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Analysis of the Effectiveness of the Implementation of the Lockout Tagout (LOTO) System in Improving Work Safety on Board Ships

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Abstract

The complexity of the work environment on board a ship, which includes the main engine, generator, hydraulic system, and other supporting equipment, requires a systematic approach in risk management. Each system has different maintenance characteristics that have the potential hazards, ranging from electrical, mechanical, hydraulic, to thermal systems. The purpose of this study is to analyze in depth the effectiveness of the implementation of the Lockout Tagout (LOTO) system in improving work safety on board ships, by considering various complex factors that influence its implementation. This study uses a mixed-methods approach with a comprehensive quantitative-qualitative research design to analyze the effectiveness of the LOTO system in improving work safety on board ships by adopting a multi-instrument approach for comprehensive data collection on the implementation of LOTO procedures on merchant ships, consisting of a structured questionnaire to measure the level of crew understanding of LOTO procedures, assess perceptions of work safety, and identify barriers to implementation. The results show that the level of understanding of LOTO procedures reached an average score of 3.55 indicating good but not optimal awareness among crew members. The inhibiting factors for LOTO implementation indicate that the variation of engine systems with a score of 3.62 is the most significant challenge. The effectiveness of LOTO implementation showed positive results, with the highest score in the accident prevention aspect 4.12 which was categorized as very effective. The compliance index reached 3.87 indicating that most respondents had implemented the procedure well. These findings yield practical implications in the form of the need for ongoing training, adaptive LOTO procedures, comprehensive documentation systems, and strengthening of safety culture.

Keywords

Safety Culture, LOTO Procedures, Risk Management, Potential Hazards

1. Introduction

Occupational safety is a critical aspect in the maritime industry which has a high level of risk and a very diverse work complexity. The maritime sector faces significant challenges related to occupational safety, with an average of 4,000 fatal accidents occurring each year worldwide [1]. One method of risk control that has proven effective is the Lockout Tagout (LOTO) system, which is a fundamental safety procedure to prevent accidents due to hazardous energy [2] [3].

Research related to the Lockout Tagout (LOTO) system in the maritime environment faces several significant gaps even though this safety procedure has been proven effective in various industries on land. Although [4] have explored the implementation of safety procedures in the shipping sector [5] [6] have studied safety management systems on merchant ships, there is a lack of comprehensive studies that specifically analyze the effectiveness of LOTO in the context of the unique maritime environment with limited spatial characteristics, technological variations, and multinational crew dynamics. [7] identified that the work environment on board ships has its own complexities that have not been accommodated in conventional LOTO standards, while a study [8] highlighted the lack of empirical research on crew compliance with LOTO procedures on various types of offshore vessels. [9] also highlighted the gap in understanding how safety culture factors specific to the offshore industry influence the success of LOTO implementation, while a study [10] showed limited documentation on the adaptation of LOTO procedures to the variety of machinery systems in the modern ship environment. Previous studies have shown that LOTO implementation can reduce the risk of work accidents by up to 80% in industrial environments with complex mechanical and electrical equipment [11]. Despite ongoing efforts, there remains a significant knowledge gap regarding the full effectiveness of safety procedures implemented on ships. A recent study found that 67% of work-related accidents on board were linked to failures in safety protocols, particularly hazardous energy control procedures [12]. The complexity of the working environment on board a ship, which includes main engines, generators, hydraulic systems, and other supporting equipment, requires a systematic approach to risk management [13]. Each system has different maintenance characteristics with varying potential hazards, ranging from electrical, mechanical, and hydraulic to thermal systems. This condition underscores the urgent need to conduct a thorough analysis of the lockout-tagout system on the ship to ensure optimal operational safety.

The novelty of this study lies in the integration of a multi-method approach to analyze the effectiveness of LOTO on board complex ships, considering not only the technical aspects of the procedure but also the organizational and individual dimensions that influence its implementation. In contrast to research [13] which only focuses on technical aspects, or studies [14] which examine human factors in general, this study develops a comprehensive analytical framework that links LOTO procedures with occupational safety outcomes through intervening variables in the form of organizational and individual factors specific to the maritime environment. This study also offers methodological novelty through the development of an assessment instrument tailored to the unique characteristics of merchant ships, complementing previous studies from [15] which used industry-based measurement parameters on land. Furthermore, this study adopts a comparative analysis approach between different types of ships and shipping routes to identify contextual factors that influence LOTO effectiveness, broadening the understanding of the adaptation of safety procedures in various operational conditions on ships that vary according to recommendations in the publication [16] [17].

The purpose of this study is to analyze in depth the effectiveness of the implementation of the Lockout Tagout system in improving work safety on board ships, by considering various complex factors that influence its implementation.

2. Method

This study uses a mixed-methods approach with a comprehensive quantitative-qualitative research design to analyze the effectiveness of the Lockout Tagout (LOTO) system in improving work safety on board ships. The research method chosen aims to provide a holistic picture of LOTO implementation through empirical data collection and in-depth analysis.

This study involved crew members from various types of merchant ships operating in Indonesian waters. The ships that were part of this study included cargo ships, tankers, and container ships. To ensure representative research results, sample selection was carried out using the stratified random sampling method.

In the sample selection process, there are several criteria that must be met by the ships to be studied. First, the ship must have a minimum operating period of three years in order to provide relevant data and sufficient experience in its operations. Second, the ship must have a documented Lockout Tagout (LOTO) procedure, as part of the work safety system implemented. Third, the crew members involved must be willing to participate in this study.

This research plan will involve 10 ships, with a total of 150 respondents consisting of various crucial positions in ship operations. Respondents involved include the captain and chief officer who are responsible for decision-making on the ship. Furthermore, the study will include the chief engineer and the second engineer, who are responsible for the maintenance and operation of the ship's machinery. The port captain and port engineer are also part of this study, given their role in ensuring that work safety standards are implemented. In addition, all crew members who are directly involved in equipment maintenance will also be part of the respondents to provide insight into the implementation of safety procedures on the ship.

This study adopted a multi-instrument approach for comprehensive data collection [18] in this case regarding the implementation of Lockout Tagout (LOTO) procedures on merchant ships, consisting of three main complementary methods: a structured questionnaire to measure the level of crew understanding of LOTO procedures, assess perceptions of work safety, and identify barriers to implementation; field observations for direct documentation of daily safety practices and assessment of their compliance with applicable standards; and semi-structured in-depth interviews with key informants such as captains, chief engineers, port engineers, and crew members responsible for LOTO implementation to explore qualitative factors that influence the effectiveness of safety procedures, including challenges and opportunities for improvement. The combination of these three instruments allows researchers to obtain accurate data from various perspectives and provide a deeper understanding of the dynamics of LOTO implementation in maintenance and repair on complex ships.

This study applies document analysis as an integral component [19] to assess the implementation of the Lockout Tagout (LOTO) system in the maritime environment, including an in-depth review of written safety procedures, incident records, and LOTO implementation documentation to identify gaps between policies and field practices. The data analysis process was carried out through a combination of quantitative-qualitative (mixed method) approach, with quantitative analysis including descriptive statistics for respondent characterization, correlation tests to identify relationships between variables, and regression analysis to predict factors that influence LOTO effectiveness, while qualitative analysis uses content analysis methods and thematic coding of interview and observation data to categorize information based on emerging themes such as implementation constraints, crew members' experiences, and safety culture factors, which are then presented in the form of narrative interpretations to provide a comprehensive understanding of the effectiveness of LOTO implementation on merchant ships.

This study explores the complex dynamics of Lockout Tagout (LOTO) implementation on merchant ships through the analysis of three interrelated variable categories: independent variables in the form of LOTO procedure implementation including compliance with safety standards, availability of locking and tagging equipment, and the level of crew members' understanding; dependent variables in the form of work safety levels measured through incident frequency, compliance level, and crew members' perceptions of a safe work environment; and intervening variables consisting of organizational factors (company policies, training, and safety culture) and individual factors (work experience, level of understanding, attitude and concern of crew members) that act as mediators between LOTO implementation and work safety levels. Through this comprehensive analysis approach, the study aims to reveal the causal relationship between the implementation of effective LOTO procedures and increased work safety, as well as to identify moderating factors that can strengthen or weaken the relationship in the maintenance and repair of ships that have unique characteristics and challenges.

3. Results and Discussion

3.1. Results

Table 1. Respondent characteristics.

Characteristics	Number	Percentage (%)
Age		
20 - 30 years	45	30%
31 - 40 years	65	43.3%
41 - 50 years	30	20%
>50 years	10	6.7%
Education		
Diploma III	35	23.3%
Bachelor/Diploma IV	80	53.3%
Master	25	16.7%
Other	10	6.7%
Work experience		
<5 years	40	26.7%
5 - 10 years	75	50%
>10 years	35	23.3%

Source: author's data processing, 2025.

As shown in **Table 1**, analysis of respondent characteristics revealed that the majority of respondents (43.3%) were in the age range of 31 - 40 years, with education levels dominated by S1 graduates (53.3%) and 5 - 10 years of work experience (50%).

Table 2. Level of understanding of lockout tagout procedures.

Indicator	Average Score	Category
Theoretical Knowledge	3.65	Good
Practical Skills	3.42	Quite good
Safety Awareness	3.78	Good
Consistency of Implementation	3.35	Quite good
Total Comprehension Score	3.55	Good

Note: <3 = not good, 3.1 - 3.5 = quite good, 3.6 - 4.0 = good, >4.1 = very good; Source: author's data processing, 2025.

See Table 2, analysis of the level of understanding of LOTO procedures showed an average score of 3.55 which is categorized as good. The safety awareness aspect recorded the highest score (3.78), while consistency of implementation obtained the lowest score (3.35). This indicates that even though awareness is high, there are still challenges in consistent implementation. The most difficult indicator for crew members to understand in practical application is "Consistency of Implementation" with the lowest average score of 3.35 which is categorized as quite good. This indicates that although the crew has good theoretical knowledge (score 3.65) and high safety awareness (score 3.78), they must still apply LOTO procedures consistently in various work situations on board. This gap is likely caused by several factors such as variations in working conditions on board, time pressure when carrying out maintenance tasks in a tight sailing schedule, lack of standardization of LOTO equipment on various machinery on board, or perhaps inconsistencies in training and supervision.

Table 3. Effectiveness of LOTO implementation.

Assessment Aspects	Effectiveness Score	Category
Accident Prevention	4.12	Very Effective
Documentation Quality	3.65	Effective
Procedure Compliance	3.78	Effective
Risk Control	3.95	Effective
Compliance Index	3.87	Effective

Note: <3 = less effective; 3.1 - 3.9 = effective; >4.0 = very effective; Source: author's data processing, 2025.

As shown in Table 3, the evaluation of the effectiveness of LOTO implementation showed positive results, with the highest score in the accident prevention aspect (4.12) which was categorized as very effective. The compliance index reached 3.87, indicating that most respondents had implemented the procedure well.

Table 4. Inhibiting factors for LOTO implementation.

Inhibiting Factors	Influence Score	Category
Space Limitations	3.45	Significant
Machine System Variations	3.62	Very significant
Change of Crew	3.35	Significant
Standard Differences	3.28	Quite significant
Training Resources	3.15	Quite significant

Note: <3.0 not significant; 3.10 - 3.29= quite significant; 3.30 - 3.49 = significant; >3.50 = very significant; Source: author's data processing, 2025.

See Table 4, analysis of inhibiting factors identified engine system variation as the most significant challenge with a score of 3.62. Space limitations and crew changes also contributed significantly to the complexity of LOTO implementation.

3.2. Discussion

This study reveals the complexity of Lockout Tagout (LOTO) implementation in terms of occupational safety on board ships. The level of understanding of the LOTO procedure which achieved an average score of 3.55 indicates good but not optimal awareness among the crew. The level of understanding of the LOTO (Lock Out/Tag Out) procedure with an average score of 3.55 indicates that the crew has a fairly good awareness of the importance of this equipment security procedure, but there is still room for improvement to reach the optimal level; this gap in understanding can be a focus area for further training and education programs to ensure that all crew have comprehensive knowledge of this critical safety procedure, which will ultimately minimize the risk of work accidents and improve operational safety standards on board. This is consistent with research [20] which emphasizes the importance of continuous training and socialization of safety procedures. The variation in understanding between theoretical knowledge (3.65) and practical skills (3.42) indicates a gap that needs serious attention.

Based on the implementation of the Lockout/Tagout (LOTO) procedure on board, a number of significant obstacles have been identified that complicate the implementation of this safety protocol. The most dominant factor is the diversity of machinery operational systems which recorded a high score of 3.62 on the obstacle assessment scale. The results of this evaluation are in line with the findings [21] which emphasize that modern maritime technology has reached a level of complexity that is quite challenging to manage uniformly. Modern ships are equipped with a variety of machinery systems that have varying characteristics, operating mechanisms, and maintenance protocols. This condition creates its own challenges in standardizing LOTO procedures, because each type of machine may require a specific safety approach. This situation is complicated by the limited physical space on the ship which limits the implementation of a comprehensive safety system. The narrow and limited operational space is a separate obstacle in implementing LOTO procedures which require energy isolation and the use of adequate locking devices.

An additional significant factor is the relatively high frequency of crew changes. Frequent personnel rotation creates challenges in ensuring consistency in understanding and compliance with LOTO procedures. Each new crew member requires adaptation time to understand the complex and diverse systems, as well as the safety protocols that are specific to each type of machine. As a result, training and socialization efforts for safety procedures must be carried out repeatedly, which increases the operational burden and the potential for misinterpretation of procedures that can threaten work safety in the maritime environment. Theoretically, this study enriches the conceptual framework of risk management in the maritime environment. The results show that the effectiveness of LOTO is not just a matter of written procedures, but rather a complex combination of knowledge, skills, safety culture, and work environment conditions.

The results of the study revealed four critical practical implications that can be applied to improve the effectiveness of the Lockout Tagout (LOTO) system when working on ships. First, the developed training program not only provides theoretical knowledge, but also improves the crew's practical abilities in implementing Lockout Tagout procedures. The training concept emphasizes simulation of real conditions, case studies of previous accidents, and direct practice on board the ship. Second, the development of the Lockout Tagout procedure must be able to adapt to the diversity of engine systems on the ship. The proposed approach includes detailed mapping of the characteristics of each type of engine, development of specific guidelines for each system, and flexible mechanisms that allow modification of the procedure according to technical needs. Third, the design of comprehensive LOTO documentation includes the creation of standardized guidelines, detailed recording of each locking and tagging process, and a tracking system that allows tracing the history of procedure implementation. Fourth, a systematic approach to building a safety culture involves a series of tiered interventions. It begins with commitment from top management, continuous socialization, recognition of good safety practices, and the establishment of a dedicated safety team on each ship.

When carrying out maintenance and repairs on machinery, engineers can install safety locks on electrical panels, hang warning labels that include information about the person in charge and the duration of the work, and document these actions in the maintenance logbook. The implementation of LOTO significantly changes work procedures by requiring each crew member to have self-awareness, adding verification steps before starting work, requiring special safety briefings before maintenance activities, and establishing emergency procedures that require written authorization from the chief engineer.

A comparative analysis of the implementation of LOTO procedures on cargo ships, tankers and container ships revealed several significant differences reflecting the operational characteristics and specific risks of each type of ship. On cargo ships, LOTO implementation tends to be simpler with a primary focus on loading and unloading equipment such as cranes and winches, using a manual documentation system and having a moderate level of compliance. Next, on tankers, LOTO is implemented with much stricter standards due to the high risk associated with hazardous cargo. The LOTO system on tankers includes cargo handling systems and inert gas systems, uses digital documentation integrated with the ship's safety management system, and has a high level of compliance. Meanwhile, container ships show unique characteristics in the implementation of LOTO with a focus on container cooling equipment (reefer units), container cranes, and container locking systems. These ships use a combination of digital and physical documentation systems with QR codes for LOTO status tracking, having a medium level of compliance.

The research findings empirically support and extend important studies in understanding the complexity of safety procedures in the maritime environment by providing concrete evidence of the various challenges faced in implementing Lockout Tagout (LOTO) [9]. Specifically, this study confirms Wang's argument that the work environment on board ships has unique characteristics that make the implementation of safety procedures very complex. The variety of engine systems, space constraints, and high crew turnover dynamics have been the main focus in supporting the findings of previous studies. The quantitative data generated provides a new perspective on how these complexities actually affect the effectiveness of safety procedures. Furthermore, the results of the analysis [22] show that factors such as differences in standards between organizations, limited training resources, and variations in engine system complexity have a substantial influence. The scores obtained for each inhibiting factor not only confirm Petersen's findings but also provide a more comprehensive analysis of the working mechanisms of these factors.

4. Conclusion

This study shows that the implementation of Lockout Tagout (LOTO) in the maritime environment is faced with significant complexity, with the level of understanding of the crew reaching an average score of 3.55 indicating good awareness but not optimal. The gap between theoretical knowledge (3.65) and practical skills (3.42) was identified as the main concern, while the variation of engine systems (score 3.62) was the most significant inhibiting factor. These findings not only enrich the conceptual framework of risk management on board ships but also produce practical implications in the form of the need for continuous training, adaptive LOTO procedures, comprehensive documentation systems, and strengthening of safety culture. Despite its limitations in terms of sample and complexity of variables, the study provides an original contribution in the in-depth exploration of LOTO implementation on board ships operating in Indonesia and provides a basis for comparative studies, development of risk predictive models, and investigation of supporting technologies in the future.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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