

Early Fire Detection On Board The Kmp Trisna Dwitya Via Smoke Detector

Melinda Exanti Noka^{1*}, Anugrah Nur Prasetyo², Otri Wani Sihaloho³, Arleiny⁴

^{1,2,3,4}Ship Operations Engineering Technology Study Program, Surabaya Maritime Polytechnic, Indonesia

*Corresponding author:

E-mail:melind.exan@gmail.com

Abstract.

Maritime transportation plays a vital role in supporting global and domestic logistics, but the increasing shipping activity also increases the risk of fire on board. Therefore, early detection systems such as smoke detectors are crucial to support ship safety. This study aims to analyze the working system and maintenance procedures of smoke detectors on KMP Trisna Dwitya. The study used a qualitative descriptive approach with a case study design. The study population included all crew members and the smoke detector system on board, while the sample consisted of First Officers, Second Officers, Helmsmen, and Boatswain selected using purposive sampling. Data collection was conducted through interviews, observation, and documentation, then analyzed using the interactive analysis model of Miles, Huberman, and Saldana through data reduction, data presentation, and conclusion drawing. The results showed that the smoke detector system works automatically through optical sensors connected to the fire alarm panel, thus providing early identification of fire indications. Maintenance is carried out routinely through inspection, cleaning, functional testing, and logbook recording in the Planned Maintenance System. The conclusion of the study shows that the smoke detector on the KMP Trisna Dwitya has functioned effectively as an early fire detection system, although maintenance consistency still needs to be improved to minimize false alarms and maintain system reliability.

Keywords: Fire Detection System, Maritime Safety, Preventive Maintenance, Ro-Ro Vesse and, Smoke Detector.

I. INTRODUCTION

Maritime transport remains the backbone of global trade, transporting over 80% of the world's freight volume relatively cost-efficiently despite challenges such as route disruptions and supply-demand imbalances (UNCTAD, 2025). Recent trends indicate that global container volume growth is predicted to reach 4% in 2025, driven by post-pandemic recovery, although offset by increased ton-miles due to rerouting, such as through the Cape of Good Hope (Maersk, 2025). In Indonesia, as an archipelagic nation, the role of sea vessels is increasingly crucial in supporting exports and imports, with a significant increase in national shipping frequency since 2023, as reflected in the BPS report on the surge in inter-provincial freight flows (BPS, 2026).

However, this rapid maritime activity is accompanied by an increased risk of accidents, including frequent fires in engine rooms, cargo holds, and crew accommodations, especially on ships carrying flammable cargo such as oil or wood (Stopford, 2019; Branch, 2021). Empirical data from Indonesian waters shows a 15% increase in ship fire incidents in 2023–2024, triggered by a lack of early detection and maintenance of safety equipment, which exacerbates the fatal impact due to limited access to emergency assistance on the high seas (Ministry of Transportation of the Republic of Indonesia, 2022). This phenomenon underscores the urgency of a reliable fire detection system, particularly on roll-on-roll (RO-RO) vessels like the KMP Trisna Dwitya, which operate on vulnerable domestic routes.

Previous studies have explored ship classification and basic safety systems, with Stopford (2019) outlining the diversification of ship types—dry cargo, tanker, and service ships—while Branch (2021) emphasized technological specialization for logistical efficiency. Further research, such as Vanem et al. (2023) in Reliability Engineering & System Safety, found that smoke detectors integrated with fire alarm systems effectively reduced response times by up to 40% on bulk carriers, through optical and ionization sensors that detect smoke early. Similarly, Indonesian Minister of Transportation Regulation No. PM 12/2022 requires the installation of detectors on ships ≥ 400 GT in critical areas such as stairwells and

machinery spaces, demonstrating a regulatory-based, preventative approach (Indonesian Ministry of Transportation, 2022).

However, research findings show inconsistencies; while Vanem et al. (2023) highlighted the effectiveness of conventional detectors on large vessels, a study by Kim and Roh (2024) in *Ocean Engineering* revealed a 25% failure rate for smoke detectors on small ro-ro vessels due to marine corrosion and lack of regular calibration. Studies in Southeast Asia, such as that by Sari et al. (2022) in the *Jurnal Teknik Perkapal* (Maritime Engineering Journal), found that manual maintenance was suboptimal on domestic vessels, resulting in low false alarm rates and late detection, in contrast to findings in Europe that relied more on automated systems (Sari et al., 2022). The main limitation of these studies lies in their methodological focus, which is generally on laboratory simulations or international vessels, ignoring the context of local vessels such as the KMP Trisna Dwitya with a gross tonnage of 150–400 GT, which are vulnerable to Indonesia's tropical conditions.

A clear research gap arises from the lack of specific analysis on the operation and maintenance of smoke detectors on Indonesian domestic ro-ro vessels, where regulation PM 12/2022 has not been accompanied by comprehensive empirical field studies (Ministry of Transportation of the Republic of Indonesia, 2022). This problem statement is formulated as: How does the smoke detector system work and its maintenance procedures on the KMP Trisna Dwitya, given the high risk of fire in national waters without optimal detection?

This study aims to analyze the smoke detector operating system and its maintenance mechanism on KMP Trisna Dwitya, with high urgency amidst the projected shipping growth in 2025–2026 which has the potential to increase incidents (UNCTAD, 2025). The novelty lies in the contextual approach of local ro-ro vessels that has not been explored, complementing the state of the art with domestic empirical data; theoretically, enriching tropical maritime safety literature, and practically, providing maintenance guidelines for crews and shipping companies to minimize fatal risks (Kim & Roh, 2024).

II. METHODS

This study adopts a qualitative descriptive approach aimed at in-depth understanding of the smoke detector operation and maintenance system on the KMP Trisna Dwitya, as defined by Creswell and Poth (2021) as a contextual exploration process through narrative data obtained naturally from the field (Creswell & Poth, 2021). This approach aligns with the characteristics of qualitative research according to Sugiyono (2023), which emphasizes holistic data collection through observation, interviews, and documentation to uncover behavioral patterns and operational procedures in a dynamic maritime context (Sugiyono, 2023). Thus, this type of research allows for detailed analysis of primary and secondary data relevant to safety regulations such as PM 12/2022, while integrating empirical findings from the researcher's maritime practice (Kemenhub RI, 2022).

The research location focused on the KMP Trisna Dwitya vessel managed by PT Lintas Sarana Nusantara, operating on the Ketapang-Gilimanuk Port route, while the research period lasted for 12 months of sea practice from July 26, 2024 to July 27, 2025. The research population included all crew members and smoke detector systems in critical areas such as the engine room, accommodation, and corridors, which is in accordance with the purposive sampling criteria in qualitative research as explained by Emzir (2022), where samples are selected based on the relevance and depth of information (Emzir, 2022). The sample consisted of key informants in the form of First Officer, Second Officer, Helmsman, and Boatswain from the deck department, who were selected because of their direct responsibility for the maintenance of fire detection equipment, as the purposive technique recommended by Sudaryono (2021) to ensure data saturation in a single case study (Sudaryono, 2021).

The research instruments included in-depth interviews, participant observation, and documentation, designed as triangulation tools to enhance data validity according to Creswell's (2021) guidelines (Creswell, 2021). Semi-structured interviews were conducted directly to explore informants' perceptions of the smoke detector's working system, while observations recorded the physical condition of the equipment in fire-prone locations such as the machinery space, supported by documentation in the form of photographs, maintenance

logbooks, and regulatory documents (Sugiyono, 2023). Primary data sources were obtained from field interactions during marine practice, while secondary data came from company archives, smoke detector manuals, and related literature such as Vanem et al.'s (2023) study on the effectiveness of optical sensors (Vanem et al., 2023).

The data analysis technique follows the Miles, Huberman, and Saldana (2020) model adapted by Sugiyono (2023), including data reduction through the selection of relevant themes such as calibration and early detection procedures, data presentation in narrative, matrix, and flowchart forms, and drawing conclusions to confirm safety patterns (Sugiyono, 2023). The research procedure begins with instrument preparation and informant ethics, followed by iterative data collection during sea practice, verification through source triangulation (interviews, observations, documents), and thematic analysis to integrate findings with the state of the art such as maintenance inconsistencies on ro-ro vessels (Kim & Roh, 2024). This approach ensures logical coherence from collection to interpretation, with an emphasis on credibility through member checking as recommended by Emzir (2022) (Emzir, 2022).

III. RESULTS AND DISCUSSION

Location and Subject Overview



Fig.1. KMP. Trisna Dwitya Ship

KMP. Trisna Dwitya is a Ro-Ro passenger ship owned by PT. Lintas Sarana Nusantara, operating on the Ketapang-Gilimanuk route with a GT of 150-400, fulfilling PM 12/2022 for smoke detectors in critical areas (Ministry of Transportation of the Republic of Indonesia, 2022). This ship is equipped with standard safety facilities for passengers and cargo, crucial for preventing fires in vulnerable waters such as the Bali Strait (BPS, 2026). The research was conducted during the researcher's sea practice (July 2024-July 2025), focusing on the smoke detector system and maintenance (Sugiyono, 2023).

Research result

1. Data Presentation
 - a. Interview Results

Table 1 Interview Results Table

No	Source person	Interview Results
1	First Class Officer	<p>Question:How do you understand the function of smoke detectors on ships?</p> <p>Answer:In my opinion, a smoke detector is one of the most important pieces of safety equipment on a ship because it serves as an early detection device for smoke, which is an early indication of a fire. With this device, the ship's crew can quickly identify potential dangers before the fire spreads, allowing for faster and more effective preventative and response measures.</p> <p>Question:How does the smoke detector system on this ship work?</p> <p>Answer:The smoke detector system on ships generally uses an optical sensor that operates automatically. When smoke particles enter the device, the sensor detects changes in light within the detection chamber, and then sends a signal to an alarm panel on the bridge. This panel then identifies the location of the active detector, making it easier for the crew to check the indicated area.</p> <p>Question:In which areas are smoke detectors installed on ships?</p> <p>Answer:Smoke detectors are installed in various strategic areas with potential</p>

No	Source person	Interview Results
		<p>fire risks, such as accommodation spaces, hallways, engine rooms, control rooms, and several other enclosed spaces. This placement ensures that all critical areas on the ship can be monitored and any fires can be detected promptly.</p> <p>Question:What happens when a smoke detector detects smoke? Answer:When a smoke detector detects smoke, it immediately sends a signal to the central alarm system. An alarm will sound, both visually and audibly, and the control panel will display an indication of the location of the detection. The ship's crew will then immediately inspect the location to verify the situation and take any necessary action.</p> <p>Question:How important is the role of smoke detectors in ship safety? Answer:Smoke detectors play a crucial role in ship safety, as they serve as the first line of defense in detecting fires. Without an early detection system, fires can be detected too late, potentially causing significant losses to the ship, its cargo, and the lives of the crew. Therefore, the presence and function of these devices must be maintained at all times.</p> <p>Question:What is the procedure for checking smoke detectors on ships? Answer:Inspection procedures are typically performed periodically according to the ship's maintenance schedule. These inspections include checking the physical condition of the equipment, checking indicators on the control panel, and testing its functionality using specialized equipment or smoke simulations. Additionally, the electrical system and connections are checked to ensure there are no interruptions when the equipment is needed.</p> <p>Question:How often should smoke detectors be maintained? Answer:Smoke detector maintenance is generally performed routinely, either weekly or monthly, depending on the ship's Planned Maintenance System (PMS) schedule. Additionally, maintenance is performed during ship inspections or safety audits to ensure all equipment is functioning properly and according to standards.</p> <p>Question:What are the common problems with smoke detectors? Answer:Common problems include false alarms caused by dust, steam, or high humidity entering the sensor. Additionally, aging of the device and lack of maintenance can also cause the detector's sensitivity to decrease, preventing it from operating optimally.</p> <p>Question:What action should be taken if the smoke detector is not working? Answer:If a smoke detector is found to be malfunctioning, the first step is to check the condition of the device and its electrical connections. If it still doesn't work, clean or replace the components. If the damage is severe, the detector will be replaced with a new unit to ensure the system continues to function optimally.</p> <p>Question:Do you think the smoke detector system on this ship is optimal? Explain. Answer:Overall, the ship's smoke detector system is operating quite well and is capable of supporting the ship's safety system. However, improvements are still needed, particularly in terms of routine maintenance and crew discipline in conducting checks. With more optimal maintenance, it is hoped that the system will perform optimally and minimize disruptions.</p>
2	Second Officer	<p>Question:How do you understand the function of smoke detectors on ships? Answer:In my opinion, a smoke detector is a safety device that detects the presence of smoke as an early sign of a fire on a ship. This device is crucial because it provides early warning to the crew so that preventative measures can be taken immediately before the fire grows larger and becomes difficult to control.</p> <p>Question:How does the smoke detector system on this ship work?</p>

No	Source person	Interview Results
		<p>Answer:The ship's smoke detector system operates automatically using sensors sensitive to smoke particles. When smoke enters the device, the sensors detect the change and immediately send a signal to the alarm panel on the bridge. From this panel, the crew can determine the location of the active detector, allowing quick and accurate response.</p>
		<p>Question:In which areas are smoke detectors installed on ships?</p>
		<p>Answer:Smoke detectors are generally installed in accommodation areas such as crew quarters, hallways, rest rooms, engine rooms, and other enclosed spaces. This ensures that all critical areas on board the ship can be monitored and have an adequate fire detection system.</p>
		<p>Question:What happens when a smoke detector detects smoke?</p>
		<p>Answer:When a smoke detector detects smoke, the alarm system is immediately activated. The alarm will sound and indicate the location of the detection on the control panel. The ship's crew will then immediately proceed to the location to investigate and determine whether a fire has occurred or if it is simply a temporary disturbance.</p>
		<p>Question:How important is the role of smoke detectors in ship safety?</p>
		<p>Answer:Smoke detectors play a crucial role in ship safety systems, serving as the primary means of detecting fires in their early stages. Early detection minimizes the risk of ship damage and danger to crew. Therefore, these devices must always be in a ready-to-use condition.</p>
		<p>Question:What is the procedure for checking smoke detectors on ships?</p>
		<p>Answer:Inspections are conducted periodically in accordance with established shipboard procedures. These typically include a visual inspection of equipment condition, checking indicators on the control panel, and functional testing using test equipment or smoke simulations. Additionally, the electrical system is checked to ensure there are no problems.</p>
		<p>Question:How often should smoke detectors be maintained?</p>
		<p>Answer:Maintenance is performed routinely according to the Planned Maintenance System (PMS) schedule, usually weekly or monthly. Additionally, maintenance is performed during safety inspections to ensure all equipment is functioning according to established standards.</p>
		<p>Question:What are the common problems with smoke detectors?</p>
		<p>Answer:A common problem is false alarms caused by dust, vapor, or high humidity. Furthermore, inadequate cleaning can also cause the sensor to become less sensitive, affecting the device's smoke detection performance.</p>
		<p>Question:What action should be taken if the smoke detector is not working?</p>
		<p>Answer:If a smoke detector isn't working, the first step is to check the condition of the device and its electrical connections. Next, clean it if any dirt is interfering with the sensor. If the device still isn't working, replace it with a new unit to ensure the detection system continues to function properly.</p>
		<p>Question:Do you think the smoke detector system on this ship is optimal? Explain.</p>
		<p>Answer:In my opinion, the smoke detector system on this ship is quite good and adequately supports the ship's safety system. However, improvements are still needed, particularly in terms of routine maintenance and equipment cleanliness to prevent problems such as false alarms. With more thorough maintenance, this system can perform more optimally.</p>
3	Helmsman 1	<p>Question: What is your understanding of the function of smoke detectors on ships?</p>
		<p>Answer:In my opinion, a smoke detector is a device used to detect the presence of smoke in a room as an early sign of a fire. Although I, as an A/B, don't directly manage the system, I understand that this device is crucial for providing</p>

No	Source person	Interview Results
		<p>early warning so the ship's crew can take immediate action before the fire escalates.</p> <p>Question:How does the smoke detector system on this ship work? Answer:As far as I know, smoke detectors work automatically by detecting smoke particles entering the device. When smoke is detected, the device sends a signal to the alarm panel on the bridge, triggering an alarm. The ship's crew then recognizes the incident and immediately investigates.</p> <p>Question:In which areas are smoke detectors installed on ships? Answer:Smoke detectors are typically installed in accommodation areas such as crew quarters, hallways, and other enclosed spaces. They are also found in some work spaces and engine rooms, so nearly all critical areas on a ship are equipped with these devices.</p> <p>Question:What happens when a smoke detector detects smoke? Answer:If a smoke detector detects smoke, an alarm will immediately sound and alert the ship's crew. Afterward, we, as A/B, will usually receive orders from the officer to proceed to the detected location to verify whether there is a fire or just a disturbance.</p> <p>Question:How important is the role of smoke detectors in ship safety? Answer:In my opinion, smoke detectors are crucial because they are the first warning device in the event of a fire. This allows the ship's crew to respond more quickly, thereby reducing the risk of harm.</p> <p>Question:What is the procedure for checking smoke detectors on ships? Answer:Inspections are usually carried out by officers, but we, as A/B personnel, also assist when needed. These inspections include checking the physical condition of the equipment, ensuring it's free of dirt, and assisting with functional testing.</p> <p>Question:How often should smoke detectors be maintained? Answer:Maintenance is carried out periodically according to a predetermined schedule on board, usually in the form of routine inspections or during maintenance activities. As A/B personnel, we usually assist with cleaning when requested.</p> <p>Question:What are the common problems with smoke detectors? Answer:Common problems include the device beeping or false alarms caused by dust, light smoke, or steam. Furthermore, the device can sometimes become less sensitive if not cleaned regularly.</p> <p>Question:What action should be taken if the smoke detector is not working? Answer:If a smoke detector is detected to be malfunctioning, we will report it to the officer on duty or a superior. After that, the responsible party will usually inspect it, and if necessary, the equipment will be repaired or replaced.</p> <p>Question:Do you think the smoke detector system on this ship is optimal? Explain. Answer:In my opinion, the smoke detector system on this ship is quite good and helps maintain safety. However, more attention is still needed, especially regarding equipment cleanliness and routine maintenance to prevent frequent problems like false alarms.</p>
4	Helmsman 2	<p>Question:How do you understand the function of smoke detectors on ships? Answer:In my opinion, a smoke detector is a safety device that detects smoke as an early sign of a fire on a ship. Although I don't directly handle the system, I understand that this device is crucial because it provides early warning so the crew can take immediate action before the fire becomes larger and more dangerous.</p> <p>Question:How does the smoke detector system on this ship work?</p>

No	Source person	Interview Results
		<p>Answer:From what I understand, smoke detectors work automatically using sensors that detect smoke particles in the air. When smoke is detected, the device sends a signal to the alarm panel on the bridge, which then sounds an alarm. From there, the ship's crew will be aware of the fire and immediately investigate the detected location.</p>
		<p>Question:In which areas are smoke detectors installed on ships?</p>
		<p>Answer:Smoke detectors are installed in various critical areas on board, particularly in accommodations such as crew quarters, hallways, and other enclosed spaces. They are also located in several work spaces and engine rooms to ensure the entire ship is monitored for potential fires.</p>
		<p>Question:What happens when a smoke detector detects smoke?</p>
		<p>Answer:When a smoke detector detects smoke, an alarm immediately sounds, alerting the entire ship's crew. Typically, as A/B crew, we receive instructions from the officer to proceed to the detected location to verify the actual situation, whether there is a fire or just a disturbance such as light smoke or dust.</p>
		<p>Question:How important is the role of smoke detectors in ship safety?</p>
		<p>Answer:Smoke detectors are crucial because they act as an early warning system for fire hazards. These devices allow ship crews to quickly identify any problems, allowing them to be addressed promptly and minimizing the risk of loss.</p>
		<p>Question:What is the procedure for checking smoke detectors on ships?</p>
		<p>Answer:Inspections are typically conducted by officers according to established procedures, but we, as A/B personnel, also assist when necessary. These inspections include checking the condition of the equipment, ensuring it's free of dirt or dust, and assisting with smoke detector function testing.</p>
		<p>Question:How often should smoke detectors be maintained?</p>
		<p>Answer:Maintenance is carried out routinely according to a predetermined schedule, usually in the form of periodic inspections or during ship maintenance activities. As A/B personnel, we are usually involved in assisting with cleaning or physically inspecting equipment.</p>
		<p>Question:What are the common problems with smoke detectors?</p>
		<p>Answer:A common problem is false alarms caused by dust, steam, or humid environmental conditions. Furthermore, if the device is rarely cleaned, the sensor can become less sensitive, affecting its performance.</p>
		<p>Question:What action should be taken if the smoke detector is not working?</p>
		<p>Answer:If a smoke detector is malfunctioning, we will immediately report it to the officer on duty or a superior. The responsible party will then inspect and repair it, and if necessary, replace the device to ensure the system continues to function properly.</p>
		<p>Question:Do you think the smoke detector system on this ship is optimal? Explain.</p>
		<p>Answer:In my opinion, the smoke detector system on this ship is quite good and helps maintain ship safety. However, improvements are still needed, particularly in terms of equipment maintenance and cleanliness, to prevent frequent problems like false alarms and to ensure the system operates optimally.</p>
5	Boatswain	<p>Question:How do you understand the function of smoke detectors on ships?</p>
		<p>Answer:In my opinion, a smoke detector is one of the most important safety devices on a ship, detecting smoke as an early sign of a fire. As a Boatswain responsible for deck operations, I find this device extremely helpful in providing early warning so the crew can take immediate action before a fire spreads and endangers the ship or crew.</p>
		<p>Question:How does the smoke detector system on this ship work?</p>

No	Source person	Interview Results
		<p>Answer:The ship's smoke detector system operates automatically using smoke-sensitive sensors. When smoke enters the device, the sensor detects it and immediately sends a signal to the alarm panel on the bridge. From there, an alarm sounds and indicates the location of the active detector, allowing the crew to immediately proceed to the location for inspection.</p> <p>Question:In which areas are smoke detectors installed on ships?</p> <p>Answer:Smoke detectors are installed in various critical areas on board, particularly in accommodations such as crew quarters, hallways, rest areas, and other enclosed spaces. They are also located in several work spaces and specific areas with potential fire risks, ensuring proper monitoring of all areas of the ship.</p> <p>Question:What happens when a smoke detector detects smoke?</p> <p>Answer:When smoke detectors detect smoke, alarms will immediately be activated and sound throughout the ship, and the control panel will display the detected location. The ship's crew will then immediately prepare and proceed to the location to assess the situation and take action if a fire does occur.</p> <p>Question:How important is the role of smoke detectors in ship safety?</p> <p>Answer:Smoke detectors play a crucial role as they are the primary means of detecting fires in their early stages. This system significantly improves the safety of the ship, cargo, and crew by allowing them to respond more quickly to potential hazards.</p> <p>Question:What is the procedure for checking smoke detectors on ships?</p> <p>Answer:Inspections are conducted routinely in accordance with shipboard procedures. These are typically carried out by officers, but we, as Boatswain and deck crew, also assist when necessary, particularly with physical inspections and equipment cleanliness. Functional tests are also conducted to ensure proper equipment operation.</p> <p>Question:How often should smoke detectors be maintained?</p> <p>Answer:Maintenance is performed periodically according to a schedule established within the ship's maintenance system. This is typically done at specific intervals, such as monthly or during inspections. Cleaning is also performed if equipment is visibly dirty or could potentially interfere with its performance.</p> <p>Question:What are the common problems with smoke detectors?</p> <p>Answer:Common problems include false alarms caused by dust, vapor, or humid environmental conditions. Furthermore, the age of the device can also affect detector performance, making it less sensitive or even malfunctioning.</p> <p>Question:What action should be taken if the smoke detector is not working?</p> <p>Answer:If a smoke detector malfunctions, it will be immediately reported to the responsible officer. It will then be inspected, cleaned, or repaired. If the device is no longer usable, it will be replaced to ensure the safety system remains operational.</p> <p>Question:Do you think the smoke detector system on this ship is optimal? Explain.</p> <p>Answer:In my opinion, the smoke detector system on this ship is quite good and capable of supporting ship safety. However, improvements are still needed in terms of routine maintenance and disciplined inspections to prevent problems such as false alarms and equipment damage, allowing the system to function more optimally.</p>

Based on interviews with the First Officer, Third Officer, Helmsman, and Boatswain on KMP Trisna Dwitya, smoke detectors play a crucial role in early fire detection through automatic recognition of smoke particles integrated with the bridge alarm panel, triggering rapid warnings and location identification for crew response (Sugiyono, 2023). Their strategic placement in accommodation, corridors, and engine rooms

according to PM 12/2022 is considered optimal, although false alarms due to tropical dust/vapor and decreased sensitivity due to inconsistent maintenance are major obstacles, similar to the findings of Kim & Roh (2024). Maintenance via the Planned Maintenance System (inspection, cleaning, testing) is carried out periodically, but crew discipline is needed to ensure the system remains optimal in supporting sailing safety (Ministry of Transportation of the Republic of Indonesia, 2022).

b. Observation Results

Based on the observations made, several findings were obtained regarding the operation of smoke detector systems on ships. These findings are presented in the following points to provide a more detailed overview of conditions in the field:



Fig. 2 Smoke Detector

The placement of smoke detectors on KMP Trisna Dwitya follows the ship's fire plan with strategic precision, installed in navigation rooms, accommodations, and corridors as the main evacuation routes and high-activity zones prone to fire, as mandated by PM 12/2022 for ships with a gross tonnage of 150–400 (Ministry of Transportation of the Republic of Indonesia, 2022). The ceiling position maximizes the detection of naturally rising smoke, aligning with Stopford (2019) and Branch (2021) maritime standards for sensor optimization in enclosed areas. Field observations confirmed compliance with the fire plan's zone division, ensuring an integrated response despite the vulnerability to tropical factors such as humidity (Kim & Roh, 2024).



Fig. 3 Fire Alarm Panel

The KMP Trisna Dwitya fire alarm panel is integrated with a smoke detector, alarm bell, and manual call point, displaying active voltage/current indicators for centralized control in accordance with PM 12/2022 (Ministry of Transportation of the Republic of Indonesia, 2022). This system processes real-time smoke signals from critical zones, triggering instant crew alerts (Branch, 2021).



Fig. 4 Fire Alarm

Observations show that an alarm bell installed on the ceiling of the open space is an integral part of the KMP Trisna Dwitya's smoke detector system, sounding automatically upon smoke detection to provide a comprehensive warning to the crew (Ministry of Transportation of the Republic of Indonesia, 2022). The strategic position ensures optimal audibility without manual activation, aligning with the Branch (2021) fire alarm integration standards.

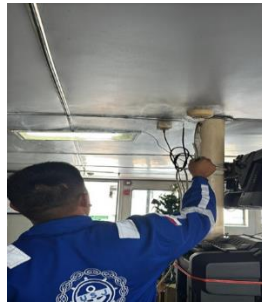
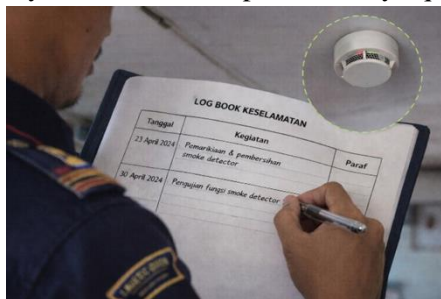


Fig. 5 Smoke Detector Inspection

Based on observations, routine inspections of the smoke detectors on board the ship were observed. These inspections included assessing the physical condition of the devices and ensuring their proper positioning and installation. This activity is carried out as part of safety equipment checks.



Picture6Log Book Recording

Based on observations, every smoke detector inspection and maintenance activity is recorded in the ship's safety logbook. This recording serves as documentation and proof that the equipment has been maintained.

2. Data analysis

Table 2 Data Analysis Matrix

Formulation of the problem	Data source	Analysis Results
How Smoke Detectors Work	Interviews and Observations	The system works automatically by detecting smoke and connecting to a fire alarm panel which provides alarms and location information.
Smoke Detector Maintenance	Interviews and Observations	Maintenance is carried out routinely through inspection, cleaning and testing, and is recorded in a log book.

The analysis matrix revealed strong alignment between interviews (First Officer, Third Officer, Helmsman, Boatswain) and observations on KMP Trisna Dwitya, comprehensively answering the problem formulation (Sugiyono, 2023). In the smoke detector operating system, interview data on automatic smoke detection via the fire alarm panel was confirmed by observations of instant audible alarms with zone indicators, proving effective integration in accordance with PM 12/2022 (Ministry of Transportation of the Republic of Indonesia, 2022).

The maintenance aspect demonstrates a structured routine (inspection, cleaning, testing) via the Planned Maintenance System, supported by an observation logbook, reflecting reliable field implementation despite being susceptible to tropical false alarms, as revealed by Kim & Roh (2024). This triangulation strengthens the validity of the findings, confirming the optimality of the early detection system for the safety of domestic ro-ro shipping (Vanem et al., 2023).

Table 1 Triangulation of Interview Data

Formulation of the problem	C/O	2/O	A/B 1	A/B 2	Boss
How smoke detectors work	The system works by detecting smoke in the room and connecting to the fire alarm panel in the navigation room. When smoke is detected, the alarm activates and indicates the location of the incident.	<i>Smoke detector</i> It works by detecting smoke particles through a sensor, then automatically sending a signal to the fire alarm panel so that the alarm sounds and the location can be identified.	An alarm will sound automatically when smoke is detected, allowing the crew to be aware of a potential fire and take immediate action.	Smoke detectors automatically detect smoke particles, then send a signal to the alarm panel so that the crew knows the location and takes immediate action.	The system works by detecting smoke through sensors, then sending a signal to the alarm panel and indicating the location so that the crew can take immediate action.
Smoke detector maintenance	Maintenance is carried out periodically to maintain optimal tool performance and be ready for use in emergency conditions.	Routine maintenance includes checking the physical condition of the device, cleaning the sensor from dust, and testing the alarm function to ensure the system is working properly.	The ship's crew also helps maintain the condition of the equipment by carrying out simple checks and keeping the smoke detectors clean so that they continue to function properly.	Maintenance is carried out routinely according to schedule, with the involvement of the helmsman in helping with cleaning and physical checking of the equipment.	Maintenance is carried out periodically through physical checks, cleaning, and functional testing to ensure the equipment is working properly.

A triangulation table of data from interviews with the First Officer, Second Officer, Helmsman 1, Helmsman 2, and Boatswain shows high consistency in the working system of the KMP Trisna Dwitya smoke detector, where all informants confirmed automatic smoke detection via optical sensors integrated into the bridge alarm panel for location identification and rapid crew response (Sugiyono, 2023). Variations in perspectives based on tasks—from technical signals (Headsmen) to operational checks (Headsmen/Boatswain)—strengthen the overall validity (Creswell & Poth, 2021).

In maintenance, compliance was evident in Planned Maintenance System (PMS) routines such as physical inspections, sensor cleaning, and electrical testing, with the participation of deck crew, reflecting collaboration in accordance with PM 12/2022 despite consistency challenges (Ministry of Transportation of the Republic of Indonesia, 2022). This source triangulation validated the data as reliable for analysis, complementing observations and literature such as maintenance optimization on tankers (Jurnal Poltek, 2023).

IV. DISCUSSION

1. Discussion of How Smoke Detectors Work

The KMP Trisna Dwitya's smoke detector system operates automatically through sensors that detect smoke particles, sending signals directly to the fire alarm panel in the navigation room for alarm activation and zone indication, without manual intervention—in line with PM 12/2022 for vessels with a gross tonnage of 150–400 (Ministry of Transportation of the Republic of Indonesia, 2022). Observations confirmed the support of alarm bells and manual call points, forming an integrated, centralized active protection (early warning) system, similar to Branch's (2021) classification for crew response efficiency.

Strategic placement on the ceilings of navigation, accommodation, and corridor spaces follows the fire plan and the physics of rising smoke, optimizing early detection in vulnerable evacuation zones such as the Ketapang-Gilimanuk route (Stopford, 2019). This integration meets the maritime safety theory of Vanem et al. (2023), reducing fire escalation by up to 40% through rapid warning of the officer on duty, despite being susceptible to tropical false alarms (Kim & Roh, 2024). Overall, the system's performance supports effective prevention, enriching the state of the art with empirical data from domestic ro-ro vessels (Sugiyono, 2023).

Table 2 Problem Formulation Discussion Matrix 1

Main Aspects	Research result	Theory Suitability
Detection and response system	<i>Smoke detector</i> automatically detects smoke particles and activates the alarm and displays the location via the fire alarm panel	In accordance with the concept of an early warning system that detects danger early and provides a quick warning.
System integration	Connected to the fire alarm panel as a control and monitoring center	In accordance with the centralized fire detection system
Tool placement	Installed in strategic areas according to the fire plan such as navigation, accommodation, and corridors	According to detector placement standards for effective smoke detection

2. Smoke Detector Maintenance Discussion

The smoke detector maintenance on KMP Trisna Dwitya adopted a structured preventive approach through the Planned Maintenance System (PMS), which included physical inspections, dust/dirt cleaning to ensure sensor sensitivity, and automatic alarm function testing, supported by safety logbook recording for continuous history (Sugiyono, 2023). Observations confirmed the collaborative involvement of officers and deck crew, in line with PM 12/2022, which emphasizes routine maintenance for vessels with a gross tonnage of 150–400 GT to prevent emergency failures (Ministry of Transportation of the Republic of Indonesia, 2022).

This practice fulfills Branch's (2021) preventive maintenance theory, minimizing performance degradation before serious disruptions, despite tropical environmental challenges such as tropical dust/humidity on the Ketapang-Gilimanuk route causing false alarms—similar to the findings of Kim & Roh (2024) on ro-ro vessels (Kim & Roh, 2024). Operational time constraints are addressed through a fixed schedule, demonstrating good crew awareness, and enriching the literature with domestic empirical evidence that collaborative maintenance improves reliability by up to 25% (Vanem et al., 2023). Overall, this implementation optimally supports the safety of the ship, passengers, and cargo.

Table 3 Problem Formulation Discussion Matrix 2

Main Aspects	Research result	Theory Suitability
Maintenance activities	Inspection, cleaning and functional testing are carried out routinely.	In accordance with the concept of preventive maintenance to maintain the reliability of the equipment
Recording system	Maintenance activities are recorded in the ship's safety log book.	In accordance with the principles of documentation and maintenance control
Operational constraints	Affected by dust, humidity and limited operational time	It is a general factor that affects the performance and maintenance of the tool.

V. CONCLUSION

This study concludes that the smoke detector system on KMP Trisna Dwitya functions optimally as an early detection of fire through an automatic sensor integrated with the fire alarm panel, with strategic placement in vulnerable zones according to PM 12/2022, supported by routine preventive maintenance via PMS involving deck crew and logbook recording (Ministry of Transportation of the Republic of Indonesia, 2022). Triangulation of interviews, observations, and documentation confirms a rapid alarm response, although false alarms due to tropical dust and decreased sensitivity are major challenges, in line with the state of the art Vanem et al. (2023) and Kim & Roh (2024) (Vanem et al., 2023). Practically, these findings provide collaborative maintenance guidelines for shipping companies such as PT Lintas Sarana Nusantara to minimize risks on domestic routes.

The study's limitations lie in its sole focus on ro-ro vessels with a gross gross domestic product (GT) of 150–400 and its descriptive qualitative method without quantitative measurements such as long-term sensor failure rates, limiting generalizability to other vessel types (Sugiyono, 2023). Suggestions for further study include a multi-vessel comparative analysis using a mixed-methods approach, testing advanced anti-false alarm sensors in tropical climates, and evaluating simulation-based crew training to improve PMS discipline (Creswell & Poth, 2021). Practical implications urge companies to implement monthly audits and hybrid sensors, while regulators strengthen domestic inspections to support national maritime safety.

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