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Consideration of Ship Reducing Speed as Collision Avoidance Action

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ABSTRACT: Navigation through the TSS represent a certain amount of stress for watch crew. In such areas the traffic is heavier and close quarter situations and collisions are more likely to occur. Despite the COLREG regulations for navigation in TSS there are always situations which are differently interpretated by navigators and due to dense traffic avoiding collision can be challenging. As the COLREG rules state the collision can be most efficiently avoided by altering ship course, however sometimes that can be difficult in TSS during heavy traffic. This paper analyses the collisions and close quarter situations in TSS which could be avoided by reducing ship speed and reproduce similar situations in navigation simulator. Such reproduction on navigation simulator is used to analyses behaviors of navigator in collision situations and what prevents them to use speed reduction in collision avoidance. The results of the research may be used to familiarize the navigators that in certain situations reducing ship speed could be most efficient action to avoid collision.

1 INTRODUCTION

Maritime navigation, particularly in Traffic Separation Schemes (TSS), poses significant challenges for watchkeeping crews due to the density of traffic and the increased likelihood of close-quarter situations and collisions. TSS are designated areas in busy waterways where traffic is organized into lanes to enhance safety and efficiency, governed by the International Regulations for Preventing Collisions at Sea (COLREG). Despite these regulations, ambiguities in interpretation and the dynamic nature of dense traffic often complicate collision avoidance efforts. The COLREG, specifically Rule 8, emphasizes that actions to avoid collisions should be positive, made in ample time, and result in a safe passing distance, typically prioritizing course alterations as the primary maneuver (IMO, 1972). However, in TSS environments characterized by constrained space and heavy traffic, altering course may not always be feasible or sufficient, prompting the need to explore alternative strategies such as reducing ship speed.

Speed reduction, though explicitly permitted under COLREG Rule 8 as an effective avoidance action, is often underutilized by navigators. This reluctance may stem from operational pressures, misjudgments of situational dynamics, or a lack of familiarity with its efficacy in specific scenarios. Existing studies on collision avoidance in TSS have predominantly focused on course alterations and the application of COLREG rules in simulated and real-world settings (Chin & Debnath, 2009; Goerlandt & Kujala, 2011). However, the potential of speed reduction as a standalone or complementary action remains underexplored. Reducing speed may increase reaction time and provide greater maneuverability in confined waters.

This paper investigates the efficiency of speed reduction as a collision avoidance action in TSS by analyzing historical collision and close-quarter

incidents that could have been mitigated through this approach. To further understand navigators' decision-making processes, the study employs a navigation simulator to replicate TSS scenarios where speed reduction could prove advantageous. The simulator-based approach allows for controlled experimentation, offering insights into how training and familiarity with speed adjustment can enhance collision avoidance outcomes.

The results could bring changes in existing training programs, encouraging navigators to consider speed adjustments as part of their decision-making toolkit in dense traffic scenarios.

2 LITERATURE REVIEW

Maritime navigation within Traffic Separation Schemes (TSS) is a critical area of study due to the heightened risk of collisions stemming from dense vessel traffic and complex navigational demands. This literature review examines existing research on collisions and close-quarter situations in TSS, with a particular focus on collision avoidance strategies, including the role of speed reduction.

The COLREG framework, particularly Rule 8, provides the foundational guidelines for collision avoidance, mandating actions that are positive, timely and result in a safe passing. However, in TSS environments, where space is limited and traffic density is high, the feasibility of course changes diminish. Research by Chin and Debnath (2009) analyzed collision incidents in the Singapore Strait TSS, identifying those misjudgments in applying COLREG rules, particularly in multi-vessel encounters, often lead to near-misses or collisions. Similarly, Goerlandt and Kujala (2011) utilized probabilistic risk models to demonstrate that the dynamic interactions in TSS amplify the likelihood of close-quarter situations, suggesting that strict adherence to course-based avoidance may not always suffice.

Human decision-making plays a pivotal role in collision avoidance, yet it is frequently undermined by operational pressures and situational misinterpretation. Statheros et al. (2008) reviewed navigational practices and found that watchkeeping officers often hesitate to deviate from planned routes or speeds due to commercial schedules or uncertainty about other vessels' intentions. This reluctance is particularly pronounced in TSS, where navigators must balance compliance with lane discipline and the need to avoid collisions. A study by Hetherington et al. (2006) on maritime human factors highlighted that inadequate training and over-reliance on automated systems, such as the Automatic Identification System (AIS), can exacerbate decision-making errors in high-traffic zones. These findings underscore the need for alternative strategies that enhance navigators' flexibility in TSS scenarios.

While course alteration dominates collision avoidance literature, speed reduction remains underexplored. However, empirical studies on its application in TSS are limited. Debnath and Chin (2010) conducted a statistical analysis of near-miss incidents in TSS and noted that speed adjustments were rarely employed, despite their potential to de-escalate critical situations. The authors attributed this to a lack of awareness or training, as well as a cultural preference for maintaining speed to meet operational deadlines.

Simulation-based research offers further insights into speed reduction's efficacy. Szlapczynski and Szlapczynska (2017) used navigational simulators to test collision avoidance strategies and found that speed reduction, when combined with course changes, significantly improved outcomes in multi-vessel TSS scenarios. However, their study focused on hybrid maneuvers rather than speed reduction as a standalone action.

The literature reveals a predominant focus on course alterations and COLREG compliance, with insufficient exploration of speed reduction as a primary or complementary strategy in TSS. Existing studies often rely on theoretical models or post-incident analyses, with limited experimental data from controlled simulations. Furthermore, navigators' reluctance to use a speed adjustment remains a challenging barrier. The proposed study's emphasis on simulator-based experimentation in order to provide providing empirical evidence on speed reduction's efficacy.

Speed reduction emerges as a promising strategy, offering increased reaction time and maneuverability. This review supports the introduction's focus on investigating speed reduction through simulation and historical analysis, with potential implications for improving navigational safety in TSS environments.

3 METHODOLOGY

This research investigates navigational decision-making in a simulated Traffic Separation Scheme (TSS) under heavy traffic conditions, with a specific focus on the use of speed reductions as a collision avoidance strategy. The methodology combines a controlled simulation environment, participant observation, and quantitative data analysis to assess behavioral patterns among participants with varying levels of maritime experience.

A total of 19 simulations were done. Participants were experienced seafarers attending regular Ship maneuvering and handling course at our training facility and also two group of students currently enrolled in our nautical undergraduate studies with limited or no practical sea experience. The inclusion of both experienced professionals and students allows for a comparative analysis of decision-making strategies influenced by practical expertise. Participants were selected based on availability and willingness to participate.

Bridge team was consisted of 4 persons acting as Master, Chief Mate, OOW and Helmsman similar to real situations on ships. The experiment utilized a full mission Transas NTPro navigational simulator capable of replicating a realistic TSS environment. The simulated scenario was designed to reflect a busy westbound traffic in TSS in Singapore Strait with heavy traffic of various kind of vessels moving at varying speeds and trajectories and based on real incidents. The scenario incorporated dynamic factors such as tidal

currents and a high density of vessels to increase navigational complexity and pressure. Each group of participants were tasked with navigating a predefined route through the TSS while adhering to the International Regulations for Preventing Collisions at Sea (COLREGs).

Participants were very familiar with the simulator controls and also with the objectives of the exercise, which included safely navigating through the TSS while avoiding collisions. No explicit instructions were provided regarding speed reductions to ensure that any use of this strategy emerged from their decision-making process. Each group completed the simulation in a single session lasting approximately 45 to 55 minutes. The instructor recorded key navigational parameters such as vessel speed, course alterations, closest point of approach (CPA) to other vessels, and time to closest point of approach (TCPA). Used vessel was laden AFRAMAX crude oil tanker where the reducing speed is often considered as less effective collision avoiding action.

Vessel speed (in knots) was logged at 10-second intervals throughout the simulation. Speed reduction events were defined as a deliberate decrease in speed using telegraph command by at least 15-20% from the initial speed, sustained for a minimum of 60 seconds, and not attributable to external factors. Instructor recorded also cases where bridge team explicitly mentioned speed adjustments or appeared to prioritize speed reduction over other maneuvers based on their interaction with the simulator interface.

The study adhered to ethical guidelines, ensuring participant anonymity and voluntary participation. No personal data beyond experience level and simulation performance were collected, and participants were debriefed on the study's purpose following their session.

The simulation environment, while realistic, may not fully replicate the stress or unpredictability of real-world TSS navigation. Additionally, the small sample size (n=20) limits generalizability, though it provides a foundation for preliminary insights due to the range of participants experience.

4 RESULTS

In the research there was 19 participant groups, with different sea experience. Three research groups were composed of senior officers, fourteen research groups were composed of junior officers and two research groups were students (Figure 1).

The simulator instructor, who was conducting the exercise, monitored the results of the exercise. The safe action was considered as course alteration, speed reduction or both, as long as the collision avoiding action had the minimum CPA larger than 0,5 M. Also, the safe collision avoidance is considered in CPA less than 0,5 miles as long it was passing astern of the vessel being avoided but not less than 0,3 M. The results from the simulations showed that 7 research groups made the safe collision avoidance action, 9 research groups came in close quarter situation, and 3 research groups collided or made reaction opposite of all rules.

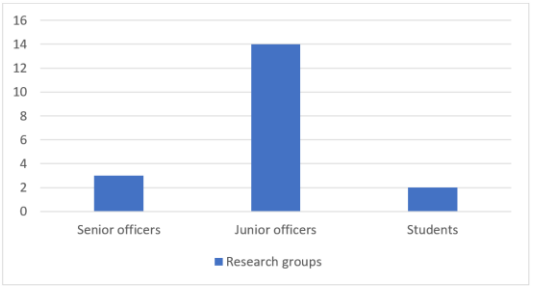

Figure 1. Research groups participants sea experience and ranks

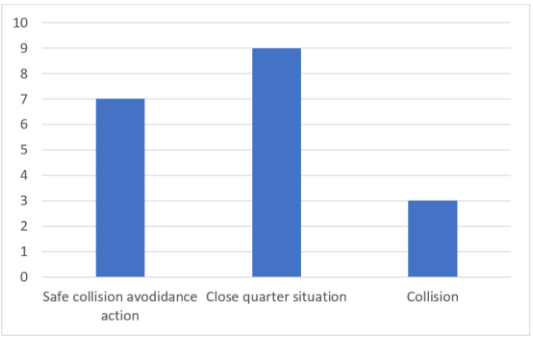

Figure 2. The results of the collision avoidance action

The results of action taken for collision avoidance show that 6 groups used vessel controlled slow down to make safe collision avoidance, and all of them resulted in safe and controlled situation.

Figure 3. The results of the taken collision avoidance action

All of the research groups conducted of senior officers made the safe collision avoidance action, and 66% of them used controlled slow down. The average vessel speed in speed reduction was 7.8 knots and the average vessel speed in other scenarios was 11.4 knots. Three collision situations occurred to junior officer, where the actions were late or opposite to collision regulations. Almost 77 % of close quarter situations were caused by junior officers and the rest of 23 % by student research groups. The actions in this situation were done without slowing down and with undecided actions to avoid collision.

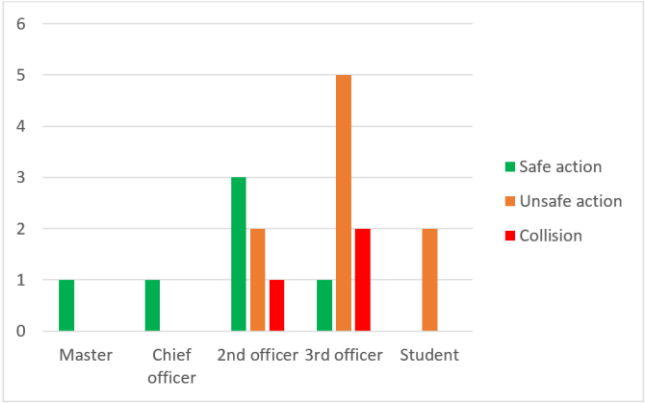

Figure 4. The results of the collision avoidance action per rank

The average CPA in cases where the vessel speed was reduces is 0,42 M and in other cases 0,16 M. This result show that the speed reduction had almost three times bigger CPA than course altering alone.

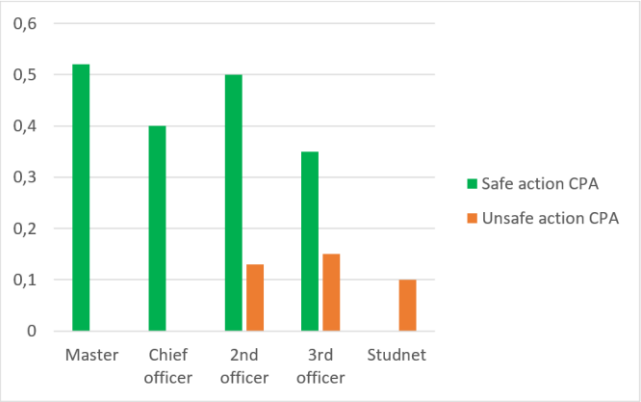

Figure 5. The results of the collision avoidance action CPA per rank

5 DISCUSSION

The simulations conducted in this study demonstrate that speed reduction serves as an effective collision avoidance strategy within Traffic Separation Schemes (TSS), yielding larger Closest Points of Approach (CPAs) averaging 0.42 miles and safer navigational outcomes compared to an average CPA of 0.16 miles in scenarios without speed reduction. Notably, all six groups employing controlled slowdowns achieved safe and controlled passages, with senior officers—comprising 66% of these groups—exhibiting a higher tendency to utilize this manoeuvre, likely due to their greater experience in assessing situational dynamics. These findings challenge the conventional emphasis on course alterations as the primary avoidance action under COLREG Rule 8, suggesting that speed reduction can be a valuable alternative or complement, particularly in the spatially constrained, high-traffic conditions of TSS. The literature indicates that navigators often underutilize speed adjustments due to operational pressures, misperceptions of efficacy (especially for vessels like the laden AFRAMAX tanker used here), or inadequate training, yet this study's results contradict such reluctance by showcasing tangible safety benefits. However, the reliance on a simulated environment and a small sample size of 19 groups limits the generalizability of these conclusions, underscoring the need for further real-world validation. Integrating speed reduction into navigational training could enhance decision-making flexibility, particularly for junior officers and students who displayed higher rates of close-quarter situations and collisions when adhering rigidly to speed maintenance or delayed actions.

6 CONCLUSION

The quantitative analysis suggests that speed reduction is a critical strategy for ensuring safe passing in a TSS under heavy traffic conditions. Participants who used controlled slowing down maintained lower speeds, achieved greater CPAs, and had a higher likelihood of safe and controlled maneuvers while remaining compliant with TSS rules. Conversely, trials without speed reduction were associated with higher speeds, smaller CPAs, and a greater incidence of critical situations or collisions, particularly among less experienced ranks (e.g., Third Mate, Student). While these results highlight the noticeably safety benefits of speed reduction, the study's reliance on a simulated environment and a relatively limited sample size of 20 groups introduces constraints on the broader applicability of the conclusions. Real-world variables—such as unpredictable weather conditions, and human factors like fatigue or communication breakdowns—were not applied, suggesting that further empirical validation in operational settings is essential to confirm these findings. Nevertheless, the results of research presented here challenges prevailing navigational practice that often prioritize course changes over speed adjustments. This research highlights the broader effects of speed reduction in collision avoidance, extending to training and policy development. Integrating speed control into guidelines could enhance navigators' decision-making, especially for less experienced mariners, while promoting a uniform approach to safer navigation in TSS environments.

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