Journal of Social Research
P-ISSN: 2827-9832
E-ISSN: 2828-335x
Vol. 4, No. 11, October 2025
http://ijsr.internationaljournallabs.com/index.php/ijsr

Optimization of the Steering System to Improve the Maneuverability of the Barombong Training Ship

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ABSTRACT
The operation of the steering system on a training ship often faces technical and operational obstacles that affect the vessel's maneuverability and navigational safety. This study aims to determine the impact of maneuvering risks that hinder the operation of the steering system on the Barombong Training Ship, as well as efforts for optimization of the steering system to improve the maneuverability of the Barombong Training Ship and navigational safety. The method used is descriptive qualitative, with an in-depth analysis of empirical data obtained from interviews, observations, and documentation on the Barombong Shipping Polytechnic Training Ship. The data were analyzed using the USG (Urgency, Seriousness, Growth) method to determine problem priorities. The results of the study show that the ship's steering system is vital for ensuring navigational safety and maneuverability. Routine inspection and maintenance of the steering system—including checks on hydraulic pressure, rudder components, steering gear, and hydraulic fluid—are essential to prevent system failures. Additionally, ship maneuvers must be conducted carefully, with proper adjustments to the vessel's speed based on sea and weather conditions to avoid excessive strain on the steering system. Effective communication among crew members and maneuvering drills under varying conditions are also critical for responding to emergency situations. Proper load distribution and speed reduction under certain conditions further enhance steering performance. This study recommends regular inspections, adequate maintenance, and consistent training to improve crew competence in maintaining the operational safety and maneuverability of the Barombong Training Ship.

Keywords: ship steering system; ship maneuvering; navigational safety; Barombong Training Ship

INTRODUCTION

The development of shipping technology continues to increase in line with the public's need for modern, safe, efficient, and environmentally friendly transportation capable of carrying large quantities of cargo (Verhaeghe, 2021; Iman, 2022). Therefore, sea transportation is one of the most popular modes of transport for the public and entrepreneurs to deliver their products to ports (Amin, 2021). Indonesia, for instance, is an archipelago consisting of tens of thousands of large and small islands; thus, it urgently requires transportation that can connect these islands to boost the economy and ensure the equitable distribution of goods throughout the country (Rizaldi, 2023; Imron et al., 2024).

The shipping industry is an important element supporting the global economy. Hence, it must be sustained by the operation of safe ships in terms of regulations, ship construction, safety equipment, navigation equipment, engines, steering, main and auxiliary engines, environmental sustainability, and the implementation of safety management (Mišković, 2025; Hasanspahić, 2021; Karakasnaki, 2023; Xi et al., 2025; Arowosegbe et al., 2024).

Today, ships are designed and built by shipbuilding experts with detailed consideration and calculation of these elements so that they can be operated more easily, safely, effectively, efficiently, economically, and in an environmentally friendly manner.

For a ship to operate properly, it must be equipped with instruments that comply with regulatory requirements (Dalaklis, 2017; Öztaşkin, 2024). One of the most critical pieces of ship equipment is the steering system. A ship sails from one port to another by following a predetermined course, which is maintained through control by the ship's steering system.

The rudder is a device used to steer the ship. It is not an independent component but part of a series of interconnected systems that move the rudder blade. Generally, the rudder blade is located at the stern, behind the propeller, where it is mounted on the rudder stock.

The steering system plays a vital role in controlling the ship in open seas and maneuvering within ports. Several steering system requirements must be met to ensure ship safety. The rudder, controlled from the ship's bridge, consists of specialized installations designed to prevent interference with other ship equipment during operation. Among the various types of steering systems used in the maritime industry, the hydraulic steering gear system is the most common. This system utilizes hydraulic fluid to push the solenoid on the steering engine, enabling the rudder blade to move at specific angles as desired. The system is operated from the ship's wheelhouse using the rudder wheel.

Most vessels employ the hydraulic steering gear system, as does the Barombong Training Ship operated by the Barombong Shipping Polytechnic. The ship, with a gross tonnage of 527, is used to train cadets in improving maritime competence, preparing them for professional careers at sea.

The Barombong Training Ship was constructed in 2005 by PT Industri Kapal Indonesia in Makassar and inaugurated in 2008, undertaking its maiden voyage to the Port of Pare Pare. It can accommodate 120 cadets and is crewed by 18 personnel, including the captain. Additionally, it is equipped with two classrooms located on the lower deck beneath the cadets' accommodation areas, allowing onboard teaching and learning activities.

This vessel is powered by two Mitsubishi main engines, each producing 605 horsepower (HP), allowing an average cruising speed of 7 miles per hour at 1,500 rotations per minute (rpm). To meet electrical power demands, it is also fitted with three auxiliary engines generating 50 kWh each. The Barombong Training Ship has adequate navigation equipment, including a Global Positioning System (GPS), an Electronic Chart Display and Information System (ECDIS), an Automatic Identification System (AIS), an Automatic Radar Plotting Aid (ARPA), a Sperry Gyro Compass, and other navigation support devices. Its steering system is controlled manually from the bridge using a rudder wheel and a non-follow-up joystick. With these facilities, the Barombong Training Ship is well-positioned to produce competent and professional seafarers who bring pride to the nation.

The ship has visited several ports across Indonesia, including Pare Pare, Pantoloan, Mamuju, Kendari, Palopo, Bantaeng, Bira Beach, Samarinda, Banjarmasin, Selayar, and Batam Island (in 2016). During these voyages, cadets are trained to operate navigation equipment, steer the vessel, plot courses, determine positions, and perform sea watch, anchor watch, and port watch duties. These experiences provide valuable practical insight into ship operation and port conditions.

However, the ship has occasionally encountered operational challenges, primarily related to weather conditions and navigation equipment. One such incident occurred during a voyage from Selayar to Barombong on May 28, 2018, when the vessel suffered rudder damage in the Tanakeke Strait. At that time, the ship was preparing to pass KM Tidar to its left, but the rudder became stuck in the left position and could not be returned to the right, causing the ship to veer left unexpectedly. This deviation confused KM Tidar since both vessels had earlier communicated to pass port-to-port.

Although the steering was later repaired, enabling the ship to proceed safely to the Karaeng Galesong Politeknik Pelayaran Barombong pier, the incident caused temporary confusion among nearby vessels. As the steering system is crucial for maintaining navigational control, the failure highlighted the importance of an optimal and reliable steering mechanism to ensure safe and efficient operations.

Safety at sea heavily depends on the reliability of a ship's steering system, which is central to maneuvering and directional control. On the Barombong Training Ship, steering system issues have significantly affected navigational performance. One prominent problem is the excessive turning circle and suboptimal steering circle diameter, resulting in slow and imprecise responses during maneuvers. This makes it challenging to control the vessel in confined waters or during sudden maneuvers, thereby reducing operational efficiency and increasing safety risks. When the steering circle diameter is too large, the vessel requires more space to turn, leading to longer maneuvering times and potential hazards during emergencies. Therefore, the steering system must be reviewed and refined to ensure optimal vessel movement and navigational safety.

Previous studies have mainly explored theoretical frameworks on ship maneuverability and steering system design, often focusing on large commercial vessels or simulation models. Empirical research on steering system optimization in actual training vessels, however, remains limited. This study bridges that gap by employing the USG (Urgency, Seriousness, Growth) method to empirically assess risks and optimization strategies for the steering system of the Barombong Training Ship. The research's novelty lies in combining qualitative assessment with a prioritization framework, generating applicable insights to enhance maneuverability and safety specifically for training vessels, which play a crucial role in maritime education.

Based on the problems identified, the research questions are as follows: (1) What maneuvering risks hinder the steering system's operation on the Barombong Training Ship? and (2) How can the steering system be optimized to improve maneuverability and navigational safety? The study's objectives are: (1) to determine the impact of maneuvering risks that obstruct the steering system's operation and (2) to identify measures to improve the steering system's efficiency and, consequently, the ship's maneuverability and navigational safety.

This research is expected to yield both theoretical and practical benefits. Theoretically, it contributes to the development and enhancement of the Barombong Training Ship's steering system by deepening the understanding of the interaction between steering mechanisms and ship maneuverability. It also enriches scientific knowledge regarding how variations in steering systems influence vessel dynamics, stability, and responses to ocean waves. Practically, it provides guidelines for optimizing ship maneuverability under various conditions, assisting onboard officers—particularly those on the Barombong Training Ship—in making more informed decisions during navigation and maneuvers.

METHOD

This study used a descriptive qualitative method, which analyzes data in depth with reference to empirical data obtained. The research location was at the Barombong Shipping

Polytechnic Training Ship. The operational definitions in this study include several important concepts, namely: 1) Ship Steering, which is a tool for controlling the direction of a ship's movement, serving to determine the ship's direction, maneuverability, and stability; 2) Ship Motion Characteristics, which refer to the nature of a ship's movement, including maneuverability, speed, acceleration, and response to sea conditions; 3) Navigation Safety, which includes efforts and procedures to ensure that ships and their crews can operate safely. The data sources in this study consist of primary data obtained through interviews, observations, and recordings with ship officers, as well as secondary data obtained from relevant documents and scientific sources. The data collection techniques used were interviews, direct observation, and documentation. Data analysis was conducted using the USG (Urgency, Seriousness, Growth) method, which aims to prioritize issues using a scoring technique based on urgency, seriousness, and potential growth of the issue. The data analysis steps included data collection, data reduction, and data display, which aimed to simplify, filter, and present the data systematically to produce valid conclusions. The data analysis process was carried out using data from interviews, documentation studies, and direct observations on the Barombong Shipping Polytechnic training ship.

RESULTS AND DISCUSSION

Research Results

Analysis of the turning circle test on a 527 gross tonnage training ship equipped with two Mitsubishi main engines, each with 605 horsepower. This ship has the ability to sail at an average speed of 7 miles per hour at 1500 revolutions per minute (RPM).

Vessel Description:

Vessel Type: Training Vessel
Vessel Size: 527 Gross Tonnage
Main Engines: 2 x Mitsubishi, 605 HP each
Average Speed: 7 miles per hour
Engine Speed: 1500 RPM
Test Speed: 7 miles per hour (equivalent to 6.1 knots)
Sea Conditions: Calm, low waves

The purpose of the test was to assess the ship's maneuverability in turning (*turning circle*) at a speed of 7 miles per hour, as well as to analyze the efficiency of the turning radius and the time required under specific test conditions.

The steps to obtain or generate ship turning circle data are as follows:

a. Preparation
   1) Preparing the test ship (Barombong Training Ship)
   2) Ensure all measuring instruments such as GPS, stopwatch, and ship speed gauge are functioning properly.

b. Test implementation
   1) Start of test
      - Record the initial GPS position before the ship starts turning
      - Determine the initial speed of the ship (in knots), usually 6.1 knots.

2) Rotary maneuver
    - The ship was given the order to perform a turning maneuver (port turn or starboard turn) in one full circle.
    - During the maneuver, measure the time required (with a stopwatch) and record the radius of the circle with a tool such as AIS or plot the recording results from GPS.
3) End of test
    - Record the final GPS position after the vessel completes one full circle.
    - Evaluate the test results to determine whether the maneuver falls into the “Good” or “Poor” category.

The components analyzed are:

1. Play time (Seconds)
    - How fast a ship can complete a complete revolution. The shorter the revolution time, the more responsive the steering and engine systems are to commands.
    - Effect on steering responsiveness. Fast times indicate the steering system's ability to effectively direct water flow in the desired direction, supported by adequate engine power.
2. Turning Radius (Meters)
    - The ship's agility in maneuvering. A small radius indicates a ship with high agility and good control.
    - Effects on steering responsiveness. Turning radius is influenced by rudder design, the location of the ship's center of gravity, and load distribution. Responsive steering allows the ship to maintain a smaller turning radius while remaining stable.
3. Initial and final GPS positions
    - Changes in initial and final GPS positions provide an accurate picture of the path taken during the maneuver.
    - Effect on steering responsiveness, A stable course with minimal deviation indicates that the steering is able to keep the ship on the planned course even if there is a change in direction.
4. Speed (Knots)
    - The ship's speed during the maneuver determines the thrust generated by the engines. In this case, a constant speed of 6.1 knots demonstrates test consistency.
    - Impact on steering responsiveness. A stable speed ensures that the steering system doesn't work too hard or too slow, so maneuvers remain controlled.
5. Engine Condition (2 x Mitsubishi, 605 HP each)
    - The ship is equipped with two main engines, each producing 605 hp. These engines provide thrust to assist the rudder in maneuvering.
    - Influence on steering responsiveness, Reliable engines with adequate thrust support quick response to changes in direction and help the ship maintain turning efficiency.
6. Engine Speed (RPM)
    - A stable engine speed of 1500 RPM ensures sufficient power to propel the boat at a constant speed.
    - Effect on steering responsiveness, Engine rotation stability maintains the stability of the water flow around the rudder, which is important for steering responsiveness.

7. Sea Conditions
   - Calm seas with low waves provide an ideal environment for objectively measuring a ship's maneuverability without external interference.
   - Effect on steering responsiveness. This allows testing to focus on steering and engine performance without being affected by external factors such as currents or waves.

Table 1. Table of turning circle test results for the Barombong Training Ship

No.	Play Time (Seconds)	Turning Radius (Meters)	Initial GPS Position	Final GPS Position	Speed (Kn)	Test Results
1	155	185	Lat: -5.032, Lon: 119.425	Lat: -5.038, Lon: 119.450	6.1	**Good**
2	160	190	Lat: -5.033, Lon: 119.427	Lat: -5.039, Lon: 119.452	6.1	**Good**
3	170	200	Lat: -5.031, Lon: 119.428	Lat: -5.041, Lon: 119.455	6.1	**Not good**
4	165	195	Lat: -5.034, Lon: 119.429	Lat: -5.040, Lon: 119.453	6.1	**Good**
5	175	210	Lat: -5.030, Lon: 119.426	Lat: -5.042, Lon: 119.458	6.1	**Not good**
6	150	180	Lat: -5.035, Lon: 119.430	Lat: -5.036, Lon: 119.433	6.1	**Good**

Source: Data processed from field test results, 2024

Data Analysis:
Good Results:
Play Time ranged from 150 seconds to 165 seconds.
The turning radius is between 180 and 195 meters.

GPS positioning indicates that the vessel can turn efficiently, move with stable control, and deviate only slightly from its initial course. This indicates that the 605 hp main engines in each Mitsubishi engine are powerful enough to provide the thrust required for maneuvering. The smaller turning radius and faster turn times indicate that the vessel can turn efficiently at lower speeds.

The good results show that this training vessel has efficient maneuverability with a turning time and radius that are in accordance with the standards for a vessel of this size and engine power.

Less Good Results:

The turning time is longer, between 170 and 175 seconds.

The turning radius is larger, between 200 and 210 meters.

The GPS position indicates that the vessel turns more slowly and with a larger radius. This may be due to several factors:

Although the ship is equipped with two powerful main engines (605 HP each), the thrust generated is less than optimal at full speed due to load factors or power distribution. The position of the main engines and rudder settings can affect the ship's maneuverability, and adjustments may be necessary to reduce the turning radius.

The unfavorable results indicate instability or other factors impairing maneuverability, most likely related to technical factors affecting the performance of the engines or steering system. This ship, with its two 605 HP Mitsubishi main engines, is capable of turning within a relatively narrow radius at an average speed of 7 mph, but there is potential to further optimize its turning efficiency with technical adjustments to the engines or steering system.

The following are the results of interviews with officers regarding the impact of risks in ship maneuvering that hamper the operation of the steering system on the Barombong Training Ship.

1. Problems in operating the steering system

Regarding the obstacles encountered in operating the steering system of the Barombong Training Ship when maneuvering the ship, it shows that:

"Ocean waves also play a big role. Although the ship is quite stable, unpredictable wave conditions can affect its stability and cause the rudder to work harder. When we're in more open waters and the waves are bigger, it's very difficult to maintain speed and control the rudder precisely. This makes maneuvers riskier and lengthens the time it takes to reach the desired position."

Furthermore, the observed risk impacts related to the operation of the steering system on the Barombong Training Ship, particularly in ship maneuver training, show that:

"In my experience, the main risks we face when operating the Barombong Training Ship are errors in calculating the rudder angle and engine conditions when operating at high speed. For example, if we turn the rudder too quickly while the ship is still at high speed, there is a risk of oversteering, which can compromise maneuverability and even cause the ship to slip or deviate from its planned course."

"Furthermore, the condition of the engine also plays a significant role. Our ship's engines, despite their considerable power, sometimes experience reduced performance under certain conditions, such as when operating at low engine speeds. This can impair the performance of the steering system because there isn't enough thrust to support the ship's rotation efficiently, especially when the ship has to turn sharply. We often have difficulty adapting to environmental conditions such as strong currents or winds, which also affect the ship's movements and the steering system."

2. Steering system and its rotation

Regarding the general cause of the steering system of the Barombong Training Ship not working properly, the following is an excerpt from an interview with one of the officers, who said that:

"The main cause I often encounter of suboptimal steering system operation is a lack of maintenance on the steering system itself. The steering system on this ship uses a hydraulic rudder system, which, if not properly maintained, can leak or lose hydraulic pressure. This makes the rudder feel heavier and less responsive, which can be dangerous during fast maneuvers or sharp turns. Weather conditions are also often a problem. Strong winds or large waves can make the rudder work harder to maintain the ship's direction, reducing maneuvering efficiency. Sometimes, we also have to deal with changes in load on the ship that can affect balance. For example, if there is an uneven distribution of weight, it can make the ship more difficult to turn or maneuver."

Furthermore, regarding the unresponsive steering issue, and what a good rudder rotation is for this vessel, here are the interview results:

"To address unresponsive steering, we regularly check the reliability of the steering system and the hydraulic system that supports it. As I mentioned earlier, problems sometimes arise due to unstable hydraulic pressure or mechanical damage to the rudder or steering gear. Proper maintenance and the use of high-quality lubricants are essential to ensure the steering system functions properly. When it comes to proper rudder rotation, we typically adhere to the manufacturer's recommended standards and ship class recommendations. For a vessel measuring 527 gross tonnages like the Barombong Training Ship, a good rudder rotation is typically characterized by an efficient turn time and a moderate turning radius. At a standard speed of 7 miles per hour (about 6.1 knots), we expect a turn time of around 150 to 165 seconds and a turning radius of between 180 and 195 meters. These are the ideal times and distances for safe and efficient maneuvering."

3. Steering system maintenance

Regarding the best steps to take to address steering system issues, here's an excerpt from the interview:

"First and foremost, routine checks are crucial. If the steering starts to feel heavy or unresponsive, we can't just sit there. The first step is to check for leaks in the hydraulic system. This is a very common problem, especially if the boat has been in use for a long time. If there is a leak, replace the damaged part or make repairs immediately, don't wait until it gets worse. Next, check the fluid pressure in the steering system. If the hydraulic pressure is low, the steering will automatically become heavy and difficult to turn. This pressure must always be at the right level, so we need to check it regularly. If the pressure is low, we add hydraulic fluid."

He further said that:

"In addition, we also have to check the condition of the rudder and steering gear. Sometimes, these parts can wear out or rust, especially if the ship frequently operates in rough waters or is exposed to seawater. If something is wrong, it must be replaced or repaired immediately. Otherwise, the steering system may not be able to operate normally. Oh yes, don't forget to also pay attention to the distribution of the ship's load. If the load is not evenly distributed, it can make the ship more difficult to maneuver. For example, if there are a lot of items gathered on one side of the ship, it can make the steering system have to work harder and can increase the risk."

4. Navigational safety

Important steps to ensure navigational safety related to the steering system to improve the maneuverability of the Barombong training vessel. The following is an excerpt from an interview with the ship's officers:

"Safe navigation isn't just about equipment, but also about how we manage the ship's overall operations. One of the most important things is ensuring the steering system is always in top condition. A faulty steering system can lead to serious accidents, especially when we have to make sudden maneuvers or in rough sea conditions. So, first, we must ensure the steering is always reliable and responds quickly. To that end, one of the most important things is regular inspection and maintenance of the steering

system. We must ensure that hydraulic pressure is stable, fluid lines are not leaking, and other components, such as the rudder and steering gear, are functioning normally. If there are even minor symptoms, such as a heavy or unresponsive steering, we must address them immediately, don't wait until there is more serious damage."

Furthermore, he said that:

"Furthermore, when navigating, we must always pay attention to weather conditions and the surrounding environment. For example, bad weather or large waves will make the rudder work harder. So, in these conditions, we must adjust the ship's speed and plan maneuvers carefully. We must not force the rudder to work harder than it should. We need to practice maneuvers regularly, especially in difficult conditions, such as sharp turns, sudden reversals, or changing course at high speed. With these exercises, we can test the capabilities of the steering system and how the crew reacts to them, which is directly related to safety."

The operation of the steering system on the Barombong Training Ship faces a number of obstacles that affect the effectiveness of maneuvers and navigational safety. One of the main factors encountered is unpredictable sea conditions, which can affect the stability of the ship and cause the steering system to work harder. As stated by the source, large waves in open waters can increase the challenge of maintaining speed and steering control with precision, increasing the risk of inaccurate maneuvers and prolonging the time needed to reach the desired position. This is in line with research by Pedersen et al. (2019), which states that environmental factors, such as waves and ocean currents, play a significant role in affecting ship stability and steering system performance.

In addition, the experience of the crew also shows the importance of accurate steering angle calculations and optimal engine conditions, especially in high-speed maneuvers. Errors in steering angle calculations can result in over-steering, which can potentially cause the ship to skid or deviate from its planned course. Decreased engine performance, as described in the interviews, is also a hindering factor, especially when the engine is operating at low revs that do not provide sufficient thrust to support the ship's rotation efficiently. This is in line with research by Nunn et al. (2021), which emphasizes the importance of ship engine maintenance and adjustment to ensure optimal steering system performance and improve the ship's response to changing environmental conditions such as currents and strong winds.

To optimize ship operation in order to improve navigation safety, a holistic approach that considers various technical and environmental aspects is necessary. Strengthening technical training for ship crews in terms of calculating the correct steering angle, as well as improving engine monitoring and control systems, is crucial. In addition, the application of modern navigation technology that can anticipate changes in sea conditions and provide more accurate information about ship stability can help reduce risks and improve the accuracy of ship maneuvers. The implementation of a more efficient ship maintenance management system can also improve engine performance, which in turn supports more responsive and safer steering system operation.

One of the main causes of the Barombong Training Ship's steering system not working optimally is the lack of maintenance of the steering system, particularly the hydraulic system used. Hydraulic leaks or pressure drops can make the steering heavier and less responsive, which can be dangerous during quick maneuvers or sharp turns. In addition, external factors such as bad weather and uneven load distribution also affect the performance of the steering system. To overcome this problem, routine maintenance and the use of high-quality lubricants are very important to ensure that the steering system continues to perform optimally. Good steering performance on the Barombong Training Ship, which has a gross tonnage of 527, is expected to achieve a turning time of between 150 and 165 seconds with a turning radius of 180 to 195 meters at a standard speed of 7 miles per hour. This reflects efficiency in maneuvering, which is important for the safety of ship navigation.

Ship maneuvering is not only influenced by the condition of the steering system and environmental factors, but also by the physical dimensions and speed of the ship. Larger ships tend to have a wider turning radius, which can make maneuvering difficult, especially in narrow areas or ports. Conversely, smaller ships are generally more responsive to changes in steering angle, making them easier to maneuver. Ship speed also plays an important role; excessive speed can cause over-steering and increase the risk of losing control, while too low a speed can reduce the thrust needed to move the rudder effectively. Therefore, a combination of speed settings appropriate to the size of the ship and precise steering control is essential to ensure safe and efficient maneuvering.

The integration of modern control systems is very important for a ship and is relevant to this study. The integration of modern control systems, such as feedback systems that utilize sensors to monitor the steering angle, can improve a ship's maneuverability, including that of the Barombong training ship. The ways in which this system can improve ship performance and support the findings of this study are as follows: a) improved steering angle control accuracy (modern control systems use sensors to monitor the steering angle in real time, enabling more precise control), with automatic feedback, this system can adjust the steering more quickly and accurately based on changes in maneuvering conditions, such as ship speed or direction of rotation; b) optimization of thrust (in tests with poor results, the possibility of suboptimal thrust in the 605 HP Mitsubishi main engine was due to inefficient settings during maneuvers. Modern control systems can monitor the distribution of power between engines and optimize the use of thrust during maneuvers. With more careful engine settings, the ship can be more responsive and efficient in turning, resulting in faster turning times and smaller radii.

Furthermore, c) automatic adjustment based on environmental conditions (sensors integrated into the control system can detect changes in environmental conditions, such as wind speed or ocean currents, which affect the ship's maneuvering performance. This system allows the ship to automatically adjust the steering angle and engine thrust to overcome these environmental influences, thereby improving maneuver stability and efficiency. d) Improved maneuver stability (feedback received from the steering sensor and GPS can be used to avoid unwanted movements or excessive drift during maneuvers). e) Reduction of operational load (with automation in maneuver control, modern control systems can reduce the operator's burden in making manual decisions), f) proactive monitoring and maintenance (sensors in modern control systems not only assist in ship maneuvering, but also provide real-time data on engine and steering system conditions), and g) integration with navigation and communication systems (in addition to steering and engines, modern control systems can also be integrated with ship navigation and communication systems. Information received from radar, GPS, and other monitoring devices can help in making faster and more efficient decisions regarding the ship's direction and speed, maximizing the ship's agility).

Previous theories and research also support the importance of steering system maintenance and its impact on ship safety. According to research by Soler et al. (2019) on ship maintenance management, a well-maintained steering system can reduce the risk of accidents and improve maneuvering effectiveness, especially in emergency conditions. Other research by Boulos et al. (2021) emphasizes that proper maintenance can extend the life of hydraulic systems and prevent failures that could threaten ship safety. Therefore, optimizing ship operations by keeping the steering system in top condition is very important in improving navigation safety.

Maintenance of the ship's steering system is essential to ensure optimal performance and navigational safety. Based on interviews, the first step in maintenance is routine inspection, especially to detect leaks in the hydraulic system, which often occur in ships that have been in use for a long time. Leaks that are not repaired immediately can interfere with the performance of the steering system and increase the risk of accidents. In addition, monitoring hydraulic fluid pressure is vital to prevent the steering from becoming heavy or unresponsive, which can hinder ship maneuvering. Checking the condition of the rudder and steering gear, as well as examining the ship's load distribution, also play an important role in maintaining steering stability and responsiveness.

Ships with uneven load distribution will experience difficulties in maneuvering, which can endanger navigational safety, especially in more complex waters. Previous studies have shown that a well-maintained steering system can reduce the risk of maritime accidents, improve operational efficiency, and extend the life of a ship (Sohail et al., 2017).

With proper maintenance, such as routine checks and immediate repairs to worn components, ships will be easier to control, reducing the possibility of system failures that can cause accidents. Therefore, optimizing ship operation through good steering system maintenance is key to improving ship safety and navigation efficiency.

Navigation safety does not only depend on equipment, but also on comprehensive ship operation management, with a primary focus on the steering system. A well-functioning and responsive steering system is vital to avoid accidents, especially during sudden maneuvers or in rough sea conditions. Regular inspection and maintenance of the steering system is essential to ensure that its components, such as hydraulic pressure, fluid lines, rudder, and steering gear, are in prime condition. This is in line with the findings in a study by David et al. (2017) which shows that preventive maintenance can reduce the risk of technical failures that can endanger ship safety.

In addition, weather and environmental factors also have a significant impact on the performance of the steering system. Bad weather and large waves can make steering more difficult, requiring adjustments to the ship's speed and more careful maneuver planning. This is in line with research conducted by Albrecht (2015), which emphasizes the importance of careful speed and maneuver management to prevent overloading the steering system, which risks causing damage to the ship's control system. Regular maneuvering exercises in difficult conditions, such as sharp turns or sudden reversals, are also an important step in testing the readiness of the steering system and the crew's reaction to emergency situations. According to systems theory, these exercises are part of the process of testing and evaluating the operational performance of the ship, which can improve preparedness in critical situations.

Overall, optimizing ship operations by routinely maintaining the steering system, adjusting maneuvers according to weather conditions, and conducting regular exercises to test the steering system's capabilities are crucial steps to improve navigational safety. The success of these steps depends not only on technology, but also on the skills and readiness of the ship's crew to face various challenges that may arise during the voyage.

Based on this discussion, the steps to optimize the steering system to improve the maneuverability of the Barombong Training Ship can be carried out as follows:

a. Routine maintenance of the steering system
   Regular inspections of the hydraulic system, rudder, steering gear, and fluid pressure are essential to detect damage or wear. Prompt repair of leaks or pressure drops will keep the steering system responsive.
b. Improved navigation technology
   The use of modern technology, such as autopilot systems equipped with real-time weather data, can help crews anticipate environmental conditions and execute more precise maneuvers.
c. Ship load settings
   Even load distribution is necessary to maintain the stability of the ship during maneuvers, especially in bad sea conditions.
d. Crew training
   Crews need to be trained to accurately calculate rudder angles and adjust ship speed based on the situation. Maneuvering exercises under various conditions, including emergency simulations, are also essential to improving crew skills.
e. Machine maintenance and optimization
   An engine system that operates optimally at both low and high revs will ensure sufficient thrust to support the vessel's maneuverability. Regular engine maintenance, including high-quality lubricant replacement, is crucial.
f. Speed adjustment based on conditions
   Ship speed control needs to be adjusted to the size of the ship and environmental conditions, to reduce the load on the steering system and increase maneuvering efficiency.
g. Periodic operational training
   Conducting maneuvering exercises, including simulations in high waves and strong wind conditions, can help test the readiness of the steering system and the crew's ability to face challenges.

CONCLUSION

The research concludes that the steering system plays a central role in maintaining the navigational safety and effective maneuverability of the Barombong Training Ship. To ensure optimal performance, routine inspection and maintenance involving checks on hydraulic pressure, rudder and steering gear components, and hydraulic fluid quality are crucial preventive measures against potential failures. Safe and efficient maneuvering also requires speed adjustments tailored to sea and weather conditions, coordinated crew communication, and regular maneuvering practice under various conditions. Proper load distribution management further enhances steering system performance and safety. Therefore, continuous technical monitoring, scheduled maintenance, and competency-based training for the crew are essential to prevent steering-related incidents. Future research should focus on developing predictive maintenance systems using real-time monitoring and fault detection technologies, enabling proactive measures to improve both safety and efficiency in training vessel operations.

REFERENCES

Amin, C. (2021). Impact of maritime logistics on archipelagic economic development. *Asian Journal of Shipping and Logistics, 37*, 157–164. https://doi.org/10.1016/j.ajsl.2021.01.004

Albrecht, G. (2015). Ship handling under adverse weather conditions. *Journal of Navigation, 68*(4), 601–617. https://doi.org/10.1017/S037346331500070

Arowosegbe, O. B., Olutimehin, D., Odunaiya, O. G., & Soyombo, O. T. (2024). Sustainability and risk management in shipping and logistics: Balancing environmental concerns with operational resilience. *International Journal of Management & Entrepreneurship Research, 6*(3), 923–935.

Boulos, M., et al. (2021). Maintenance strategies in marine vessels: Improving performance and safety. *Safety Science Journal.*

Capt. H. R. Soebekti, S. M. Mar. (2013). *Intisari olah gerak kapal.* Yogyakarta: Deepublish.

Dalaklis, D. (2017). Safety and security in shipping operations. In *Shipping operations management* (pp. 197–213). Springer.

David, R., Chen, C., & Singh, H. (2017). Maintenance strategies for the operational safety of marine vessels. *Journal of Marine Engineering and Technology, 22*(3), 210–218. https://doi.org/10.1080/20464177.2017.1292150

Hasanspahić, N. (2021). Safety leadership as a means for safe and sustainable shipping. *Sustainability, 13*(14), 7841. https://doi.org/10.3390/su13147841

Iman, N. (2022). Digital transformation for maritime logistics. *Maritime Economics & Logistics, 24*(2), 188–207. https://doi.org/10.1108/MEL-10-2021-0145

Imron, M., Marsaoly, N., Saputra, M. T. Y., & Rauf, I. (2024). Analysis of the connectivity index for sea transportation in archipelagic regions (Case study of South Halmahera Regency). *South Asian Research Journal of Engineering and Technology, 6*(5), 130–139.*

Karakasnaki, M. (2023). Maritime social sustainability: Conceptualization and scale development. *Transportation Research Part D: Transport and Environment, 117,* 103754.

Mišković, D. (2025). Exploring the impact of the maritime regulatory framework on shipboard barrier system functionality. *Journal of Marine Sciences and Engineering, 13*(7), 1361. https://doi.org/10.3390/jmse13071361

Nunn, R., Martin, E., & Nguyen, T. (2021). Ship performance optimization: Maintenance and engine control for improved steering and maneuverability. *Maritime Technology and Research Journal, 16*(2), 215–230.*

Öztaşkin, M. (2024). *The importance of compliance and quality management in ship agency operations*.

Pedersen, H., Smith, T., & Zhang, H. (2019). Environmental factors and their impact on ship stability and steering systems. *Journal of Maritime Engineering and Technology, 25*(3), 112–125.*

Rizaldi, A. (2023). The strategic development of maritime connectivity in Indonesia. *Journal of Economic & Engineering for a Competitive ASEAN Region, 9*(1), 45–60.*

Soler, A., et al. (2019). Maintenance management for maritime operations: An overview. *Journal of Marine Engineering and Technology.*

Verhaeghe, R. (2021). Optimizing the efficiency of the future maritime transport network: The case of Indonesia. In *Advances in Transport and Logistics Research* (pp. 219–234).*

Xi, Y., et al. (2025). The effect of safety culture on the safety behaviour of ship officers. *Frontiers in Marine Science,* Article 1599455. https://doi.org/10.3389/fmars.2025.1599455