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Improvement of a Maintenance Management System to Enhance the Reliability Performance of Public Transport Ferries: A Case Study of TEMESA Magogoni Ferry in Tanzania

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The study tackles the urgent problem of maintenance management concerns on public transport vessels along with establishing a maintenance management system for the TEMESA Magogoni public ferries. These difficulties frequently lead to prolonged downtime, passenger ferry unavailability, schedule disruptions, and negative effect on passenger safety. Thus, the present study aims to develop an optimized system by evaluating key factors that influence maintenance practices, such as preventive maintenance, predictive maintenance, asset management, safety, adaptability, and communication between systems and devices. The study used a combination of experimental analysis and descriptive analysis to evaluate the effectiveness of the proposed system. The results suggest that predictive maintenance, preventive maintenance, and spare parts management are significantly affected by the lack of a computer-based maintenance management system. The relative importance of index values for predictive maintenance (0.89), preventive maintenance (0.87) and spare parts management (0.85) underlines their crucial role in ensuring the reliability and operational efficiency of the ferry. The implementation of the developed management system for ferry maintenance resulted in less downtime compared to traditional strategies. The computerized maintenance system significantly increased the reliability of ferry equipment, streamlined maintenance planning, and improved decision-making processes. The results of the study underscore the need to introduce technology-enabled ferry maintenance solutions to improve operational efficiency and passenger safety. The study advocated for further research to scale up the application of Artificial Intelligence (AI) in the system.

1. Introduction

Public transport ferries play a critical role in connecting communities, promoting trade, and enhancing mobility in coastal and riverine regions. The reliability and performance of these ferries are vital to ensuring the safety and satisfaction of passengers while supporting socio-economic development. However, operational challenges such as equipment failures, inefficiencies in maintenance practices, and inadequate resource allocation often compromise the reliability of public transport ferry services (Alhouli, 2017). Bye et al., (2021) reported that many ferry systems face challenges related to maintenance management, which directly impacts their reliability, safety, and overall performance. Poorly maintained ferries can lead to frequent breakdowns, delays, increased operational costs, and safety risks for passengers and crew.

The Magogoni Ferry, operated by the Tanzania Electrical, Mechanical, and Services Agency (TEMESA), is a prime example of a critical transport service that frequently experiences maintenance-related issues (Sogoye et al., 2024). The ferry provides essential connectivity between the Kigamboni and Kivukoni areas in Dar es Salaam, serving thousands of passengers and vehicles daily. Despite its significance, recurrent breakdowns and delays have led to reduced service reliability, passenger dissatisfaction, and increased operational costs (Sogoye et al., 2024). Current maintenance practices in many public transport ferry systems are often reactive rather than proactive, relying on ad-hoc repairs and addressing issues only after failures occur (Egbuonu et al., 2021). This approach can result in downtime, higher repair costs, and a shortened lifespan of critical assets. Additionally, inadequate maintenance planning and the lack of systematic tracking of asset conditions exacerbate the problem, leaving operators unable to anticipate potential failures effectively (Bye et al., 2021).

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Public transport ferries also are a critical component of urban mobility, especially in regions where waterways form a significant part of the transport network. The reliability of these ferries directly impacts the safety and efficiency of public transportation, affecting the thousands of commuters daily (Egbuonu et al., (2021). Considering their significance, many ferry systems struggle with operational reliability, which frequently results in delays in operation and higher maintenance expenses. According to the EN 13306:2001 standard, maintenance is a combination of all technical, administrative, and managerial actions during the life cycle of an item intended to retain it in or return it to a state so it can perform the required design function. The goal of maintenance is to maximize the performance of equipment by ensuring that it functions regularly and efficiently, trying to prevent breakdowns or failures, and minimizing the losses brought on by breakdowns or failures (Shagluf et al., 2014). When integrated maintenance management is implemented correctly, it may reduce purchasing by 25%, reduce emergencies by 75%, enhance preventative maintenance by 100%, and boost warehouse accuracy by 95% (Lee, 2015). On the other hand, if maintenance can reduce costs by up to 35%, this may be considered effective management (Azhar & Mansor, 2013).

The absence of a robust maintenance management system (MMS) also contributes to challenges in resource allocation, including spare parts, manpower, and budgeting (Sogoye et al., 2024). Moreover, insufficient integration of modern technologies, such as predictive maintenance tools and data analytics, limits the ability to optimize maintenance schedules and enhance reliability performance. Although predictive maintenance and condition-based monitoring are increasingly used in other industries, their implementation in public transport ferries might still be in its infancy. There could be a lack of research on leveraging IoT, AI, and machine learning to optimize maintenance scheduling and improve reliability in this domain. To address these challenges, a robust Maintenance Management System (MMS) is essential to enhance reliability and performance and ensure continuous delivery of service. Effective maintenance management involves implementing proactive strategies such as preventive maintenance, real-time monitoring of equipment performance, and efficient spare parts management. These strategies minimize downtime, reduce repair costs, and improve the overall reliability of the ferry system. This study focuses on improving the Maintenance Management System for TEMESA's Magogoni Ferry to enhance its reliability performance. A Computerized Maintenance Management System (CMMS) is employed to centralize maintenance information and coordinate all actions related to the complex system's productivity, maintainability, and availability. By analyzing existing maintenance practices, identifying critical gaps, and proposing solutions aligned with best practices in maintenance management, this research aims to provide actionable recommendations for improving ferry operations. The findings of this case study are expected to contribute to the broader discourse on enhancing public transport systems' reliability, particularly in maritime contexts.

2. Methodology

2.1 Descriptive Analysis

A descriptive research design was used in this study. Through this, the researcher better understood the qualities and features of the study variables and the link between them. The study was conducted at TEMESA Magogoni which is the main station in Tanzania and handles most of the country's passengers and cargo. Data was gathered through documentary reviews, field observations, and questions with ferry staff and TEMESA administrators. The purposive sample was used to select participants based on their expertise and involvement in the maritime management system. In light of this, the study selected 73 staff from the Ferry and 36 administrators in the main office of TEMESA Magogoni. The total numbers of respondents were 109 individuals. This population was provided with reliable and valid information concerning the subject of the study. The analysis was conducted using SPSS, focusing on the Relative Importance Index (RII) to identify key maintenance factors affecting the reliability performance of public ferries at TEMESA Magogoni. To present the results effectively, Table 1 is used to summarize the key factors influencing the maintenance management system's effectiveness. The identified factors were used as a key area to develop the system.

2.2 Experimental

JAVA Script tool was used to formulate a comprehensive management system. The physical information was gathered from different staff and interaction with administration gave directions to take and highlighted what modules to focus on to achieve the desired result. The research conducted enables to develop the efficiency and practical design system. The maintenance staff had a very difficult time keeping track of the user and maintenance support information when this procedure was done manually by entering them in specific maintenance support. Over time, this procedure has grown increasingly burdensome and complicated. Figure 1 shows the entire workflow of the proposed system while Table 2 presents the factors influencing maintenance management system effectiveness.

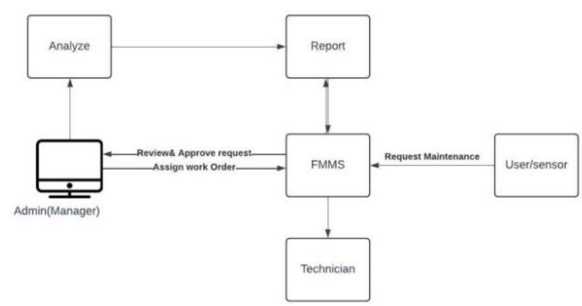

Figure 1. Work Order Flow Chart.

Table 1. Factors Influencing Maintenance Management System Effectiveness

Factor	Description	Impact on Reliability and Continuous Operations
Predictive Maintenance	Use of data-driven insights and condition monitoring to identify potential issues early	Reduces unexpected breakdowns and maintains continuous operations.
Preventive Maintenance Scheduling	Proper scheduling of maintenance activities to systematically address wear and tear	Ensures ferries are in optimal condition and reduces the risk of sudden breakdowns.
Availability of Spare Parts	Comprehensive inventory management system ensuring necessary parts are readily available.	Reduces downtime due to part shortages
Skilled Personnel	Continuous training and development programs for maintenance staff	Ensures timely and accurate execution of maintenance tasks
Efficient Communication	Clear communication channels within the maintenance team	Enables quick response to issues, ensures coordinated maintenance operations
System Updates and Adaptability	Regular updates to the maintenance management system based on technological advancements	Ensures the system evolves with changing needs and maintains long-term reliability.

3. Results and Discussion

3.1 Evaluation of the Factors that Influence the Maintenance Management System Effectiveness

The results indicate that several key factors influence the system's effectiveness. The analysis revealed several critical factors influencing the effectiveness of the maintenance management system at TEMESA Magogoni Ferry. Based on the findings of the surveys, six factors were found, analyzed, and compared to one another using the Relative Importance Index (RII). The elements were then grouped into five groups. Table 2 displays the data collection and analysis for each maintenance element taken into account. The RII was utilized to prioritize these factors, highlighting the most significant contributors to downtime and mechanical failures.

Table 2. RII of Maintenance Management Factors.

Rank	Factor	Relative Importance Index (RII)	Significance Level
1	Predictive Maintenance	0.89	High
2	Preventive Maintenance Scheduling	0.87	High
3	Availability of Spare Parts	0.85	High
4	Skilled Personnel	0.83	High
5	Efficient Communication	0.80	Medium
6	System Updates and Adaptability	0.78	Medium

Preventive and Predictive Maintenance

Preventive and predictive maintenance play a pivotal role in minimizing unplanned breakdowns and ensuring ferry availability. According to Mobley (2002), predictive maintenance techniques, such as condition monitoring and failure analysis, significantly reduce maintenance costs by identifying potential failures before they occur. Similarly, studies by Tsang (2002) and Alsyouf (2007) highlight that organizations implementing robust preventive maintenance programs experience lower operational costs and extended equipment lifespans. The findings of this study reinforce these claims, as predictive maintenance (RII = 0.89) and preventive maintenance (RII = 0.87) were identified as the most influential factors in ferry maintenance effectiveness.

Spare Part Management and Asset Reliability

Efficient spare part management is crucial for minimizing downtime and ensuring smooth ferry operations. Studies by Gopalakrishnan and Banerji (2013) emphasize that inadequate spare part inventory leads to extended repair times, directly affecting service reliability. In alignment with these findings, this study identified spare part management as a key determinant (RII = 0.85), indicating a strong correlation between spare part availability and reduced mechanical failures. Further, asset management strategies, as outlined by Amadi-Echendu et al. (2010), stress the need for integrated maintenance frameworks to enhance asset reliability, a notion that is supported by this study's results.

3.2 Development of Ferry Maintenance Management System

A maintenance management system for improving the public ferry vessel at TEMESA Magogoni was developed based on study findings and observation. The developed maintenance management system will allow users to insert and store the condition monitoring which will be used to detect performance changes. The system allows data from various users to be sent to the maintenance monitoring control unit, where all maintenance is coordinated based on the resource availability and priorities as expressed in Figure 2. In addition, as Figure 3 illustrates, it is advantageous to select the asset before any malfunction, breakdown, or deterioration that can affect the equipment's availability on the ferry vessels. The adoption of Computerized Maintenance Management Systems (CMMS) has been widely recognized as a transformative approach to improving maintenance efficiency. According to Wireman (2004), CMMS aids in data-driven decision-making, optimizing maintenance scheduling, and resource allocation. This study corroborates these benefits, as the implementation of a computerized maintenance system demonstrated improved equipment reliability and reduced downtime at TEMESA Magogoni Ferry. Additionally, research by Muchiri et al. (2011) suggests that CMMS enhances communication between systems and equipment, ensuring a seamless flow of maintenance data for better operational control.

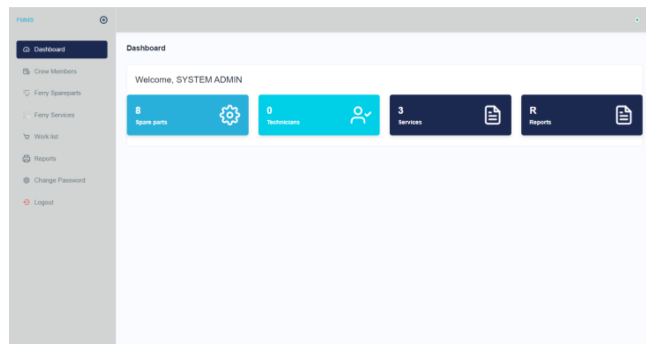

Figure 2. FMMS Dashboard.

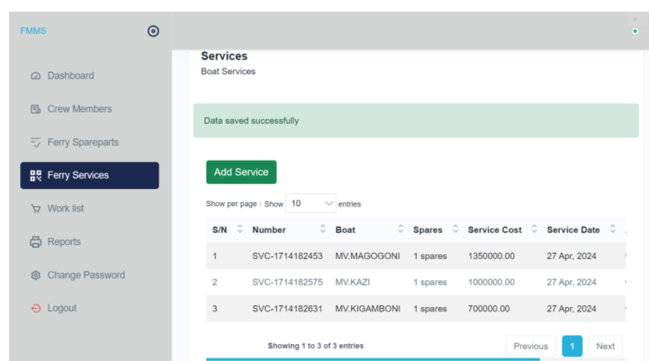

Figure 3. FMMS Maintenance Planning, Scheduling, and Breakdown Activities.

3.3 Comparative Analysis

Table 3 presents the key performance indicators (KPIs) used to measure the effectiveness of the maintenance management system before and after its implementation (Efficiency, 2024). The frequency of unexpected breakdowns was reduced by 66.67%, indicating significant improvement due to predictive maintenance. Preventive maintenance compliance increased by 50%, showing better adherence to maintenance schedules. The availability of spare parts improved by 35.71%, highlighting enhanced inventory management. Maintenance task accuracy improved by 26.67%, reflecting the benefits of skilled personnel and continuous training. Communication efficiency scored a 38.46% improvement, emphasizing the importance of clear communication channels within the maintenance team. The frequency of system updates increased by 300%, demonstrating the system's adaptability and continuous improvement. These KPIs collectively illustrate the substantial positive impact of the maintenance management system on ferry operations at TEMESA Magogoni.

Table 3. Key Performance Indicators (KPIs).

KPI	Baseline (Before Implementation)	Post-Implementation	Improvement (%)
Unexpected Breakdown Frequency	15 per month	5 per month	66.67%
Preventive Maintenance Compliance	60%	90%	50%
Spare Parts Availability	70%	95%	35.71%
Maintenance Task Accuracy	75%	95%	26.67%
Communication Efficiency Score	65/100	90/100	38.46%
System Update Frequency	Annually	Quarterly	300%

4. Conclusion

The findings indicate that the developed maintenance management system for the TEMESA Magogoni ferry has shown promising results in improving the availability performance of public transport ferries. This system integrates various components such as preventive maintenance scheduling, real-time monitoring, and efficient resource allocation. The implementation of HTML and JavaScript in the system ensures a user-friendly interface and robust functionality. The analysis revealed that the availability of skilled maintenance personnel, spare parts, and effective communication significantly impact ferry availability. By addressing these factors, the developed system can predict maintenance needs, schedule timely interventions, and reduce downtime. The use of regression analysis to model these factors provides a reliable basis for the system, ensuring that it can adapt to varying operational conditions and maintain optimal performance. Moreover, the system's design considers the unique challenges faced by the ferry operations at Magogoni, such as the harsh marine environment and the need for compliance with international regulations. This tailored approach ensures that the system not only meets current needs but also is scalable for future demands.

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