route exchange concept but instead all participants were in general positive to the concept of voyage plan coordination; younger somewhat more than older. Even if older participants were more concerned with issues like de-skilling they still accepted the system. A pensioned captain with 40 years of experience said: “I don’t like this, but I see it coming, and I guess it is all right.”

The most discussed issue was on control; if voyage plan coordination would lead to control being shifted from the ship to the shore. Most bridge officers pointed out that it was important that the captain still had the last word, being on the scene and experiencing the situation first hand. Several participants saw a likelihood of conflicts between the STCC and vessel on the issue of control, and between the STCC and ship owners on the issue of costs.

From a shore perspective, the ability to check routes and see vessels’ intentions was welcomed but concerns were raised about the workload when dealing with several vessels in a heavy traffic or emergency situation.

On the question of whether a route exchange system has a future, comments ranged from

- it is inevitable, over
 - it may have a positive effect on the quality of navigation if captains can learn to trust it, to
 - it will never be accepted by captains and ship owners (said by participants not being captains or ship owners).
- Procedural level - Participants in vessels and STCC felt that new routines were involved in operating the system, but within a familiar environment so that once they understood what was expected of them and how to do it, it was easy to get accustomed. With regard to vessel manning, some felt that the new system may require an extra person on the bridge in dense traffic situations to leave the on-watch officer free to navigate and avoid collision. Depending on the degree of freedom allowed to deviate from the planned course without changing the voyage plan, it was felt by some that the result would be extra an workload when having to go through a new route agreement each time you needed to deviate of your planned course for a fishing boat.

Routines in the new coordination centre, as opposed to the existing VTS stations, would depend on the role of the new coordination centre. Issues raised by the operators were workload, the capacity to deal with heavy traffic, the ability to plan routes around obstructions and the time constraints involved. Most participants felt that the role of the STCC in the drifting timber scenario should be limited to entering the area on the chart not re-routing affected vessels.

- Survey - In a survey that was sent to the participants several weeks after they participated in the study the question “What is your opinion about the tested route exchange concept?” was asked. 18 answers were received out of 28. 14 were “positive” or “very positive” and 4 “did not know”. No one was negative. On the question “Do you think a similar route exchange concept will become reality in the future?” 17 answered “probably or most probably” and only 1 answered “probably not”.

Most participants, both younger and older, were more or less positive to the ship traffic management concept. Having said that, there was discussion on the yet undecided scope of the proposed route exchange system and the role of the new coordination centre; would it be monitoring, advisory, assistance or full control? Would it involve a change to the established principle that the captain is ultimately responsible for the vessel? Would the captain be required to relinquish some degree of control of the vessel to the shore centre? Where would responsibility and liability lie for delays, costs incurred, accidents, etc.? Several participants

expressed the likelihood of conflict between the coordination centre and vessel on the issue of control and the coordination centre and ship-owners on the issue of costs. All participants agreed that the final decision needed to stay with the captain onboard.

3.3. The Korean ship study 2014

The test in South Korea was conducted during a 24 h exercise onboard two Korean maritime academy training ships. Due to safety concerns the tests was conducted back bridge without controlling the ship. Ten cadets and 8 experienced officers participated in the experiment. The scenarios was the same as in the Swedish test related above, but set in an Korean scenario on the route from Mokpo and Busan, respectively, and to Yeosu on the Korean south east coast. On the issue of acceptance, a questionnaire handed out to the participants after the test, Table I. The figures within parentheses are the answers from the 18 Swedish cadets and experienced officers that did the test above.

Table I: Answers to the questionnaire handed out after the trial

	Very good	Good	Don't know	Bad	Very bad
What is your opinion about the tested route exchange concept?	11 (4)	8 (9)	0 (4)	0 (0)	0 (0)
	Most probably	Probably	Don't know	Probably not	Most probably not
Do you think a similar route exchange concept will become reality in the future?	6 (4)	12 (13)	1 (0)	0 (1)	0 (0)

Table II: Professional Acceptance Rating Scale. The question was: What is your professional opinion about the system tested? (Put an X in the box which best fits your opinion)

Scale value	Scale name	Description	Results (numbers of x)
0	Totally unacceptable	I think this is a very bad idea. Definitely not.	0
1	Not very acceptable	Not a good idea. Best let it be.	0
2	Neither for, nor against	I am neutral.	0
3	Acceptable	Good idea. I am for it.	3
4	Very acceptable	I think this is a very good idea. I am definitely for it	14
5	Extremely acceptable	One of the best ideas I have heard of. (Even regular users would seldom give this score.)	2

The overall opinion of the concept was very positive from the Korean test persons (as for the Swedish participants from the 2013 test). However, concern was also expressed:

- Effects of all non-AIS vessels including fishing vessels
- Navigational risk by over-reliance on the route exchange system
- In congested areas, during close encounter situations, and in narrow channels, the Officer of the Watch (OOW) needs to give full attention to look-out. The work load may then be too large to allow an exchange of information between ship and coordination centre.
- Human error due to display misunderstanding
- The EPD terminal display represents an overflow of information. Frequently, the OOW needs to have customized information and also a simplified screen. Especially when there is not enough time to understand information shown in the display for urgent situations.
- Shipping companies are not likely to open their ships' route information.
- A novice tends to over-rely on the EPD, while a senior officer may be reluctant to use the EPD.
- In stressed situations, the OOW may fail to notice new route information including new

- dangerous areas to be avoided.
- The relieving officer may overlook new route information at handover.

3.4. The Humber simulation study 2014

11 professional British, Swedish and Danish bridge officers, harbour masters, pilots and VTS operators with experience from traffic in the Humber area participated in the test.

- Conceptual level - All participants agreed that this service was valuable. “I might not have said so three days ago, but now having used it: Yes, the concept is very good. Provided the data that is displayed is correct.” (Humber pilot with 12 years’ experience). On a question if someone in the group was against the concept, there were head shakes and silence. Several of the participants soon got used to the service where they could see ships intentions; one said “after having used the system for six hours I find it annoying not being able to see ships’ intentions.” (He was referring to the fact that some of the target vessels intentionally did not send out Intended routes. Something we thought would be realistic.)

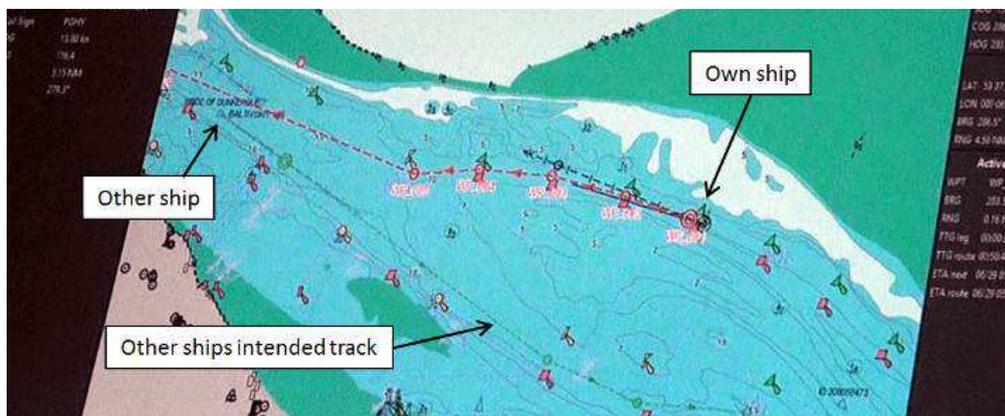


Fig. 6: Screen shot from the EPD in the Humber Estuary. Own ship is west bound in the top channel, an east bound ship passing through the main channel below is sending its intended route.

Several participants talked about the importance of “correct data”: that the voyage plan was updated and correct and from berth-to-berth. It is necessary that the bridge personal are trained and can handle the system. Generally today, the Humber participants explained, the tankers coming into river have very good passage plans because they are heavily vetted. The general cargo and bulk carries, however, generally tend to have a voyage plan that either stops at the pilot station, or – if it goes all the way to the berth – do so by a couple of haphazard waypoints. If the displayed data is not correct it could be a dangerous concept: you think you know where someone is going, but instead they are going a completely different route. E.g. there might be a change in the voyage plan and because the 2nd officer responsible for voyage planning is not on watch, the new intentions are not displayed.

One of the pilots said: On a big ship like the P&O ferry they have the time and people to do the voyage plan prudently with the right speed on all legs, etc. But on a small coaster they will just click out the waypoints, they don’t have the time or the people to do anything else. “So my concern is not so much the quality of the proposed system, much more so, the quality of the people onboard that must be able to use the system.”

The participants felt that it is important that rather than displaying all ships’ Intended routes all the time (which would clutter the display) you can (as indeed was the case) “interrogate” the display for intentions of vessels of interest. A discussion took place of what to do if a ship for some reason had to deviate from its route. One suggestion from the developers was that there should be an easy (or maybe even automatic) way of turning off the transmission of the Intended route if the vessel for some reason deviated too far from its intended voyage plan.

One of the pilots answered “Yes, having no data is better than having the wrong data.” There was an agreement that it could be a good thing if the system stopped sending route intentions if the ship was some predefined distance from its intended route for a predefined amount of time. But for minor deviations from the intended route, like overtaking, or giving extra space in a meeting situation, no one in the group felt it was necessary to stop sending, or changing the intended route. It would be obvious why the deviation was made. There was also an agreement that the Intended route service should not be used as a collision avoidance tool in close quarters situations.

It was felt that the Intended route service was probably more important in open seas than in port approaches like the Humber River, because there is already a risk mitigation service like pilot onboard and VTS that keep an eye on things. For ships coming to the pilot station it is good, but there are also uses on the river. Approaches to junction points is an example where the Intended route service can be very valuable, e.g. a small ship leaving the Baltic Sea destined for Rotterdam may equally well take a route via The Sound, the Great Belt or the Kiel Canal. Being able to see the intended route allows an overtaking ship to place itself on the proper side of the other ship.

One of the participants said on whether he would trust an Intended route, he would trust it in the same way he today trusts the AIS information. “I will not trust 100%, but it is helpful.”

- Planned speed vs. current speed - There was a major discussion on whether planned speed or current speed should be used when calculating a ship’s future position. The Intended route service as it was implemented in the prototype system was using the planned ETA in all waypoints to calculate where own and other ships would be at a certain time. The planned speed was based on the notion that ships should be at their final destination precisely in the planned arrival time. However, one of the pilots commented that in reality ships will not be following their planned speed exactly. Thus the ETAs in different waypoints (at least the closest ones) should reflect the actual, current, speed of a vessel. “You always want to go a little bit faster to make sure that you can make your ETA. ‘Rush to wait’. You will burn a little bit more fuel, but it cost more to let the stevedores, the lorries, etc. wait.”
- Procedural level - It was discussed if the Intended route service would increase workload compared with today to a point where you would need to have an extra person on bridge just to run the system. Observation during the test scenarios showed that the usability of the system was not optimal yet and the participants were given help when they did not know how to activate a feature. Several participants commented however that they would expect the handling of the service to be smooth once they mastered the system. The test scenarios took place close to port or in the approach and this is where you would normally be two persons on the bridge. In a deep-sea passage there would be only one officer on the bridge, but then the situations would normally be a lot calmer. “The workload re-mains the same, but the system will increase the quality of decision making,” was one comment.

The Intended route service might lessen workload for the pilot as the rest of the bridge team can see the intentions and future whereabouts of other vessels. One of the pilots mentioned that he spent a lot of time explaining to the captain or watch officer what was the intentions of other ships in the area leaving berth or entering into the approach channel.

One of the VTS operator said that, given the VTS had Traffic Organization Service (TOS) authority, the Intended route service would greatly increase the opportunity to organize the traffic. This would be of great value but would also increase the workload in the VTS.

- Functional level - Normally you have your ECDIS off-centred with most of the space in front of your ship and very little space behind you. But sometimes you are overtaken by a much

faster ship. If you use route CPA as a filter for turning on Intended routes automatically you might get too many intended routes visible cluttering the screen, but it would be nice if you could have a “guard zone” astern which would turn on Intended routes only from overtaking ships. It would probably be necessary to have a “harbour” and a “sea” mode with different route CPA filter settings.

An issue could be when you are making an approach. You investigate the other vessels' intended routes and you make a strategy for how you want to deal with upcoming meetings. Then one of the vessels changes his intended route. The chance is that you will not notice that. It might be useful with some form of highlighting of changed intentions.

- HMI level - The user-friendliness of the system was discussed. It was pointed out that it was important that all watch officers on-board could use the system so that updates of Intended routes did not have to wait for that the responsible navigation officer (normally 2nd mate) was on watch. “But I think if we were here for another week we would be a lot quicker and comfortable with it. It is not a difficult system to use. It is more a question of familiarity, rather than the system being complicated.”

During the first round of tests users commented on the HMI that it was difficult to distinguish intended routes from each other as they all had the same light green colour, and also to know which track belonged to which ship (the label with ship information was only shown on mouse-over on the vessel AIS target triangle). Because we had the programmer present during the tests the interface was updated for the next set of trials starting the day after. In the new HMI an Intended track could be queried by pointing at it with the cursor. The track would then become highlighted in a darker green colour, the vessels icon would become highlighted with a circle and the position on the intended track line where the cursor pointed would be connected to the own ship's position at the same time by a CPA Guidance Line. These lines could be used to query another ships track about the closest point of approach (CPA). The second round of participants found these new features useful and de-cluttered the interface somewhat.

Overtaking another vessel on a similar route is still difficult because the intended route of the other vessel may be hidden by your own route. It was also mentioned that routes needed to be transparent so that they did not hide e.g. depth figures. “The green colour of the intended routes makes them difficult to see; especially if you got more than one. Maybe you could use different colours; you need to be able to separate one vessel from another.”

- Survey - The participants were asked to summarize their impressions about the service in a survey with three questions. 9 of the 11 participants answered the survey.
 1. “What is your opinion about the tested In-tended routes concept?” All participants answered “Good” or “Very good”.
 2. “Do you think a similar Intended routes concept will become reality in the future?” All participants answered “Probably” or “Most probably”.
 3. “What is your professional opinion about the system tested?” The participants were asked to rank their acceptance on a scale between 0 and 5 (0 = “Totally unacceptable”, 1 = “Not very acceptable”, 2 = “Neither for, nor against”, 3 = “Acceptable”, 4 = “Very acceptable”, 5 = “Extremely acceptable”). The mean score was 3.7, i.e. between “Acceptable” and “Very acceptable”.

4. Conclusions

This paper summarised four studies focusing on human factors issues of the new Ship Traffic Management concept proposed in the EU projects EfficienSea, MONALISA and ACCSEAS. The work spans over a period of 6 years from 2009 up to 2015. The early studies were conducted with

early iterations of the user interface (HMI) and as time went on new and more mature versions were developed based on input from the earlier studies.

The main focus has been on the “professional acceptance” of route sharing. Much to our surprise, the participants have been much more positive than expected all through the development period. Ideas and comments from the participants have greatly helped to improve the subsequent interface versions.

Another focus has been safety and unintended consequences of the new system. But apart from the new behaviour of negotiating to avoid entering into a close quarter’s situation, we did not make any alarming observations. That does not mean that we in any way have explored all possible ways of misunderstanding or misusing it.

For the coming year, simulations of route exchange using the newly developed European simulator network will be done. Up to twenty live ships (simulator bridges from all over Europe) will sail in scenarios involving both strategic and tactical route exchange.

Acknowledgement

This research has been possible thanks to funding from the European Union’s Seventh Framework program for infrastructure TEN-T (MONALSIA), InterReg IVB Baltic (EfficienSea) and North Sea (ACCSEAS) programs and from the Region Västra Götaland, Sweden.

References

DMA, Danish Maritime Authority. (2003), *Causality Report: Collision between Chinese bulk carrier ‘FU SHAN HAI’ and Cypriot container vessel GDYNIA*, Division for investigation of maritime accidents, File 199935831

GRAHAM, P. (2012), *Casualty and World Fleet*, Int. Union of Marine Insurance (IUMI), London

IALA (2008), *IALA VTS Manual*, Int. Association of aids to navigation and Lighthouse Authorities, Saint Germain-en-Laye

MAIB (2014), *Report on the investigation of the grounding of Ovit in the Dover Strait on 18 September 2013*, Marine Accident Investigation Branch, Southampton

PORATHE, T.; BORUP, O.; JEONG, J.S.; PARK, J.H.; ANDERSEN CAMRE, D., BRÖDJE, A. (2014), *Ship traffic management route exchange: acceptance in Korea and Sweden, a cross cultural study*, Int. Symp. Information on Ships (ISIS), Hamburg, pp.64-79

PORATHE, T.; LÜTZHÖFT, M.; PRAETORIUS, G. (2013), *Communicating intended routes in ECDIS: Evaluating technological change*, Accident Analysis and Prevention 60, pp.366-370

PORATHE, T.; DE VRIES, L.; PRISON, J. (2014), *Ship voyage plan coordination in the MONALISA project: user tests of a prototype ship traffic management system*, Human Factors and Ergonomics Society Europe Chapter 2013 Annual Conf.

PORATHE, T.; BRÖDJE, A.; WEBER, R.; ANDERSEN CAMRE, D.; BORUP, O. (2015), *Supporting situation awareness on the bridge: testing route exchange in a practical e-Navigation study*, TransNav Conf., Gdynia