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Safe Vessel Operations – The Tacit Knowledge of Navigators

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ABSTRACT: The collision regulations include several qualitative terms without providing guidance as to how these terms could be understood in quantitative terms. These terms must therefore be interpreted by navigators, which poses a problem for autonomous ships. Extend the knowledge of how navigators interpret the collision regulations, with a specific focus on how they interpret the rule covering the requirement to proceed at a safe speed. Qualitative study based on interviews of a convenience sample of eight Norwegian navigators. Data was analysed with systematic text condensation. Navigators characterise safe speed as a speed in which they have control. Navigators do not look at different factors mentioned in the collision regulations in isolation, but within the context of the situation. Determining the safe speed of a vessel is more complicated than made out in the literature. As autonomous ships will have to cooperate with conventional vessels, their programming must include the knowledge of how the collision regulations are interpreted by human navigators.

1 INTRODUCTION

Collisions have been the second top cause for shipping casualties and incidents in 2022 [1]. The Norwegian Maritime Authority – which collects incident statistics that combine Norwegian vessels regardless of location, and foreign vessels operating in Norwegian waters – reports that in every year since 2011 at least 16 collisions have occurred [2].

To prevent collisions from occurring, the International Maritime Organization (IMO) has published the International Regulations for Preventing Collisions at Sea 1972 (COLREGs). These rules apply to all vessels upon the high seas and in all waters connected therewith navigable by seagoing vessels [3]. As such, maritime autonomous surface ships (MASS) will also be required to follow these rules.

Having entered into force in 1977 – they were presumably written without having modern autonomous cargo vessels in mind. The COLREGs include various qualitative terms – such as "early", "substantial" and "safe" – without providing any information as to how these terms could be understood in quantitative terms. The result is a rule system that relies heavily on the interpretation of the navigator. While ambiguity is a desired trait of the COLREGs (a completely prescriptive and rigid rule-system would be infinitely complicated [4]), it has led to a situation where there may be a large discrepancy between the legal interpretation of the COLREGs and the conventional way navigators avoid collisions [5]. In practice this means that navigators are pressured both to follow convention, in order to avoid collision, and the law, to avoid prosecution should anything go wrong [5].

This distinction between the legal interpretation and convention was highlighted in a study by Dreyer [6], where it was shown that vessel speeds predicted by legal interpretation of the COLREGs and actual observed vessel speeds did not align: The idea put forward by legal scholars that visibility is the most important factor when it comes to safe speed [7-9] was not mirrored in the data of actual ship behaviours.

As collision avoidance between vessels is seen as a game of coordination, where navigators on different vessels have to independently choose mutually compatible strategies [5], the control system of a MASS must not only be aware of the legal interpretation of the COLREGs, but also of the conventional way navigators apply the rules in practice. Indeed, if MASS are "too strict" in following the legal interpretation of the COLREGs they might – at times – jeopardize the safety of a ship encounter [10].

As a better understanding of the conventional way navigators apply the COLREGs in practice is necessary, this study aims to extend the knowledge of how navigators interpret the rules, with a specific focus on how they interpret the rule covering the requirement to proceed at a safe speed.

2 BACKGROUND

Rule 6 of the COLREGs deals with safe speed. It requires that "every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions". To determine what speed may be considered safe, the COLREGs provide a number of factors that shall be among those taken into account, including visibility, traffic density, manoeuvrability of the vessel, background light, the state of wind, sea and current, the proximity of navigational hazards and the draught in relation to the available depth of water [11].

3 3 MATERIALS AND METHODS

3.1 *Participants*

A purposive sample of two fast ferry captains and six maritime pilots (eight men, no women) aged 33 – 61 years working in Norway participated in the study. The lack of gender difference largely reflects the situation in the maritime industry where the majority of seafarers are men [12]. The strategy for selecting the study subjects (purposefully) was influenced by homogenous sampling (in terms of professional background) and convenience sampling [13]. The concept of saturation was considered when deciding on the amount of interviews to conduct in this study [14]. Saturation is achieved "when gathering fresh data no longer sparks new theoretical insights, nor reveals new properties of your core theoretical categories" [15]. Following the eight semi-structured interviews that were conducted, saturation was achieved.

The professional seafaring experience of the participants ranged from 8 – 38 years. Seven participants had 21 years of experience or more.

3.2 *Interview Procedure*

The author conducted the interviews. One interview was conducted via the videotelephony software program Zoom Meetings, one interview was conducted in a meeting room at the interviewer's workplace and the rest of the interviews were conducted at the homes of the interviewees. The interviews lasted from 58 minutes to 2 hours and 6 minutes. A semi-structured interview guide was used as a tool to obtain detailed descriptions of the seafarers' experiences in order to grasp the tacit knowledge of seafarers that is so important in ensuring safe vessel operations. The main questions were: How do you ensure the safe and smooth operation of your vessel? What factors go into your decision for setting your vessels speed? How do you determine safe speed? Could you rank influencing factors by importance?

All interviews were recorded and transcribed.

3.3 *Data Analysis*

The data collected in this study was analysed by means of systematic text condensation [16]. The approach is described as a four-step procedure: (1) reading the transcripts to get an overall impression and identifying preliminary themes; (2) extracting meaning units from the transcripts and sorting them into codes and code groups; (3) condensing the meaning within each code group; (4) summarizing the content into meaningful descriptions [16, 17]. The author conducted all steps of the analysis. In this regard it must be noted that the author's background as a navigational watch officer with knowledge and experience within the field has influenced the process of collecting and interpreting data. As the final descriptions were developed and refined over time, the interview transcripts were read repeatedly to ensure that the constructed descriptions were grounded in the empirical data.

3.4 *Ethical Considerations*

The Norwegian centre for research data approved the study. The interviewees received an information letter and provided consent to participate. They were informed that they could withdraw from the study at any time (until publication) without providing any reason. Data was treated confidentially and information about the seafarers is presented in such a way that they are not identifiable.

4 FINDINGS

It was found that navigators predominantly experience a vessels speed to be safe when they feel comfortable with the ship and feel that they are in control. While COLREG rule 6 – the rule covering the safe speed requirement – mentions several factors, and legal scholars have pointed to visibility as being the most important factor, the navigators had a different view. Navigators highlight that the factors affecting safe speed are very dependent not only one another, but also the context of the situation. Indeed, as the context is often confused and complicated, ranking different factors by importance will likely be an oversimplification that does not cover all scenarios. While visibility is seen as an important factor, the impact visibility has on "safe" speed depends on the specific circumstances of the situation. These findings are elaborated below. The findings include authentic illustrative quotations (AIQ), which are not necessarily direct citations but descriptive synthesized quotations that aim to grasp the essence of the opinions voiced by all interviewees [16, 18].

4.1 *Ensuring Safe and Efficient Navigation*

When asked how they ensure safe and efficient navigation, interviewees responded by firstly mentioning one of the following two concepts: Comfortableness with the vessel, and knowledge of the area. How comfortable they are with the vessel they are on depends on both the manoeuvrability of the vessel itself, as well as outside factors affecting the vessel. When the navigator is comfortable with the vessel, less attention is required for keeping the vessel on course. This frees up mental capacities that can be focused on other important tasks such as overseeing the traffic situation.

If you are very comfortable with the vessel, and you encounter bad weather, then you do not need to use so many brain cells and energy on thinking about how to turn the vessel.

The same principle applies to being comfortable with the area the navigator is navigating in. Being well versed in the area includes being aware of the safe path(s) through the area, navigational aids and dangers as well as areas where encountering other traffic is likely.

If you know the area, the way, the courses, and the navigational aids, then you can function as a human sensor: even if there is a technical failure in the vessel's navigation equipment, you should still be able to find your way.

Actively utilising the available navigational aids means that navigators can traverse an area without having to constantly check the (electronic) navigational charts or relying on technical support. This both introduces redundancy as well as it frees up mental capacities which the navigator can then focus on other important tasks.

4.2 *The Meaning of Safe Speed*

When it comes to safe speed, it was difficult to get a clear definition of the concept. During some interviews it seemed as if the interviewees understanding of the concept was inconsistent.

Safe speed is a speed which allows you to stop before you get into a dangerous situation. If something suddenly appears in front of you, you must be able to stop. This would mean that you should not be underway when visibility is so poor that you cannot see past your own bow. But in reality, safe speed is so individual that it is difficult to define properly. We go through tight waterways with full speed because we feel like we are in control of the vessel. So maybe safe speed really is the speed that you as the navigator feel safe in.

The above AIQ illustrates how the interviewee initially thought of the legal understanding of the term safe speed, and later adjusted the meaning according to how they apply it in practice. This gap between legal interpretation and the conventional way seafarers determine safe speed was pointed out specifically by another interviewee.

Safe speed is quite juridical … I don't know, but that term is perhaps very broad. When I think about setting a speed that is safe, I don't usually think about the COLREGs. What I'm concerned about is that the vessel steers and moves as I want it to, and that I feel confident that I can navigate safely.

The importance of keeping control of the vessel and the situation was echoed by the majority of the interviewed navigators. Factors such as manoeuvrability of the vessel, traffic situation, external environmental factors and navigation area play a large role in this regard.

The most important thing is that you feel in control of the vessel and the situation around you. Going with full speed reduces your options and means you require more room to manoeuvre. Reducing the vessels speed generally increases your manoeuvrability and provides additional flexibility. It also means that you have more time to evaluate and execute the correct choices. But be careful to not reduce your speed too much – you will sacrifice your steering and lose control.

As the navigators tightly coupled safe speed to the feeling of being in control, they stated that for any situation there is no such thing as the one correct safe speed.

Safe speed is an unclear term. In the same situation one navigator may proceed at a safe speed of 10 knots, while another proceeds at 5 knots. It will be wrong to set any boundaries, as that may force some navigators to proceed at a speed that they do not feel comfortable with – which would also be dangerous. Maybe that is why the term is a bit unclear – to give navigators some leeway to navigate in a way that is most comfortable to them.

4.3 *Standard Speed and when to Deviate*

When setting the vessels speed in practice, the interviewees unveiled that full speed ahead is the default. The speed generally only gets adjusted when the navigator deems this necessary to stay comfortable and in control.

If there is no traffic you go with full speed. Sometimes you meet captains who want to reduce in certain areas, and that wish gets respected.

However, some interviewees shared that a reduction of speed may sometimes be a bureaucratic process that might involve repercussions. As a result, they sometimes feel pressured to proceed at speeds that they themselves deem unsafe. Examples of these situations were coupled solely to vessels with passengers on board.

In the passenger ferry industry, we proceed at high speeds because we must keep a schedule. People expect to arrive on time. There is a conflict of interest here: We don't want accidents, but we also have an obligation to get people from A to B on time. In practice this means that you only reduce speed for very special things – and as a result we don't reduce speed more than a couple of times a year. But you can see the same happening with cruise ships – 300-metre-long vessels going through the fjords at 25 knots, even in the middle of the night, just because the passengers should wake up in a new place the next morning. It's completely wild.

Consideration for others was also mentioned as a reason for reducing the vessels speed. A vessels wake can cause problems for other vessels, particularly small craft and moored vessels, and navigators highlighted that they would reduce their speed in particular areas to reduce the size of their wake – and thereby keep any disturbance to others to a minimum.

4.4 *Specific Moments to Consider when Setting a Safe Speed*

In the following subsections, different specific moments that navigators consider when setting a safe speed will be presented. This illustrates both what navigators deem important to consider, as well as highlight which conclusions navigators draw from the information they gather. When asked if there is some sort of hierarchy that determines that some moments are more important than others, some initially pointed to a specific moment that they deemed most impacting. This quickly changed however, and the interviewees pointed to how the factors are dependent on one another, and that the importance of the different moments depend on the context.

Fog is worse than anything else. But really this was back in the day – but nowadays we have such good equipment. Now visibility might be important in confined waters with much traffic, but not so much in open waters. When I think about it all these factors depend on the situation, the vessel you are on and where you are going. Any hierarchy of the factors is changing along with the conditions and is not constant.

Because of the many dependencies, interviewees were critical of the possibility of creating a general safe-speed-flowchart, which could be followed to determine the safe speed in that particular situation. One interviewed navigator voiced restrained optimism for the possibility of creating such a flowchart for one specific vessel in one specific location but also mentioned that a general flowchart would be complicated as there is so much variance in how the different factors affect which speed would be safe.

4.4.1 *Is Slower Safer?*

As mentioned in 4.2 above, the most important thing about safe speed is being in control. So, while reducing speed gives the navigator more time to evaluate and execute their options, it also amplifies the effect of external weather factors – such as wind and current – on the vessel. After reducing the vessels speed below a certain point, most vessels will even lose their ability to manoeuvre. As a result, the interviewed navigators disagree with the sentiment that a reduction of speed necessarily leads to a safe speed. Indeed, examples of the opposite have been shared by many interviewees.

In some of the Norwegian ports there are speed restrictions limiting speed to 5 knots. For many vessels, going at a speed of less than 5 knots in these ports is unsafe. Fast ferries are much easier to steer when going 10 to 12 knots, and some of the old cruise ships do not swing – but only go straight ahead – when going at less than 10 knots. The same applies for some of the other more confined areas – when you go too slow, the wind and current takes you and you run aground. Reducing to zero in these areas would be lunacy – so personally I like to keep a little higher speed to be in control of my own fate.

4.4.2 *Visibility*

Visibility is mentioned as the first factor to consider in the COLREGs and is generally seen as the most important factor for the determination of safe speed by the legal community, where it is stated that is not safe to go fast when visibility is poor. But when is visibility poor? While not all navigators provided the same values, they seemed to agree that more than 1 nautical mile visibility can be considered good, between 5 cables and 1 nautical mile they start to raise their alertness, and below 5 cables they would consider reducing speed. Additionally, the interviewees highlighted the following concepts as important: The size of the vessel you are on, the amount of navigable space around you and the reason for the reduced visibility.

900 metre visibility is completely fine on a vessel that is 100 metres long, but for a vessel that is 300 metres that same visibility does not seem so fine anymore. But it also depends on the area you are in: In open waters you have so much room to manoeuvre that a reduction in visibility really doesn't have an effect anymore – especially since we have such good equipment. With radar you can see even in thick fog. The only time where radar cannot help you in reduced visibility is when you encounter wet snow – then you get false echoes and cannot trust the radar picture.

The above AIQ highlights how navigators can – under specific circumstances – deem a visibility range of 900 metres as completely fine. The interviews highlighted that the importance of visibility is not independent, but instead depends on the context as well. Only when other safety margins are reduced – such as navigating in a narrow channel or in an area of high traffic – would navigators start to adjust their speed. If, however, they encountered reduced visibility in open waters with no other traffic, they would continue proceeding at their normal speed. In general, the interviewed navigators mentioned visibility less with regards to collision avoidance, but more with regards to keeping the vessel on track. They voiced their content with both the available and planned aids to navigation along the Norwegian coast and stated that they used classical i.e., visual navigation methods as their preferred way of navigating along the coast. A reduction in visibility would mean that they would need to switch to technical navigation methods instead.

You can obviously use the chart and radar to sail in this area, but we mostly use these tools to check for other traffic. The navigation happens mostly by eye: We use the aids to navigation that we have along the coast, as for example the sector lights. That is a very pleasant way of navigating. But when visibility is poor, we must switch to technical navigation. Then we must allocate more time to utilizing those tools and have less time for looking outside the window.

The danger of not being able to detect another vessel in poor visibility was not generally seen as great enough to warrant a reduction of speed no matter the context. Furthermore, it was pointed out that it is generally smaller pleasure craft that are most at risk of not being discovered in bad weather – and that these would generally not be out on the water in bad weather.

But this is a type of risk assessment. When it is dark, visibility is low and there are gale force winds that mean that I have a bit of wave clutter on the radar, then I do not expect small vessels to be out on the water. And then I don't reduce speed just because of the off chance that they could be there.

The above AIQ highlights the kind of risk assessment that takes place. While in that instance it was highlighted why a reduction of speed may not be necessary it was also highlighted by navigators that if they pass areas where they know the likelihood of encountering small vessels to be larger, they would either try to take a different route or reduce speed pre-emptively.

4.4.3 *Traffic*

While there is generally less traffic in Norway than in other parts of the world, traffic was mentioned as an important factor throughout the interviews.

The interviews showed that dense traffic is a somewhat vague concept, that depends on a lot of other factors. Firstly, not only the number of vessels in the area is important, but also how they are positioned and how they are manoeuvring. Traffic that is organised in a way that encounters are minimized – as for example in a traffic separation scheme – would be considered less dense than traffic that is unorganized. Additionally, navigators described that – when compared to open waters – fewer vessels were required in confined waters for them to feel as though traffic was dense. The types of vessels encountered also influences the perception on the density of traffic – leisure vessels are seen as less predictable and therefore more difficult to collaborate with than vessels with professional crew on board. Finally, traffic is dense or not dense in relation to the vessel you are on yourself. If you experience numerous vessel encounters from different directions, the manoeuvrability of your vessel will determine how constrained you will feel. As a result, traffic density in the same situation might be considered low when steering a highly manoeuvrable vessel, and high when steering a vessel that is hardly manoeuvrable at all. Overall, traffic is not considered to be dense if they feel comfortable in their ability to keep clear from all vessels. The more difficult it gets to understand and react to other traffic, the more navigators feel that traffic is becoming dense.

I feel traffic to become dense when I feel that I cannot steer away from the different vessels with my standard speed in a proper manner.

Interestingly, the issue of traffic was generally not discussed in terms of what to do when you encounter dense traffic, but more in the way of how you can actively avoid getting into situations with dense traffic and numerous close quarters situations.

I will always try to avoid getting into situations where I will experience multiple vessel encounters. Instead, if I notice that I am running into such a situation, I will rather reduce speed ahead of time, wait for the situation to clear, and then continue with normal speed. If I were to continue and then reduce when encountering the dense traffic, my reduction of speed introduces new dangers, such as drift. In an area where there is little space and maybe current this introduces a new danger in itself – and the last thing I want to do in an already difficult situation is to add more distracting factors.

Looking ahead like this means that navigators look at traffic density not only reactively, but proactively. They proactively look out for situations where dense traffic may occur, and try to either not get into that situation, or come prepared. This tendency for proactivity was also highlighted by navigators stating that they will not only consider traffic that they have observed, but also traffic that has not been observed yet.

There are areas where the likelihood of encountering other traffic is just so much higher. In open waters we encounter fewer vessels than when passing ports and cities. And then there are times where we know that more pleasure craft will be on the water – such as the national day.

4.4.4 *Area*

For the area moment, both the proximity to shore or other navigational hazards and available depth of water was combined. The most important aspect of the area is that the navigator must be comfortable navigating in it. Furthermore, the area plays a large role in providing context: The effect of both visibility and other traffic were enhanced when they were taking place in a confined area.

The interviewees working onboard fast ferries basically did not see proximity to shore or other navigational hazards as problematic and stated that they would proceed at full speed even when close to shore.

There are times where we have rocks and shore within 5 metres of the side of the vessel, but we still go with full speed. Tight spaces by themselves do not warrant a reduction in speed.

This is likely due to the generally supreme manoeuvrability of the fast ferries employed in Norway. The maritime pilots who work on many different types of vessels had a more nuanced view. The pilots highlighted the superiority of a U-turn over a stopping manoeuvre when encountering a dangerous situation. As a result, the consensus was that the border between open and confined waters was where the vessel could safely execute a U-turn. A differentiation between open and confined waters therefore depends on the manoeuvrability of the vessel involved. However, from experience, the maritime pilots stated that most vessels below 140 metres in length, having 5 cables of water around them, would be navigating in what they would consider to be open water.

When it comes to the effect the depth of water has on safe speed, the fast ferry navigators stated that the waters off the Norwegian coast are generally so deep that it does not have an effect. While some of the maritime pilots highlighted the increase in turning circle and stopping distance in shallow water, the interviewees indicated that they would reduce speed in shallow areas with the sole intention of reducing the effect of squat and the resulting possibility of touching the bottom.

4.4.5 *Wind, Waves and Current*

Interviewees stated that wind is a factor of great importance, that needs be taken into account during nearly all operations. This includes not only the wind speed, but also the wind direction. Wind is seen as more problematic when blowing perpendicular to the vessels course, and less problematic when blowing parallel to the vessels course. The effect of wind speed on safe vessel speed is generally seen to be inverted, i.e. high wind speeds require high vessel speeds. This is because the drift inducing effect wind has on a vessel is larger at lower speeds, and less at higher speeds.

It is wind that we struggle with the most. Wind causes you to drift, and if you then reduce speed you drift even more. That is why you need high speed in high winds.

Reduction of drift is important for several reasons. If you are in a tight space, the introduction of drift makes the space even tighter as the required leeway angle to keep the vessel on course means that the vessel takes more space in the waterway. The leeway angle increases with increased drift or reduced vessel speed, up to a point where the vessel will not be able to keep on track and risks being pushed aground. Finally, large drift may lead other traffic to become uncertain about your intentions, as illustrated by the AIQ below:

Our own leeway angle can, in some places, create uncertainty with regards to my intentions. So that if I compensate for drift with adjusting my course, it can look like I'm steering straight towards someone – even though I'm not. I want to avoid creating wrong signals - or signals that can be misunderstood – at all times.

The effect of waves on safe speed was generally not connected to collision avoidance, but rather to the reduction of forces that may cause damage to the vessel. Interviewees therefore mentioned that high waves would cause a reduction in speed to reduce the chance of damages to the own vessel.

Interviewees did not mention current as a factor that induces drift but were more focused on current that sets either in the same, or opposite direction to the vessels course. In this regard the navigators highlighted that current that sets opposite to the vessels course is generally seen as having a positive influence on control over the vessel, while current that sets with the vessel has a negative influence on control over the vessel. Vessels that proceed against the current might be able to reduce their speed over ground to zero, while maintaining enough speed through water to maintain manoeuvrability. On the other hand, it is virtually impossible to come to a stop when the current sets in the same direction as the vessel, as the vessel will loose steering due to low speed through the water before ever coming to zero speed over ground. With this being said, navigators still stated that in practice current only has an impact on their alertness, and not on their selection of speed.

4.4.6 *Background Light*

Background light had two meanings for the interviewees – it could come from both inside and outside the navigational bridge. In any case, it is seen as a disturbance and – where possible – steps were being taken to reduce their occurrence. This includes asking others on the bridge to switch off any background light on the bridge, as well as a case where navigators took contact with a quay to ask them to modify a newly installed floodlight in a way that it becomes less interfering.

Navigators stated that the disturbing effect of background light is largest when navigating in unknown areas, and is significantly reduced by both modern support technology such as radar and AIS and when a navigators knows the area so well that he is able to quickly filter out background light and focus on the lights that are important for safe navigation.

In practice this means that background light influences safe speed only when the navigator does not feel comfortable with the situation.

In a normal setting when experiencing background light, the radar image gives me such a good picture of where I am, where I am going, where I am going to turn, and which boats are around that it does not affect my set speed.

5 DISCUSSION

The results presented above show that the real-world problem of determining safe speed is too complex to be adequately captured by overly simplistic descriptions. The interviews show that the different factors affecting safe speed cannot be looked at in isolation, but within the context in which they occur on the water. Navigators therefore do not determine safe speed by following rule 6 of the COLREGs word for word, taking into account each factor in order, but instead interpret it as a goal-based rule. Navigators equate the requirement of proceeding at a speed where they can take proper and effective action to a speed where they feel in control and adjust their speed accordingly. Importantly, navigators do not only focus on being in control in the current situation, but also in the foreseeable future. This understanding is exemplified by navigators mentioning reducing speed in open waters and good conditions to avoid meeting other vessels in confined waters with possibly less favourable conditions.

5.1 *The Gap Between Work-as-Done and Work-as-Imagined*

This way of determining safe speed is in contrast with the way legal scholars approached this problem, taking each factor for itself and interpreting its effect on the safe speed in isolation. This indicates a difference between the work-as-done by the navigators and the work-as-imagined by theorists and legal scholars and is in line with the findings of a study, where the speeds of vessels in different visibility conditions was analysed [19]. That study found that contrary to the legal understanding of "safe speed", vessels did not significantly reduce their speed in poor visibility. A large distance between how work is imagined, and how work actually is done indicates an ill-calibration at the blunt end to the challenges and risks encountered at the sharp end of real operations [20]. This distance might be attributed to legal scholars having a worldview where safety and compliance with rules are the only factors that affects speed. In reality, it is widely known that "human behavior in any work system is shaped by objectives and constraints which must be respected by the actors for work performance to be successful" [21]. These objectives and constraints can often be contradictory. In practice, the interviewees have shared how the objective to proceed at a safe speed may clash with the objective to follow the rules (as with the case where some speed restrictions in place in Norway would require navigators to proceed at unsafe slow speeds), or with the economic objectives of the shipping company (as with the case where navigators are pressured to proceed at high speeds in order to stay on schedule).

With collision avoidance being a game of coordination, where navigators on different vessels have to independently choose mutually compatible strategies [5], it is feasible to predict that MASS designed according to how work is imagined and not how work is done will have trouble coordinating with conventional vessels. Furthermore, as informal work-systems and adaptations often develop when humans come into contact with systems designed according to work-as-imagined [22], one can expect seafarers on other vessels to develop new ways of interacting with MASS that are designed according to work-as-imagined. These new habits may be degrading safety and causing new types of hazardous situations in the shipping routes and fairways [23].

As the ability to elicit and represent the knowledge of experts is a growing concern in systems design [24, 25], the results of this paper can be seen as an exchange of knowledge between navigators and the designers of MASS, hopefully contributing to bridging the gap between work-as-imagined and work-as-done.

5.2 *Limitations*

The findings and generalisability of this study must be seen considering some limitations. The informant group is made up of a limited number of navigators that were selected as part of a convenience sample. Only Norwegian navigators were included in the study, leaving the possibility that navigators of other countries interpret the rules in a different way. Exploring the possibility of different interpretation of the COLREGs by navigators educated in different countries is something that could be looked at in future research. However, considering the international nature of the maritime industry, where navigators work with international colleagues and are subject to international regulation, the conclusions drawn may still have broad relevance and should be further investigated to find whether they resonate with the navigators in general.

6 CONCLUSION

The objective of this study was to extend the knowledge of how navigators interpret the rules, with a specific focus on how they interpret the rule covering the requirement to proceed at a safe speed. Although a small-scale qualitative study, valuable insight into the tacit knowledge of navigators and how they interpret the requirement to proceed at a safe speed was obtained.

It was found that the most important aspect for navigators with regards to safe speed was the feeling of being in control. The major factors impacting this feeling was the navigator's comfortableness with both the vessel and the area they are navigating in.

The navigators' interpretation of the factors mentioned in COLREGs rule 6 shows how navigators must determine the safe speed in a real world that is complex, and where each factor must be seen in relation to the context of the overall situation. This breaks with the view of how legal scholars approach this problem, where each factor is analysed in isolation. While legal scholars conclude that it is unsafe to proceed at high speeds in low visibility, navigators have no problem with proceeding through fog at high speeds, given that they are in open waters with no other traffic around.

Interesting take-aways include the fact that a slower vessel speed is not safer by default. Indeed, a too low speed can also be an unsafe speed. Another interesting take-away is that navigators include future situations in their determination of safe speed in the present. Navigators are aware of situations where a change in speed does not affect the safety of navigation in the present but has an impact of the safety of navigation in the future. An example here would be navigators reducing their vessels speed in open waters ahead of a confined waterway, with the intention of letting another vessel leave the waterway before entering the waterway themselves.

The conclusion of this paper is that determining a safe vessel speed is more complicated than made out in the literature. As the MASS of the future will have to collaborate with conventional vessels, it is important to ensure that MASS are not programmed with only work-as-imagined in mind, but also by considering the work-as-done in practice.

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