Ship voyage plan coordination in the MONALISA project: user tests of a prototype ship traffic management system

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Abstract

EU has promised to reduce emissions by 80 % by 2050. For the shipping industry "slow steaming" for just-in-time arrival promises reductions of emissions. But a rapid increase in the construction of offshore wind farms planned in the North Sea may lead to ships facing a very complex and safety critical traffic environment in the future. Both of these issues bring ship traffic management to attention. In the Baltic Sea, the EU project MONALISA (Motorways & Electronic Navigation by Intelligence at Sea) has been looking at a voyage plan coordination system where a Ship Traffic Coordination Centre (STCC) handles a specific area, e.g. the Baltic Sea. A prototype system was developed and tested in a full mission bridge simulator environment for some simple scenarios. Qualitative data were collected; the main aim was to test mariners' acceptance of such a system. The participants were in general positive to the tested system; younger somewhat more than older. Some concern was expressed over risks of de-skilling and a common concern was the importance of the final control of the vessel resting with the captain on-board.

Introduction

This paper will present work on ship voyage plan coordination done in the TEN-T EU project MONALISA. Ship voyage plan coordination will be introduced from three perspectives: an environmental, an efficiency and a safety perspective.

The environmental perspective

EU has promised to reduce greenhouse gas emissions by 80 % by 2050 (European Commission, 2012). That is a substantial promise. The shipping industry is responsible for about 4-5 % of all greenhouse gas emissions globally (Harrould-Kolieb, 2008). That may not be much. But if the collective shipping industry was a country, it would be the 6th largest producer of greenhouse gas emissions. While land transportation can drive on electricity produced by wind, water and fossil-free fuels, these options are very limited for shipping. One large opportunity lies in what is called *slow steaming*. By reducing the speed of a typical container vessel by 30 %, a 50 % reduction in fuel consumption, and thereby also fuel costs and emissions, can

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be achieved (Cariou, 2011). This is, however, a complex issue, as slower speed also means that more ships have to be engaged in order to maintain the transport capacity. The bottom line is that slow steaming has a potential to reduce emissions from the shipping industry. A study by Pierre Cariou (2011) shows that slow steaming has the potential of reducing emissions by around 11%, looking at data from 2 years back. This is close to the target of a 15% reduction by 2018 that was proposed by the International Maritime Organisation's Marine Environment Protection Committee, 2009.

The efficiency perspective

Today, ports have a very close horizon. The harbour masters of Scandinavia's biggest port, Gothenburg, and Humber Ports, one of U.K.'s largest ports, reveal that they do not know more than 2-3 hours beforehand whether a ship will arrive on time or not (personal communication 2012 and 2013). This leads to ports operating on a "first come, first served" basis which in turn leads to ships normally going full speed ahead and then anchoring up, issuing their notice of readiness. If slow steaming is to become a reality, a just-in-time, ship traffic management system with time slots has to be put in place that allows ship arrivals and departures to become predictable. This would in turn be beneficial to the entire transportation chain, on into the hinterland. Another factor is the increased complexity of ship traffic. The North Sea is an extremely busy shipping area and the English Channel the busiest strait in the world (133,444 ship passages in 2012).

A study in another EU research project, ACCSEAS, predicts that this number will increase to 200,000 by 2025 (ACCSEAS, 2013). To further complicate the picture, there is a rapid exploitation of sea areas for wind energy. In the German Bight, for instance, 10,000 wind turbines are currently being planned to replace German nuclear power. And to achieve the EU goal of 80 % reduction mentioned above, sea-based wind farms must keep expanding. In Figure 1 (left) the projected state of the North Sea is shown, with the amount of ship traffic passing the red lines (and the 2012 figure in brackets). The dark blue polygons are areas where today there is open sea, and tomorrow there will be wind mill farms. In Figure 1 (right) there is a close up of the "windmill city" of the German Bight, where shipping risks being conducted under more or less "street-like" conditions.

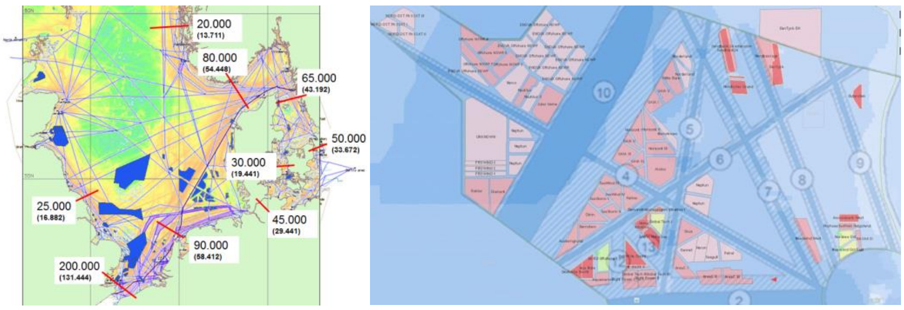


Figure 1. To the left, the predicted number of ships in the North Sea passing each red line in 2025 (the figures in brackets are the actual numbers in 2012). The blue areas are the planned

wind farms. To the right is a close up of the German Bight area, with the planned wind farms and shipping lanes (data from the ACCSEAS project, 2013).

However, if slow steaming is to be standard practice, a still larger increase in the number of ships is needed to not only keep up, but increase transportation capacity. Add to that the expected reduction in available sea space. Both these factors also bring ship traffic management to attention.

The safety perspective

On the 31 May 2003, the 225 metre long Chinese bulk carrier *M/V Fu Shan Hai* collided with the 100 metre long Cyprus registered container ship *M/V Gdynia*, about 3 nautical miles north of the island of Bornholm, in the southern Baltic Sea. The collision was the result of a failed avoidance manoeuvre by *Gdynia* as the give-way vessel. 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).

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 the 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 totally lost after a collision at sea (IUMI, 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, so-called SOLAS vessels are required to make a “berth-to-berth voyage plan” before leaving port, according to Reg. 34 of SOLAS Chapter V and IMO Resolution A.893(21) (IMO, 2010). When *Fu Shan Hai* left Ventspils, she had such a plan for her voyage across the Baltic Sea, up through the Belt and on all the way to China. Taking into account her service speed, the crew could calculate an estimated time of arrival in China. The same would be true for any point on the voyage. Also, *Gdynia* had such a voyage plan.

If these two plans could have been superimposed on top of each other in a central coordination system, it would, knowing the service speed of both vessels, have been possible to predict that they would be at some point at the same time. Then only a very slight change of speed would lead to the avoidance of the close quarters situation which occurred. 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 study has been seeking to answer how the suggested MONALISA voyage plan coordination system is perceived by Swedish mariners.

MONALISA and the concept of route exchange

MONALISA is a TEN-T EU project, started in 2010 and which will be finished in 2013. The project has been coordinated by the Swedish Maritime Administration. Other partners in the project are Chalmers University of Technology, Sweden; Danish Maritime Authority; Finnish Transport Agency; Gate House, Denmark; SAAB Transponder Tech, Sweden; and SSPA Sweden AB. The MONALISA project deals with different maritime questions, but in this paper only the particular issue of route exchange will be considered.

In order to avoid yet another system on the bridge, the route exchange system needs to be integrated into the Electronic Chart and Display Information System (ECDIS) that already is central on a ship's bridge. ECDIS is a computerised information system that contains electronic nautical charts, and will become mandatory on deep sea vessels by 2018. The voyage plan is, for instance, made in the ECDIS and resides in the navigation computer, and thus could easily be shared if relevant infrastructure and standards were in place.

In order to test route exchange, a prototype "ECDIS-like" ship-based test platform was developed to mimic a standard ECDIS, but which was equipped with functionality to exchange routes. A corresponding shore-based station was also developed where routes could be received and compared. A first set of user tests, with simple cases of route exchange between only one ship and a shore centre, were carried out in a simulator centre at Chalmers University of Technology, in Sweden, with bridge officers and Vessel Traffic Service (VTS) operators.

The main research question was whether such a system would be accepted by the professional participants. Secondary questions had to do with workload, changes in procedures and usability improvements. Another major task was to look for unintended consequences of change, as new technologies always carry an inherent risk of new types of accidents.

Theory

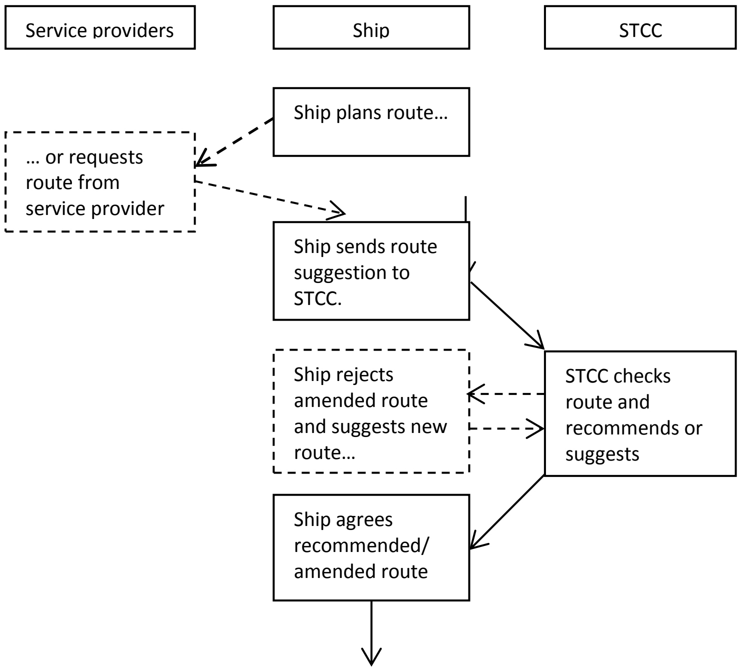
The theories behind this type of system are well-known to all human factors researchers. Donald Norman (1988) introduced the notion of *knowledge in the head and knowledge in the world*. A nautical chart is a representation of the physical world. It represents a crystallisation of knowledge from generations of hydrographers and geographers. By drawing a pencil line representing an intended voyage, knowledge is stored (in the form of checks for under keel clearance, risks etc.), and cognition is downloaded during the voyage. The projection of the chart is such that, by measuring the bearing of the intended path, the course to steer is immediately clear. The nautical chart is used, here, as a *cognitive tool* in a process of *distributed cognition*, investigated by Edwin Hutchins (1995). On a more general level, this is all part of the area of Joint Cognitive Systems (Hollnagel & Woods, 2005), and earlier, Cognitive Systems Engineering (Rasmussen et al., 1994), to mention just some important examples.

Method

In order to test ship traffic management in an ecologically valid way, route exchange needed to be tested on a practical level in a ship and shore simulator. The first step was to design a prototype application where captains and shore operators could experience, first hand, the effects of such a system. Although much focus was put on the conceptual level of acceptance within the maritime community, it was also necessary to ascertain that procedures on the bridge were not changed in such a way that would increase workload or require more manning.

Information flow in route exchange

The information flow can, from a user perspective, be described as follows. The voyage is planned on-board as usual (or maybe requested from a service provider, e.g. a weather routing service or a route library). Once the route has been validated (checked for under-keel clearance, and that it follows fairways and traffic separation schemes), and departure and arrival times have been added, the route is sent to the STCC. The route is now “pending” (signified by a yellow dashed pattern in the chart systems). The STCC checks the route, (checks it for under keel clearance, violation of NoGo areas and loss of separation, i.e. conflicts with other ships or traffic congestions, not tested in this study). The STCC can now either “recommend” the route as it is, or send the route back with suggested changes (signified in the charts by green dashed/”recommended” and red dashed/”not recommended” routes). If the STCC suggests changes, the ship can either accept or reject these changes, or suggest another modification. Routes can be sent back and forward until an agreement is reached and a final solid green/”agreed” route is reached (see Figure 2).



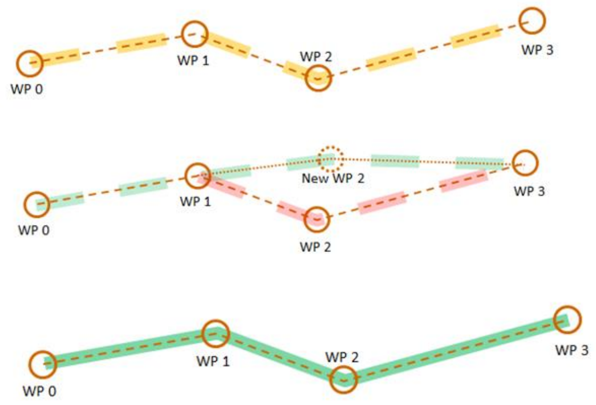


Figure 2. On top, is a simplified diagram of the information flow for the route exchange process. To the bottom, is the symbology used in the electronic chart systems to signify (top) a "pending" route sent from ship to shore, now awaiting optimisation, then a stage in a route negotiation (middle) where a deviation is "recommended" (green) instead of the original (red) segment. Finally (bottom), the "recommended" route has been "acknowledged" by the ship and becomes green/"agreed".

Two prototype systems were developed and tested during this study: one from SAAB Transponder Tech and one from the Danish Maritime Authority. Both systems had a ship and a shore display, and there were no significant differences between them. In this paper, we will make no distinction between the two systems.

The prototype systems were set up in the full mission bridge simulator environment at Chalmers University of Technology in Gothenburg, Sweden, using one bridge and one shore station. AIS targets and routes were sent between ship and shore using prototype protocols developed for the test. The technical details of these protocols will later be presented through the MONALISA 2 project.

The first user tests with simple cases of route exchange between one ship and a shore centre were carried out in two sessions, in May and September 2013, with 12 ship captains, 11 maritime academy 4th year cadets and 5 VTS operators. This gave a sample of subject matter experts: 25 male, 3 female; ages 27-66, mean age 42; professional experience from none (cadets) to 40 years, the mean being 15.7 years of professional experience (cadets excluded).

Each block of the study consisted of 4 scenarios where one captain and a cadet manned the ship bridge and a VTS operator the STCC. Each such block took about 3 hours to conduct, including familiarisation with the prototype systems, the 4 scenarios and a debriefing session.

Scenario 1: Route planning initiated by ship. The ship is anchored outside Hirtshals in the northern part of Denmark and the bridge crew plan a route from their present position to Helsingborg in southern Sweden along the standard "T-route" (the deep water route through Kattegat). Once planned, the route is sent to STCC. STCC checks the route and sends a "recommended" route back. The ship finally "acknowledges" the route (see Figure 3, left).

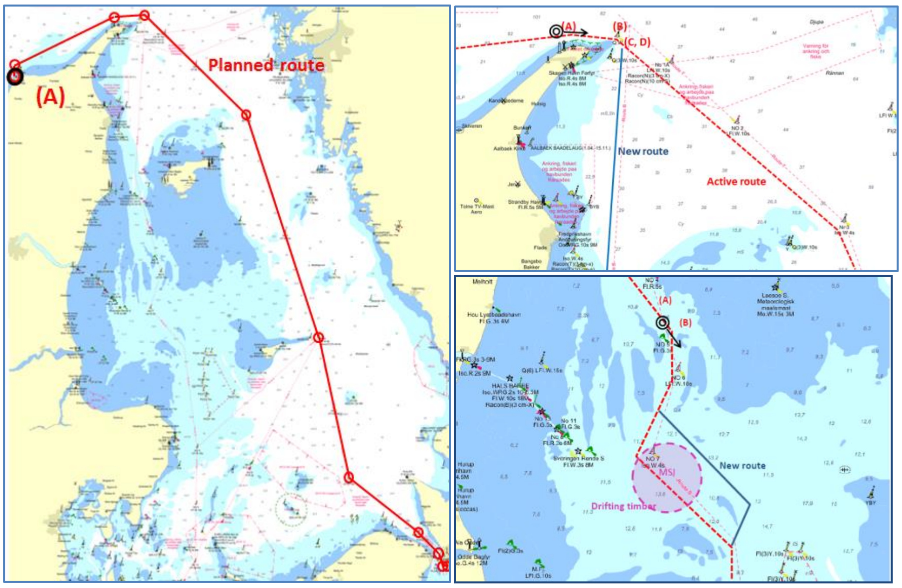


Figure 3. Three of the four test scenarios. Left scenario 1 with the route from Hirtshals to Helsingborg that the bridge crew was to plan. Top right, scenario 2, a route change done en route, initiated by the ship. Bottom right, scenario 4: drifting timber causing STCC to suggest a route deviation. (The images are just scenario descriptions, not ECDIS with MONALISA symbology).

Scenario 2: Route change initiated by ship. An hour later, the ship is en route to Helsingborg on its agreed route, just north of Skaw, on the northern tip of Denmark. The engine room calls and says they will need to do some repair in the engine room. They ask if the bridge can provide calmer conditions. The captain decides to change the route to the "B-route" (in the west part of Kattegat), in the sheltered waters along the eastern shores of Denmark. The new route is planned and sent to STCC (see Figure 3, top right).

Scenario 3: Route change initiated by STCC. There has been a delay in port operations at Helsingborg, and a request to slow down is sent from STCC to the ship. New ETAs (Estimated Times of Arrival) are suggested in the waypoints ahead. The change is negotiated and finally agreed.

Scenario 4: Route change initiated by STCC. A ship ahead has lost part of its deck cargo (timber), which is now floating in the water. An MSI (Maritime Safety Information) is sent out and displayed in the chart (see Figure 3, lower right). STCC suggests a route change around the dangerous area, which is negotiated and agreed (see Figure 4).

Figure 4. Watch officer and captain on the simulator bridge. The route is visible in the prototype screen (scenario 4, before the MSI with drifting timber has been received).

Data collection

Qualitative data were collected using video recordings during sessions, and a debriefing with both ship and shore participants after the four blocks. An observer was also present both in the ship simulator, and at the shore station, taking notes and prompting participants to think aloud. A questionnaire was also sent out by mail to the participants after a couple of weeks.

Results and discussion

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 in this paper.

Conceptual level

The hypothesis was that ship-board participants would be negative towards the route exchange concept, but instead all participants were, in general, positive towards the concept of voyage plan coordination; younger somewhat more than older. But 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 alright.”

The most discussed issue was that of control; if voyage plan coordination were to 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 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 pointing out that it is inevitable, to stating that it may have a positive effect on the quality of navigation if captains can learn to trust it. Some comments were to the effect that it will never be accepted by captains and ship owners.

Procedural level

Participants in both vessel 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.

All differentiated between the planning and monitoring functions of the system, and the need for separate routines for each. In most cases, physical separation of the functions, either separate screens or a separate workplace, were suggested. It was pointed out that individual vessels have different routines for route planning, either first using paper charts, or using the ECDIS straight away, which, depending on the method currently employed, could lead to a change in routine.

With regard to vessel manning, some felt that an extra person may be needed on the bridge in heavy traffic situations, to leave the on-watch officer free to navigate and avoid collision. It was also felt by some that, depending on the degree of freedom allowed to deviate from the planned course, implementation of such a system would result in extra workload for the captain, who would be required to approve all changes made.

Routines in the STCC, as opposed to the existing VTS stations, would depend on the role of the STCC. Issues raised by the participants 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 an MSI situation should be limited to entering the area on the chart and sending to 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. Eighteen answers where received, out of 28, and 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".

Conclusion and future studies

Most participants, both younger and older, were more or less positive towards 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 STCC; 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 mentioned the likelihood of conflict between the STCC and vessel on the issue of control, and between the STCC and ship-owners on the issue of costs. All participants agreed that the final decision needed to stay with the captain on-board.

One has to be aware of the limited validity of these findings, considering the small number of participants and the cultural homogeneity (all Swedish). Also, the tested scenarios only involved one ship, without the complexity of routing several ships. Future studies will target both these limitations. Preparations for test-beds in other parts of the world have started, and, in the MONALISA 2 project, complex simulation involving more ships will be conducted.

Acknowledgements

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