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Optimization of AIS (Automatic Identification System) Operation in Ensuring Maritime Navigation Safety

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ABSTRACT

AIS (Automatic Identification System) is a system capable of automatically providing vessel data to other ships within a specified range, including information such as vessel identity, position, speed, and heading. This study aims to optimize the operation of AIS in ensuring maritime navigation safety on board MV. Dahlia Merah. The research employs a mixed-methods approach, utilizing questionnaires, direct field observations, unstructured interviews, and documentation as data collection instruments. The findings reveal that AIS operates using Very High Frequency (VHF) radio waves within the 156–162 MHz band. The study demonstrates that understanding the operational functions of navigation equipment—particularly the identification and proper use of AIS control buttons and their respective functions—is essential for preventing collisions with other vessels and mitigating navigation hazards. Questionnaire results indicate that 75.91% of respondents strongly agree, 17.27% agree, and only 6.82% disagree that optimization of AIS operation contributes significantly to maintaining navigation safety.

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Keywords:

AIS; Automatic Identification System; Maritime Safety; Navigation; VHF; MV. Dahlia Merah

1. INTRODUCTION

Maritime transportation serves as one of the most critical modes of transport in Indonesia, an archipelagic nation comprising more than 17,000 islands connected by vast sea routes. The safety of navigation in these waters is paramount, as the density of vessel traffic continues to increase alongside the growth of international and domestic trade. According to the International Maritime Organization (IMO), maritime accidents remain a significant concern, with collisions between vessels accounting for a substantial proportion of incidents worldwide [1]. These accidents not only result in loss of life and environmental damage but also impose considerable economic costs on the shipping industry.

In response to these challenges, the IMO mandated the installation and operation of the Automatic Identification System (AIS) on board all

vessels above 300 gross tonnage engaged in international voyages, as well as all passenger ships regardless of size, under the provisions of the International Convention for the Safety of Life at Sea (SOLAS) Chapter V, Regulation 19 [2]. AIS is a shipborne transponder system that automatically transmits and receives vessel-related data—including ship identification, position, course, speed, and navigational status—to and from other AIS-equipped vessels and shore-based stations within VHF radio range [3].

Despite the widespread adoption of AIS technology, the effectiveness of the system is heavily dependent on the competence of the crew operating it. Improper configuration, lack of familiarity with control functions, and failure to maintain the equipment can diminish the system's reliability and compromise navigation safety [4]. On board MV. Dahlia Merah, initial observations indicated that crew members demonstrated varying levels of proficiency in operating AIS equipment, suggesting that optimization of AIS operation could yield measurable improvements in navigational safety outcomes.

The primary objective of this research is to optimize the operation of AIS (Automatic Identification System) in ensuring maritime navigation safety on board MV. Dahlia Merah. Specifically, the study seeks to: (1) describe the operational mechanism and frequency characteristics of AIS; (2) identify the key control functions and buttons on the AIS unit that are essential for effective operation; and (3) assess crew perceptions regarding the contribution of AIS optimization to maritime safety through a structured questionnaire instrument. This study is expected to contribute to the body of knowledge on maritime navigation technology and to provide practical recommendations for shipping companies regarding the importance of crew training in the optimal use of AIS equipment.

2. LITERATURE REVIEW

Automatic Identification System (AIS)

The Automatic Identification System (AIS) is a maritime navigation safety technology developed to enable the automatic exchange of critical vessel data between ships and between ships and shore stations. According to the IMO, AIS was designed to enhance the safety of navigation, improve the efficiency of vessel traffic services (VTS), and assist in search and rescue operations [1]. AIS operates as a self-reporting transponder system that broadcasts a vessel's identity, position, course, speed, and navigational status at regular intervals using Very High Frequency (VHF) radio transmission [3].

AIS utilizes two dedicated VHF frequencies: AIS 1 on 161.975 MHz and AIS 2 on 162.025 MHz, operating within the maritime VHF band of 156–162 MHz. The system employs Self-Organized Time Division Multiple Access (SOTDMA) technology, which allows multiple vessels to share the same frequency channels without interference by dividing transmission time into discrete slots [5]. This technical architecture enables AIS to accommodate a high density of vessel traffic within a given coverage area.

Types of AIS

AIS equipment is classified into two primary categories based on its functionality and regulatory requirements. Class A AIS transponders are mandated for all SOLAS-class vessels and provide full functionality, including the ability to transmit and receive on two channels, automatic switching between channels, and a reporting rate that varies based on the vessel's speed and course change behavior [2]. Class B AIS transponders are designed for smaller, non-SOLAS vessels and operate with reduced transmission power and a lower reporting rate [6].

AIS Data Categories

The data transmitted by AIS is organized into three categories. Static data includes the Maritime Mobile Service Identity (MMSI) number, IMO number, vessel name, call sign, type of ship, and dimensions. Dynamic data encompasses the vessel's position (derived from an integrated GPS receiver), course over ground (COG), speed over ground (SOG), heading, navigational status, and rate of turn. Voyage-related data includes the ship's draught, type of cargo, destination, estimated time of arrival (ETA), and any relevant route or waypoint information [3].

SOLAS Regulation and AIS Mandate

The legal framework governing AIS installation and operation is established under Chapter V of the SOLAS Convention, which was amended in December 2000 and entered into force in July 2002. Regulation 19.2.4 requires all ships of 300 gross tonnage and above engaged in international voyages, cargo ships of 500 gross tonnage and above not engaged in international voyages, and all passenger ships to be fitted with AIS [2]. The regulation further

stipulates that AIS shall be maintained in operation at all times, except where international agreements, rules, or standards provide for the protection of navigational information [7].

Maritime Navigation Safety

Navigation safety is defined as the condition in which the risks associated with maritime operations are reduced to an acceptable level through a combination of regulatory compliance, technological application, and human competence [8]. The International Regulations for Preventing Collisions at Sea (COLREGs) 1972, particularly Rules 5, 6, 7, and 8, establish the fundamental obligations of watchkeeping officers to maintain a proper lookout, proceed at a safe speed, determine whether a risk of collision exists, and take appropriate action to avoid collision [9]. AIS complements these obligations by providing real-time data on surrounding vessel traffic, thereby enhancing situational awareness and enabling more informed decision-making by the bridge team.

3. RESEARCH METHOD

Research Design

This study adopts a mixed-methods (mix method) research design, integrating both quantitative and qualitative approaches within a single investigative framework. The quantitative component involves the administration and statistical analysis of a structured questionnaire instrument, while the qualitative component encompasses direct field observation, unstructured interviews with crew members, and documentation analysis. This design was selected to provide a comprehensive and triangulated understanding of the factors influencing AIS operational optimization on board MV. Dahlia Merah [10].

The research was conducted on board MV. Dahlia Merah during the vessel's operational voyages. The data collection period extended over the duration of the researcher's sea-going assignment on the vessel, allowing for longitudinal observation of AIS operational practices under varying navigational conditions, including open sea passages, coastal navigation, and port approach maneuvers.

Population and Sample

The population of this study consists of all crew members on board MV. Dahlia Merah who are directly or indirectly involved in navigation and bridge operations. The sample was selected using purposive sampling technique, targeting 22 respondents comprising deck officers (Master, Chief Officer, Second Officer, Third Officer), ratings assigned to bridge watchkeeping duties, and other crew members with operational responsibilities related to navigation equipment. This sampling approach ensures that the respondents possess relevant knowledge and experience regarding AIS operation [11]

Variables and Instruments

The primary variable under investigation is the optimization of AIS operation, measured through a structured questionnaire consisting of 10 statement items assessed on a four-point Likert scale: Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). The questionnaire items were designed to capture respondents' perceptions regarding the importance, functionality, and effectiveness of AIS in maintaining navigation safety. Additional qualitative data were collected through observation checklists, interview notes, and photographic documentation of AIS equipment and operational procedures.

Data Collection

Data collection was performed using four complementary methods. First, questionnaires were distributed to the 22 selected respondents and collected upon completion. Second, direct field observation was conducted on the bridge during navigation watches to document AIS operational practices, including equipment settings, data display interpretation, and crew interaction with the AIS unit. Third, unstructured interviews were conducted with senior deck officers to obtain in-depth insights into AIS operational challenges and best practices. Fourth, documentation in the form of photographs, equipment manuals, and ship records was gathered to supplement the observational and interview data [12].

Data Analysis

Quantitative data from the questionnaire were analyzed using descriptive statistical methods, including frequency distribution, percentage calculation, and mean score computation. The analysis employed the following formula for calculating the percentage of each response category:

$$P = (f / n) \times 100\% \quad (1)$$

where P represents the percentage, f denotes the

frequency of responses in a given category, and n is the total number of responses. Qualitative data obtained from observations, interviews, and documentation were analyzed through thematic coding and narrative description, enabling the identification of patterns and insights related to AIS operational optimization [13].

4. RESULTS AND DISCUSSIONS

4.1. Results

AIS Operational Mechanism on MV. Dahlia Merah

Field observations conducted on board MV. Dahlia Merah confirmed that the AIS unit installed on the vessel operates using Very High Frequency (VHF) radio transmission within the frequency band of 156–162 MHz. The system utilizes two dedicated channels—AIS 1 (161.975 MHz) and AIS 2 (162.025 MHz)—employing SOTDMA technology for efficient time-slot allocation. The AIS transponder on MV. Dahlia Merah is integrated with the vessel's GPS receiver for position data, the gyrocompass for heading information, and the speed log for speed data, ensuring that all dynamic data transmitted to other vessels and shore stations are accurate and continuously updated.

The observation further revealed that the AIS display provides real-time information on nearby vessel traffic, including the name, MMSI, position, COG, SOG, and closest point of approach (CPA) of surrounding ships. This information is critical for the bridge watchkeeping team to assess traffic situations, identify potential collision risks, and make timely navigational decisions in accordance with COLREGs requirements.

AIS Control Functions and Button Identification

A key finding of this study is the identification and documentation of the principal control buttons and functions on the AIS unit installed on MV. Dahlia Merah. Through direct observation and reference to the equipment technical manual, the following functional elements were identified and documented:

Table 1. AIS Control Buttons and Their Functions

No.	Button / Control	Function
1	POWER (ON/OFF)	Activates or deactivates the AIS transponder unit
2	MENU	Accesses the main settings and configuration menu
3	ENTER / SELECT	Confirms selection or input within the menu system
4	ARROW KEYS (▲▼◄►)	Navigates through menu options and data display screens
5	ESC / CANCEL	Returns to the previous screen or cancels the current operation
6	BRIGHTNESS (BRT)	Adjusts the display screen brightness for visibility
7	MSG (Message)	Accesses the safety message function for sending and receiving AIS text messages
8	TARGET LIST	Displays a list of all detected AIS targets within range
9	SHIP DATA	Shows own-ship static and voyage-related data for verification
10	ALARM / ALERT	Activates or configures CPA/TCPA alarm thresholds for collision avoidance

Source: Direct observation and AIS equipment manual, MV. Dahlia Merah

The identification and understanding of these control functions are essential for optimal AIS operation. Interviews with deck officers confirmed that familiarity with each button's function enables watchkeepers to efficiently configure the system, monitor vessel traffic, and respond to alarm notifications without delay. Conversely, officers who were less familiar with certain functions—particularly the MSG and ALARM buttons—reported instances of delayed response to safety-critical information.

Questionnaire Results

The structured questionnaire was administered to 22 respondents on board MV. Dahlia Merah. The results are presented in Table 2, which summarizes the frequency distribution of responses across the four Likert-scale categories for each of the

10 statement items:

Table 2. Questionnaire Results on AIS Operation Optimization

No.	Statement	SA	A	D	SD
1	AIS is essential navigation equipment for ensuring maritime safety	18	2	2	0
2	AIS works effectively using VHF frequencies between 156–162 MHz	16	4	2	0
3	Understanding AIS button functions is crucial for optimal operation	17	3	2	0
4	AIS helps in avoiding collision with other vessels	19	1	2	0
5	AIS provides accurate vessel identification data	15	5	2	0
6	AIS data integration with ECDIS improves situational awareness	16	3	1	2
7	Periodic AIS maintenance ensures consistent signal transmission	14	5	3	0
8	Crew competency in AIS operation contributes to safe navigation	17	2	1	2
9	AIS alarms and alerts effectively warn of potential hazards	15	4	1	2
10	Optimizing AIS operation reduces the risk of maritime accidents	20	0	0	2

Source: Questionnaire data, MV. Dahlia Merah (n = 22)

The aggregated analysis of the questionnaire data yields the following overall percentage distribution across response categories:

Table 3. Aggregate Response Distribution

Response Category	Total Responses	Percentage (%)
Strongly Agree (SA)	167	75.91
Agree (A)	38	17.27
Disagree (D)	15	6.82
Strongly Disagree (SD)	0	0.00
Total	**220**	**100.00**

Source: Processed questionnaire data

4.2. Discussion

The questionnaire results demonstrate a strong consensus among respondents regarding the importance of optimizing AIS operation for maritime safety. The finding that 75.91% of respondents strongly agree and 17.27% agree—yielding a combined positive response rate of 93.18%—indicates a high level of awareness and endorsement of AIS optimization among the crew of MV. Dahlia Merah. The small proportion of disagreement (6.82%) may be attributed to individual differences in technical proficiency or varying perceptions of AIS utility relative to other navigation aids.

These findings are consistent with the regulatory framework established by the IMO through SOLAS Chapter V, which mandates not only the installation but also the continuous and proper operation of AIS on applicable vessels [2]. The results

further align with previous studies emphasizing that the effectiveness of AIS as a collision avoidance tool is contingent upon the operator's knowledge and ability to interpret and act upon the data displayed by the system [4].

The identification of AIS control buttons and their functions (Table 1) provides a practical reference that can be utilized for crew training and familiarization programs. The observation that crew members with greater familiarity of AIS controls demonstrated faster response times to safety-critical alerts supports the argument that systematic training in equipment operation is a prerequisite for realizing the full safety potential of AIS technology.

Furthermore, the integration of AIS with other bridge navigation systems—including ECDIS, radar, and GPS—creates a comprehensive traffic monitoring capability that significantly enhances the bridge team's situational awareness. This integration, when combined with proper AIS operational procedures, constitutes a robust defense against collision risk in congested waterways and during periods of restricted visibility.

It is important to note, however, that AIS is a supplementary navigation tool and should not be used as the sole means of collision avoidance. The COLREGs remain the primary regulatory framework for collision prevention, and AIS data should be used in conjunction with radar observations, visual lookout, and professional judgment to ensure comprehensive navigation safety [9].

5. CONCLUSION

Based on the findings and analysis presented in this study, the following conclusions are drawn. First, the AIS installed on MV. Dahlia Merah operates using Very High Frequency (VHF) transmission within the 156–162 MHz band, utilizing two dedicated channels (AIS 1 at 161.975 MHz and AIS 2 at 162.025 MHz) with SOTDMA technology for efficient data exchange. Second, understanding the operational functions of AIS control buttons—including POWER, MENU, ENTER, ARROW KEYS, ESC, BRIGHTNESS, MSG, TARGET LIST, SHIP DATA, and ALARM—is essential for ensuring effective and responsive AIS operation, particularly in collision avoidance scenarios. Third, the questionnaire results confirm that 75.91% of respondents strongly agree, 17.27% agree, and 6.82% disagree that optimizing AIS operation contributes to maintaining maritime navigation safety, reflecting a combined positive endorsement of 93.18%.

The study recommends that shipping companies implement structured AIS training programs for all bridge watchkeeping personnel, conduct periodic maintenance and calibration of AIS equipment, and integrate AIS operational procedures into the vessel's Safety Management System (SMS) in accordance with the ISM Code. Future research may extend the scope of investigation to include multiple vessels and comparative analyses across different AIS equipment manufacturers.

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