

## **Evaluation Of The Implementation Of The Planned Maintenance System In Improving Docking Time Efficiency And Maintenance Cost Control Of TB. Flores 1 At PT. Bintang Samudera Mandiri Lines**

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### **Abstract**

*The efficiency of ship maintenance is essential to ensure operational readiness, minimize docking duration, and control maintenance costs. In practice, the implementation of the Planned Maintenance System (PMS) on TB. Flores 1 at PT Bintang Samudera Mandiri Lines is influenced by operational schedules, maintenance windows, crew workload, equipment conditions, spare-part availability, procurement lead time, and ship-shore coordination. This study aims to evaluate the existing implementation of PMS, analyze its implications for docking time efficiency and maintenance cost control, and identify supporting and inhibiting factors as well as strategies for PMS optimization. The research employed a qualitative evaluative case study approach. Data were collected through in-depth interviews, observation, and documentation, followed by thematic analysis and source and technique triangulation. The findings indicate that PMS has been implemented through maintenance planning, execution, monitoring, documentation, and coordination; however, its effectiveness remains influenced by overdue maintenance, limited maintenance windows, spare-part delays, hidden defects, additional work, and coordination issues. PMS supports docking efficiency and cost control primarily through early defect identification, reliable maintenance history, accurate repair lists, pre-docking readiness, and improved material and budget preparation. The study concludes that PMS should be developed from a scheduling and recording system into an integrated maintenance management system. It is recommended to strengthen overdue control, critical-equipment monitoring, spare-part planning, documentation, pre-docking assessment, cost integration, human-resource competence, and an integrated PMS dashboard.*

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**Keywords:** Planned Maintenance System (PMS), Docking Time Efficiency, Maintenance Cost Control, Ship Maintenance Management, Pre-Docking Readiness, Tugboat.

## **INTRODUCTION**

Marine transportation is a strategic component of logistics and trade, particularly for an archipelagic country such as Indonesia. Its sustainability depends heavily on fleet readiness and reliability, as ships are not only transportation facilities but also high-value operational assets requiring systematic management to ensure safe, efficient, and sustainable operations. One essential aspect is ship maintenance management, which maintains machinery, structures, and equipment in accordance with safety and seaworthiness requirements. Inadequate maintenance may increase the risk of equipment failure, breakdown, downtime, operational delays, and repair costs.

Ship maintenance management has increasingly shifted from corrective maintenance toward preventive and planned approaches. One important instrument is the Planned Maintenance System (PMS), which integrates the planning, scheduling, execution, recording, and evaluation of maintenance activities based on time intervals, equipment running hours, technical conditions, manufacturer recommendations, and classification and safety requirements. PMS implementation also involves human resources, spare-part availability, work control, documentation, ship–shore coordination, managerial decision-making, and operational cost control. Bicen and Celik (2023) demonstrate that PMS development based on reliability, availability, and maintainability can support more appropriate maintenance decisions at both operational and managerial levels.

The importance of PMS becomes more evident when a vessel enters the docking period. Docking involves inspection, maintenance, repairs, and other activities that cannot be fully performed while the vessel is operating. Longer docking periods increase downtime and opportunity loss, while previously unidentified defects may generate additional work, increase material and spare-part requirements, extend repair duration, and cause actual costs to exceed the planned budget. Therefore, PMS should play a strategic role in pre-docking preparation by enabling early identification of component conditions, spare-part planning, work prioritization, work list preparation, and more accurate budgeting.

However, the formal existence of PMS does not necessarily guarantee effective implementation. Challenges may arise from delayed maintenance activities, limited human resources, mismatches between maintenance schedules and vessel operations, spare-part procurement delays, weak coordination between ship crews and technical departments, inadequate documentation, and previously unidentified defects. These

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issues are particularly relevant to TB. Flores 1, operated by PT Bintang Samudera Mandiri Lines, because tugboats have high maneuvering frequency, dynamic engine loads, and intensive operations that may increase mechanical component stress. Consequently, consistent PMS implementation is essential for maintaining the vessel's technical readiness.

Previous research in this proposal initially employed a quantitative approach to examine the relationship between PMS, docking-time efficiency, and maintenance costs. However, such an approach is limited when the objective is to understand why and how PMS implementation produces particular conditions during docking. Quantitative indicators such as docking duration, actual costs, equipment failures, or PMS compliance can describe what happens, but may not fully explain the underlying causes, which can include spare-part availability, management decisions, vessel schedules, crew capabilities, ship–shore communication, and technical conditions.

Therefore, this study adopts a qualitative approach with an evaluative case-study design to gain an in-depth understanding of PMS implementation on TB. Flores 1. The study evaluates PMS implementation processes, identifies supporting and inhibiting factors, analyzes their implications for docking time and maintenance cost control, and formulates appropriate optimization strategies. Data are obtained through in-depth interviews, observation, and documentation of PMS records, maintenance history, work orders, docking reports, repair lists, spare-part procurement data, and maintenance-cost documents. This approach is expected to provide a comprehensive understanding of the relationship between technical, human, organizational, logistical, time, and cost aspects while producing applicable managerial recommendations for PT Bintang Samudera Mandiri Lines.

## **LITERATURE REVIEW**

### **Maritime Transportation Management**

The theory of maritime transportation management in this study is rooted in the concepts of Maritime Logistics Connectivity and Reliability and Fleet Operations Management. According to Stopford (2009), effective maritime transportation management is designed to optimize ship cargo-space utilization and minimize unit operating costs per mile by reducing downtime. To achieve such efficiency, fleet reliability is an essential prerequisite, strictly governed through the standardization of the International Safety Management Code (ISM Code), in which the Planned Maintenance System (PMS) serves as a crucial technical governance instrument (IMO, 2023). Maritime transportation performance is conceptually intertwined with the internal logistics capabilities of shipping companies. As explained by Harefa, Rudianto and Rumambi (2024), the operational performance of an entity is strongly influenced by the smooth

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functioning of its logistics system; in the maritime industry, this is reflected in the timely availability of spare parts and maintenance materials, which directly determines the successful execution of PMS. Disruptions in the maritime logistics supply chain can directly interfere with domestic shipping schedules and trigger systemic inefficiencies across the fleet (Nofrisel & Hardianto, 2023).

Furthermore, from the perspective of shipping economics, maritime transportation management is required to maintain a dynamic balance between fleet productivity and operational expenditures at shipyards (docking management). Asmara et al. (2022) emphasize that the efficiency of commercial maritime transportation, particularly for tugboats supporting national logistics mobility, is highly sensitive to docking duration. A structured pre-docking PMS theoretically serves to reduce critical repair activities during the docking period, thereby significantly minimizing deviations in docking duration and controlling increases in operational expenditure (Bicen & Celik, 2023; Ilhami, 2023). Therefore, the theory of maritime transportation management in this study positions PMS not merely as a technical machinery maintenance system, but as an empirical data-driven managerial strategy for maintaining the commercial seaworthiness of TB. Flores 1 and ensuring the sustainable continuity of the maritime supply chain.

### **Risk Management and Effectiveness Concepts**

The risk management and effectiveness concepts in this study position the Planned Maintenance System (PMS) as a preventive mechanism for identifying, assessing, and mitigating operational risks arising from human factors, internal processes, technical systems, and spare-parts supply chains. Hopkin and Thompson (2022) emphasizes that operational risk management aims to address risks before they develop into financial losses, while the PMS supports preventive maintenance of critical ship components (IMO, 2023). Effective spare-parts logistics is also essential because supply delays may increase operational risks and leave latent defects unaddressed (Harefa et al., 2024; Nofrisel & Hardianto, 2023).

From a financial perspective, inadequate technical risk management before docking may result in unexpected cost overruns and extended downtime. Dhillon (2002) emphasizes the importance of integrating reliability, maintainability, and maintenance management in controlling maintenance activities and associated costs. In this study, disciplined PMS implementation on TB. Flores 1 is therefore viewed as a mechanism for identifying technical conditions earlier, preparing maintenance requirements, and supporting more predictable docking duration and maintenance expenditure. Effectiveness is assessed not merely through procedural compliance but through actual outcomes, particularly fleet reliability, operational continuity, resource utilization, and maintenance performance (IMO, 2023; Mobley, 2021; Robbins & Judge, 2022).



Time efficiency refers to the ability to complete activities according to established schedules by effectively managing time, resources, coordination, and critical activities. Romadhani, Badi'ah, and Wicaksono (2025) highlight the importance of identifying critical activities in controlling completion time, while Jiang et al. (2023) demonstrate that maintenance planning and operational scheduling are closely interconnected. In this study, time efficiency is examined through the contribution of PMS to pre-docking readiness, early identification of maintenance requirements, repair-list preparation, spare-parts availability, and control of additional work that may cause deviations between planned and actual docking duration.

Cost control involves planning, monitoring, evaluating deviations, and implementing corrective actions to ensure that maintenance expenditures remain within established plans. Oh, Cho, and Lee (2023) demonstrate that a life-cycle cost approach can support maintenance decisions by considering asset performance, intervention timing, repair requirements, and projected costs, while (Jiang et al. (2023) emphasize the relationship between maintenance planning, operational efficiency, and total cost control. Accordingly, this study examines how PMS supports the planning of spare parts, labor, vendors, and docking activities while addressing potential cost deviations arising from hidden defects, additional work, emergency procurement, scope changes, and work delays.

### Conceptual Framework

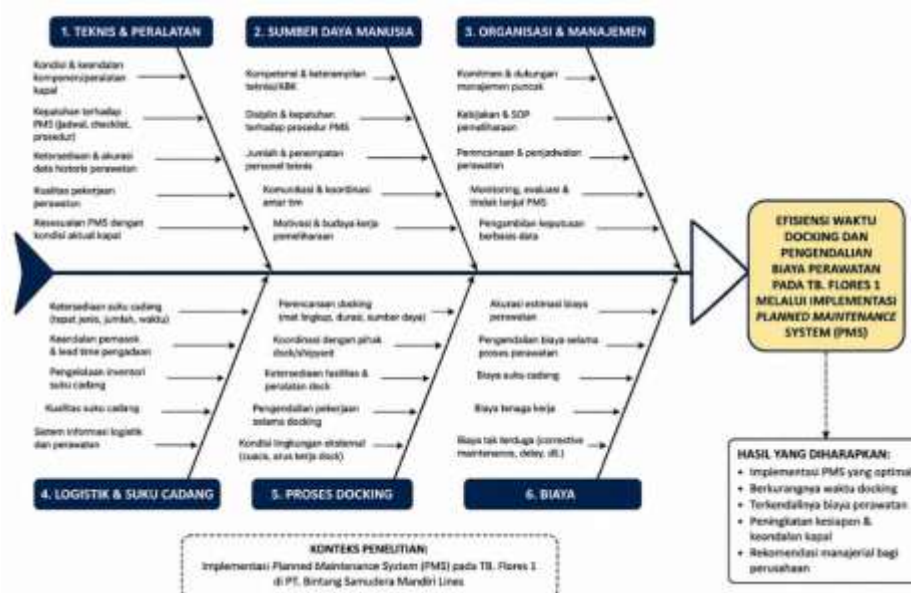


Figure Conceptual Framework

**RESEARCH METHODOLOGY**

This study employs a qualitative approach with an evaluative case study design to gain an in-depth and comprehensive understanding of the implementation of the Planned Maintenance System (PMS) on TB. Flores 1 at PT Bintang Samudera Mandiri Lines based on the experiences, perceptions, actions, actual conditions, and documentary evidence of directly involved personnel (Creswell & Poth, 2018; Yin, 2018). The study evaluates PMS planning and scheduling, maintenance implementation, monitoring and control mechanisms, supporting and inhibiting factors, and their implications for docking-time efficiency and maintenance-cost control. The findings are used to identify gaps between PMS planning and implementation and to formulate strategies for improving PMS effectiveness. Rather than applying statistical hypotheses or testing relationships between variables, the study interprets patterns, themes, informant perspectives, field conditions, and documentary evidence obtained through interviews, observation, and documentation to provide a comprehensive understanding of PMS implementation, its influencing factors, its implications for docking and maintenance costs, and appropriate optimization strategies for PT Bintang Samudera Mandiri Lines.

The data analysis method in this study employs interactive and thematic qualitative analysis, conducted continuously from data collection through conclusion drawing. The analysis begins with historical and contextual analysis of PMS implementation on TB. Flores 1, including maintenance history, PMS schedules, breakdown records, spare-parts procurement, docking activities, and maintenance costs, followed by data reduction, coding, and categorization of relevant information such as PMS overdue, crew workload, equipment failure, spare-part delay, procurement lead time, ship–shore coordination, additional work, docking delay, and cost overrun. Related codes are then grouped into broader themes covering technical and equipment conditions, human resources, organization and management, logistics and spare parts, docking processes, and cost control. The analysis further compares perspectives among informants according to their roles and experience and triangulates them with observations and documentary evidence, with findings presented through descriptive narratives, thematic matrices, comparative tables, interview quotations, and maintenance or docking timelines. Finally, conclusions are synthesized to describe PMS implementation, its implications for docking-time efficiency and maintenance-cost control, supporting and inhibiting factors, and optimization strategies, without statistically testing causal relationships but by interpreting how and why PMS implementation relates to docking efficiency and maintenance-cost control at PT Bintang Samudera Mandiri Lines.



## RESULT AND DISCUSSIONS

### A. Existing Conditions and PMS Implementation

#### *Existing PMS of TB. Flores 1*

Maintenance activities in the engine room are carried out by assigning responsibilities according to the equipment under each personnel member's responsibility. The engine crew inspects the condition of the equipment and records the activities performed. The observation also revealed communication between the Chief Engineer and engine personnel regarding upcoming maintenance tasks and equipment conditions requiring attention.

These findings indicate that, structurally, the PMS already incorporates elements of planning, implementation, recording, and control. However, the formal existence of the system does not automatically ensure that all maintenance activities can be completed according to schedule. The main issue arises during implementation, particularly when the maintenance schedule interacts with the vessel's operational

#### *PMS Planning and Scheduling*

Planning is an important stage because it determines when a component should be inspected, maintained, repaired, or replaced. Based on the interviews, PMS scheduling considers time intervals and equipment running hours. However, its implementation must also take into account the vessel's operational conditions.

The observation showed that some minor maintenance tasks can be performed when the vessel is operating under certain conditions, whereas tasks requiring engine shutdown, component disassembly, or relatively extended working time require specific scheduling.

Therefore, the issue in PMS implementation is not merely the existence of a maintenance schedule, but also the company's ability to establish a maintenance window that allows maintenance activities to be carried out without compromising operational requirements.

#### *PMS Implementation and Overdue Maintenance*

The interviews showed that not all PMS tasks can be completed according to the planned schedule. Some tasks require extended engine shutdowns while the vessel is operating, while others are delayed due to spare-part unavailability. Overdue maintenance may therefore result from several factors, including continuous vessel operations, material shortages, vendor requirements, or the need to stop the vessel. Thus, overdue maintenance should not be interpreted solely as crew negligence, as it may arise from operational, material, technical, vendor, and resource-related factors.



Field observations indicated that when maintenance cannot be performed as scheduled, engine personnel continue monitoring equipment conditions. However, prolonged delays may increase risks, particularly when the affected equipment is highly critical. The longer maintenance is postponed, the greater the potential risk, especially for critical components.

Therefore, overdue maintenance should be managed through a risk-based prioritization approach. Since not all overdue tasks have the same consequences, the classification of critical equipment is essential for effective PMS monitoring and control.

### ***Human Resources Factors***

Human resources are a key element in PMS implementation because vessel crew members are directly responsible for equipment inspection, maintenance, record-keeping, and early identification of changes in equipment conditions. During periods of intensive operations, available maintenance time becomes more limited. Routine tasks can generally continue, while maintenance activities requiring longer periods must be rescheduled. This indicates that human-resource issues involve not only competency but also workload and the availability of sufficient maintenance windows.

Observations showed that engine personnel understood their respective equipment responsibilities; however, potential overlaps may occur between routine operational duties, equipment monitoring, and maintenance activities requiring longer durations. Therefore, the Man factor in the study's fishbone analysis encompasses personnel competency, staffing levels, experience, documentation discipline, and workload, all of which can affect the effectiveness of PMS implementation.

### ***PMS Monitoring and Documentation***

Monitoring serves as the controlling function within PMS, requiring maintenance tasks that cannot be completed as scheduled to be accompanied by clear identification of the underlying causes, such as operational constraints, material shortages, manpower limitations, or technical considerations. PMS quality therefore should not be assessed merely by its ability to record completed or overdue tasks, but also by whether overdue maintenance is followed by a clear completion target and appropriate managerial action.

Maintenance history is also an essential component of PMS documentation because it provides information on previous maintenance activities, equipment conditions, replaced components, and recurring failure patterns. Such historical records can support more informed maintenance decisions and serve as an important basis for docking planning.

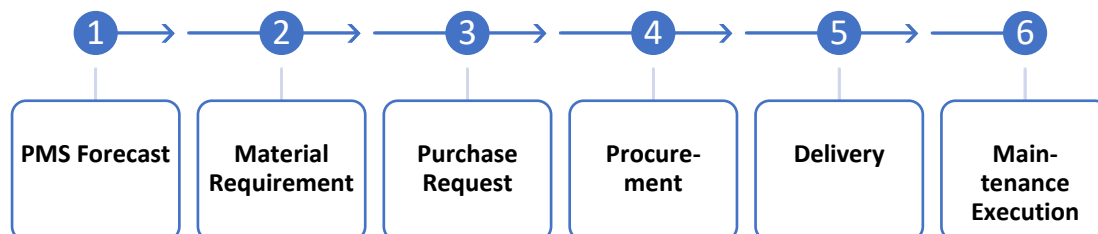


**Logistics and Spare Parts Support**

Logistics emerged as a consistent theme across the various perspectives. The availability of spare parts is a key prerequisite for completing maintenance activities, particularly those involving component replacement. Delays in material availability can therefore directly affect the completion of scheduled PMS tasks.

From the procurement perspective, providing PMS forecasts at an early stage allows more effective sourcing and procurement planning, whereas late requests close to the maintenance due date significantly reduce the available lead time. These findings indicate that PMS implementation cannot be separated from logistics and supply chain management, particularly in ensuring timely availability of spare parts and maintenance materials.

The identified relationships can be presented as illustrated in the following diagram:

**Triangulation of Research Data on Existing Conditions**

The findings indicate that PMS implementation on TB. Flores 1 constitutes a socio-technical and managerial system, rather than merely a machinery maintenance activity. Its implementation is influenced by planning, human resources, equipment condition, materials, operations, documentation, and control.

When analyzed through management functions, PMS reflects the planning function through maintenance scheduling, organizing through the division of responsibilities between the vessel and shore office, actuating through maintenance execution, and controlling through the monitoring of maintenance tasks, defects, and overdue activities.

The synthesis of Research Question I indicates that the success of PMS implementation on TB. Flores 1 is determined not only by the availability of maintenance schedules but, more importantly, by execution consistency, the ability to provide adequate maintenance windows, human-resource readiness, spare-parts availability, documentation quality, and the effectiveness of ship–shore monitoring.

## **B. PMS Implementation and Its Implications**

### ***PMS as a Basis for Docking Preparation***

The findings indicate that the relationship between PMS and docking primarily occurs through the availability of technical information before the vessel enters the shipyard. A well-documented PMS enables the company to identify maintenance history, defects, overdue tasks, and components requiring attention. Pre-docking inspections and discussions of maintenance requirements can therefore support the preparation of a more accurate repair list, making PMS an important information backbone for docking preparation.

Another important finding concerns the distinction between unavoidable additional work and potentially preventable additional work. Some hidden defects can only be identified after dismantling or detailed inspection and therefore do not necessarily indicate PMS failure. However, defects that have shown symptoms previously but were not followed up may indicate weaknesses in PMS implementation. Accordingly, the study categorizes additional work into (1) unavoidable additional work, arising from hidden defects that could not reasonably be detected beforehand, and (2) potentially preventable additional work, which could potentially have been identified through PMS, inspections, defect history, or condition monitoring.

### ***Implications for Docking Time Efficiency***

The interview findings illustrate how additional work can affect docking duration. Additional requirements for materials, machining, specialist services, or approval processes may alter the planned schedule and extend the docking period. Therefore, effective PMS does not necessarily eliminate all additional work, but rather reduces technical uncertainty before docking by improving maintenance planning and preparation.

This has direct implications for vessel availability, as prolonged docking means that the vessel remains unavailable for operations for a longer period. From a maritime transportation management perspective, the findings indicate that docking-time efficiency depends not only on shipyard performance but also on the vessel's level of maintenance readiness before entering the shipyard.

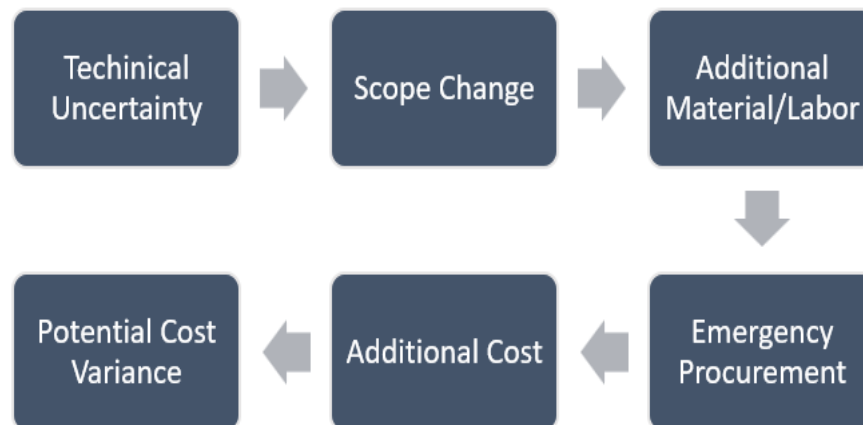
### ***Implications for Cost Control***

The same mechanism was identified in cost control, where the greater the number of requirements discovered only after work has begun, the more difficult it becomes to keep actual expenditures within the initial plan. In addition, emergency procurement tends to provide fewer vendor options and less time for negotiation. These findings indicate that



technical uncertainty can develop into financial uncertainty, potentially affecting the accuracy of maintenance cost planning and control.

The mechanism is as follows:



### ***Data Triangulation for Research Question II***

The findings indicate that the relationship between PMS implementation, docking time, and maintenance costs occurs primarily through pre-docking readiness. Consistent PMS implementation provides reliable maintenance history and technical-condition information, which support the preparation of an accurate repair list, identification of spare-parts requirements, budget allocation, and work planning. This process improves vessel readiness before docking and reduces uncertainty regarding the scope and requirements of work to be performed at the shipyard.

The study does not conclude that PMS has a statistically significant effect on docking time or maintenance costs. Instead, it identifies a qualitative mechanism in which effective PMS can support docking-time efficiency and cost control through early detection of equipment conditions, reliable maintenance records, accurate repair-list preparation, improved pre-docking readiness, and reduced uncertainty and potentially preventable additional work. Thus, the quality of PMS implementation provides a basis for better planning and control of docking activities and maintenance expenditures.

### **C. Supporting and Inhibiting Factors in PMS Implementation**

Based on the research findings, PMS implementation on TB. Flores 1 is supported by six interrelated dimensions: Man, Method, Machine, Material, Money, and Management/Operation. These include crew competence, experience and awareness; PMS scheduling, monitoring and reporting; equipment-condition data and critical-equipment identification; spare-parts readiness; maintenance and docking budgets; and management support and ship–shore coordination. These factors are interdependent, as

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competent personnel alone cannot ensure effective maintenance without available materials, while material availability without sound maintenance planning may lead to inefficient inventory management.

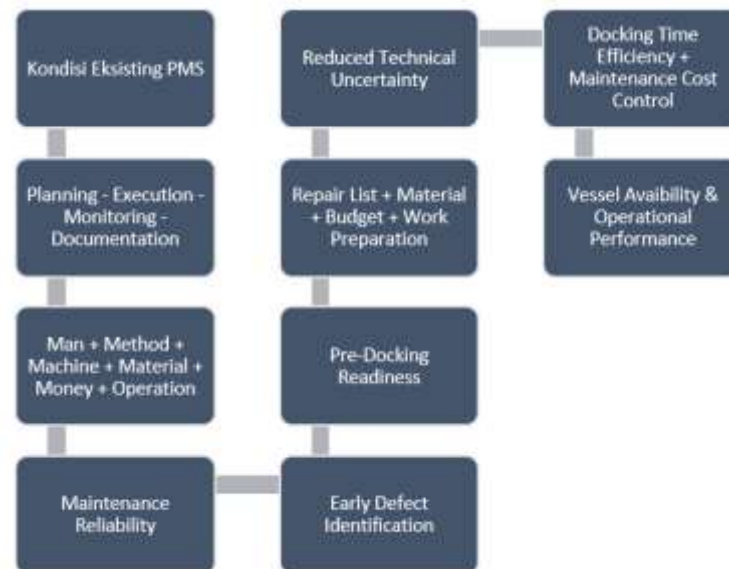
The analysis also indicates that PMS implementation is constrained by operational schedules, overdue maintenance, critical equipment, spare-part lead times, insufficient follow-up, hidden or additional work, and cost uncertainty. These findings demonstrate that maintenance performance cannot be attributed solely to shipboard personnel because PMS is a cross-functional process involving technical, human-resource, logistics, financial, operational, and managerial aspects. The gap analysis further identifies the need for adequate maintenance windows, risk-based critical-equipment control, forecasting, action tracking, pre-docking assessment, and integration between maintenance planning and cost control.

Based on these gaps, the study proposes several optimization strategies, including risk-based PMS monitoring, maintenance forecasting, integration of PMS with inventory and procurement, systematic use of maintenance history and defect records for pre-docking assessment, integration of PMS with budgeting and cost control, and gradual adoption of condition-based or predictive maintenance for critical components where technological and human-resource readiness permits. The implementation roadmap consists of quick wins (0–6 months) through overdue audits, critical-equipment mapping, minimum-stock reviews, and reporting standardization; medium-term actions (6–18 months) through maintenance forecasting, procurement integration, PMS dashboards, and competency development; and long-term actions (>18 months) through condition monitoring, predictive maintenance, and integration of PMS, procurement, finance, and docking.

Overall, the findings indicate that PMS optimization should extend beyond software improvements and address people, methods, equipment, logistics, financing, and operational governance. Therefore, PMS implementation on TB. Flores 1 should be positioned as an integral component of asset and fleet management, rather than being treated solely as an engine-department work program.



#### D. Research Synthesis



Based on this synthesis, four main conceptual findings emerge.

First, PMS is a cross-functional management system. Its success is not solely the responsibility of the Chief Engineer or engine crew, but depends on coordination among the vessel, technical department, procurement, finance, and shipyard.

Second, pre-docking readiness serves as the main mechanism linking PMS with time and cost efficiency. PMS does not directly “reduce docking days”; rather, it provides information and readiness that can reduce uncertainty regarding the required work.

Third, additional work should be distinguished between unavoidable work and work that could potentially be prevented. This distinction is important to ensure that PMS evaluation does not lead to overly simplistic conclusions.

Fourth, spare-parts logistics is an integral component of PMS effectiveness. A maintenance schedule has limited operational value if the required materials are unavailable when the maintenance work needs to be performed.

#### Proportion of Research Findings

The effectiveness of the Planned Maintenance System (PMS) on tugboats is achieved through the integration of maintenance planning, implementation discipline, human-resource competence, technical-condition monitoring, spare-parts readiness, ship–shore coordination, and management control. This integration enhances pre-docking readiness through improved identification of technical conditions and more effective planning of the repair list, materials, and budget, thereby reducing work-related uncertainty and supporting docking-time efficiency and maintenance-cost control.

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Accordingly, the final research model shifts from the paradigm of PMS as a Maintenance Schedule to PMS as an Integrated Maintenance Management System. PMS therefore serves as a link between technical reliability, human resources, logistics, docking planning, cost control, and operational management.

## **CONCLUSION**

The findings indicate that PMS on TB. Flores 1 has become an integral part of the vessel maintenance management system, covering maintenance planning and scheduling based on running hours and calendar periods, maintenance execution, monitoring, documentation, and ship–shore coordination. Although the system is structurally preventive and planned, its effectiveness is influenced by operational schedules, limited maintenance windows, crew workload, equipment condition, spare-parts availability, procurement lead time, vendor requirements, documentation quality, and ship–shore monitoring. Consequently, overdue maintenance should be understood as a multidimensional issue involving Man, Method, Machine, Material, Money, and Operation, rather than solely as a matter of crew discipline.

Regarding docking-time efficiency and cost control, the study finds that PMS contributes primarily through pre-docking readiness. Consistent PMS implementation generates reliable maintenance history, defect records, equipment-condition information, and records of outstanding work, which support pre-docking inspections, repair-list preparation, scope definition, spare-parts and specialist planning, and budgeting. Additional work is distinguished into unavoidable additional work, arising from hidden defects that cannot reasonably be detected before dismantling, and potentially preventable additional work, which could potentially be identified through PMS, maintenance history, defect monitoring, and pre-docking inspections.

Additional work involving materials, machining, specialists, scope changes, approvals, or new procurement may extend docking duration and affect vessel availability. Similarly, emergency procurement, scope changes, and unplanned work may increase cost uncertainty and deviations. However, the study does not establish a statistically significant effect of PMS on docking time or costs; rather, it identifies a qualitative mechanism whereby effective PMS supports early detection, reliable maintenance records, accurate repair-list preparation, material and budget readiness, and stronger pre-docking readiness, thereby reducing uncertainty and potentially preventable additional work.

The supporting and inhibiting factors demonstrate that PMS effectiveness depends on the interaction of human resources, methods, equipment, materials, finances, and operations. Accordingly, optimization requires stronger overdue maintenance control, critical-equipment mapping and prioritization, maintenance



forecasting, improved documentation and maintenance history, competency development, PMS integration with procurement and spare-parts inventory, use of PMS data in pre-docking assessment, and integration with docking planning and cost control. Overall, the findings support a transformation of PMS from a maintenance scheduling and recording system into an integrated maintenance management system connecting technical reliability, human resources, logistics, operations, procurement, docking planning, and cost control to strengthen vessel readiness, operational continuity, and vessel availability.

### **RECOMMENDATION**

Based on the research conclusions, the recommendations are directed toward improvements that can be implemented gradually by considering priorities, resource requirements, and the organizational readiness of PT Bintang Samudera Mandiri Lines:

1. Strengthening Overdue Maintenance and Critical Equipment Control
2. Synchronizing Operational Schedules with Maintenance Windows
3. Integrating PMS with Spare Part Planning and Procurement
4. Strengthening Documentation and Maintenance History
5. Strengthening Pre-Docking Assessment
6. Integrating PMS with Cost Control
7. Enhancing Human Resource Competence and Coordination
8. Developing an Integrated PMS Dashboard
9. Implementing the Recommended Strategies

In addition, the author provides recommendations for future research to expand the unit of analysis by involving several tugboats with different operational characteristics, thereby enabling comparative studies of PMS practices and docking management. Further research could also employ a mixed-methods approach to quantitatively examine the patterns identified in this study, for example, by comparing PMS compliance, overdue maintenance, breakdown frequency, additional work, docking time variance, and maintenance cost variance over specific periods. Furthermore, future studies could focus on the implementation of condition-based maintenance and predictive maintenance to assess technological readiness, human-resource capabilities, and their economic benefits in tugboat fleet management.

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