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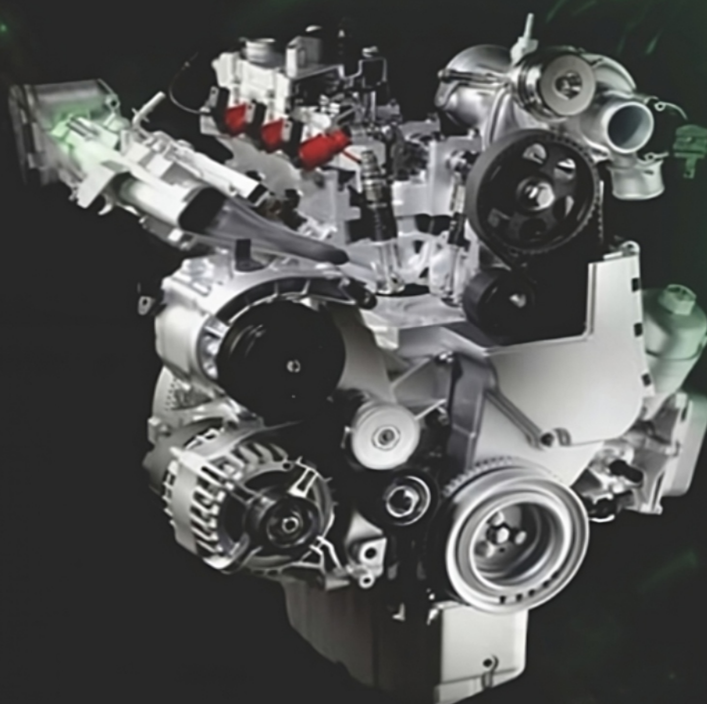

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DEVELOPMENT OF A MAINTENANCE MANAGEMENT SYSTEM TO IMPROVE THE AVAILABILITY PERFORMANCE OF THE HOISTING SYSTEM A CASE STUDY OF PSSSF MILLENNIUM TOWER II

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ABSTRACT

This dissertation examines the development of a maintenance management system for the hoisting system at Millennium Tower, a high-rise building currently operating with only one functional elevator out of six and two escalators. The rapid stopping of the elevator is caused by a lack of protection from fluctuations in power, which damages the operation card brake line system, which works in conjunction with the door sensor, magnet level, and magnetic switch. These factors led to the poor operation of the car lift, with the rapid breakdown of the equipment being the primary issue. The methodologies employed included a literature review and a questionnaire, as well as data analysis tools such as SPSS, Excel, and C++ programming, to develop a *maintenance management system. The study identifies the key factors affecting performance by analysing maintenance performance data, internal logs, maintenance history, and survey results supported by a literature review and questionnaire. The maintenance management model was formulated using data analysis tools, including Excel and SPSS, to enhance the system's availability and performance. Finally, the study builds upon the developed model of a comprehensive maintenance management system designed to enhance hoisting system performance. This new maintenance management system incorporates advanced predictive maintenance strategies, real-time monitoring, and data analytics to optimise maintenance schedules and enhance system reliability. The effectiveness of this system was tested through simulations and practical applications, revealing notable improvements in operational efficiency and reductions in downtime. Hence, a hoisting maintenance management system was recommended to improve the availability performance of the hoisting system.*

Keywords: Maintenance Management, Hoisting System, Elevator Performance, Predictive Maintenance, System Reliability, Data Analysis, Real-Time Monitoring, High-Rise Buildings.

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1. INTRODUCTION

Hoisting systems play a crucial role across various sectors of Tanzania's economy. One sector that uses the hoisting system is the Public Service Social Security Fund (PSSSF, 2022). The Public Service Social Security Fund owns various commercial buildings in Tanzania, including Millennium Tower Phase II and Twin Tower, Sam Nujoma Complex Building, and Garden Avenue Tower, among others.

Significant advancements have marked the evolution of hoisting technology, enhancing performance, reliability, and safety. Modern hoisting systems exhibit greater lifting capacities and operational flexibility, incorporating state-of-the-art safety features to mitigate potential hazards. Millennium Tower is a 29-story commercial building, including basements 1 and 2, located on the ground floor. Within the building, there are two escalators and seven elevators: five for passengers, one panorama elevator, and one elevator for carrying loads. This data has resulted in an availability performance of 22%, compared to the desired 95% availability.

Maintenance of the hoisting system is essential because it needs safety and longevity during operation. After all, the installation of this mechanical device is costly. Proper preventive maintenance will ensure the safety and longevity of the equipment. Frequent breakdowns after repair are a current characteristic of these lifting systems, and the following are the causes of these breakdowns. (Metatron, 2023).

The brake line system frequently fails to supply the power to the brake line system for proper adjustment during operation. The door sensor, limit switch, and magnetic level are always unsupported, along with the Alignment of guide rails, fluctuations in the power system, and failure of batteries to emergency landing devices. Additionally, the escalator of the PSSSF Millennium Tower has not been functioning smoothly for the past six years due to the high maintenance costs of the equipment. Therefore, the property manager has decided to close the escalator for operation.

Therefore, the challenges posed by proper maintenance management require a proactive approach prioritising preventive maintenance, regular inspections, and adherence to industry best practices. By investing in comprehensive maintenance programs and leveraging technology-enabled solutions, building owners and facility managers can mitigate risks, optimise the equipment's performance and lifespan, and ensure the safety and reliability of hoisting systems. It highlights the need for a maintenance management system to improve the availability performance of the hoisting systems.

The primary objective is to develop a maintenance management system that enhances the availability of hoisting systems at PSSSF Millennium Tower II. It will be achieved through three specific objectives:

i. Identify the factors causing the low availability of the hoisting systems.
ii. Develop maintenance management models to improve availability and performance.
iii. Develop a maintenance management system to improve availability.

Problem Statement

Commercial buildings require high availability and performance from their hoisting systems, ensuring the safety of customers who use the building and the system's longevity. The elevator and escalator operation at PSSSF Millennium Tower lacks a maintenance management system, resulting in decreased performance availability. The absence of real-time monitoring, standardised procedures, and proactive maintenance strategies hampers the reliability and longevity of the hoisting system.

Therefore, this study aimed to develop and implement a maintenance management system to improve the availability and performance of the hoisting system by improving operational efficiency, reducing downtime, and ensuring the safety and longevity of the equipment.

Literature

Hoisting system

A hoisting or lifting device is an electromechanical apparatus designed for safely lifting and lowering heavy loads in various directions. (Mushiri, 2006). An elevator, also known as a lift, is a vertical transportation device that moves people or goods between floors or levels within a building or structure. Elevators typically consist of a cab or platform guided along vertical rails or tracks within a shaft. Elevators are widely used in buildings with multiple floors to provide convenient access for occupants and to improve accessibility for individuals with mobility impairments. (Pintelon, 2008). An escalator is a moving staircase consisting of steps that continuously circulate on tracks, allowing people to move between different building levels without using stairs. (Papadopoulos, 2018). A panoramic elevator features glass walls that provide passengers with a wide, unobstructed view of the surrounding environment as they travel between floors. These elevators are often installed in buildings with scenic views or architectural features that occupants would enjoy seeing. Panoramic elevators are designed to enhance the overall experience of riding an elevator by providing passengers with a sense of openness and connection to their surroundings. (Wireman, 1986).

An elevator typically consists of the following main elements: **The car,** also known as the cabin or platform, is the enclosed space where passengers or goods are transported. It moves vertically within the elevator shaft (Anderson J, 2007). The counterweight is a balancing weight that helps to offset the weight of the car and its occupants, making the elevator system more energy-efficient. It moves in the opposite direction of the car and is connected to it by cables or ropes (Kim, 2018). The hoist mechanism raises and lowers the elevator car. It typically consists of an electric motor, a pulley or sheave system, and cles or ropes attached to the car and the counterweight (Xu, 2021). Guide rails are installed along the length of the elevator shaft to guide the movement of the elevator car and ensure its stability and safety (Martin, 2016). The control system comprises a stabiliser, drives, and an Emergency Landing Device. It controls door and elevator operation, including starting and stopping, directing the car's movement, opening and closing the doors, and ensuring safety features such as door operation and emergency stops (Keshtkar, 2017). Elevator doors provide access to the elevator car from the building's floors. They typically consist of two panels that slide open and close automatically when the elevator arrives at a floor (Anderson, 2007) The prime **mover** consists of a motor and speed governor, which are the prime mover of the car operation and are comprised of brakes to ensure the safety of the operation (Parmelee, 2008).

Maintenance of hoisting systems such as elevators and escalators is crucial to ensure their safe and efficient operation. Maintenance is retaining the equipment or machine in its original condition (Alhouli, 2011). In the hoisting system, the following are recommended items: Scheduled Inspections according to the manufacturer's manual, lubrication of parts as recommended to reduce friction and wear, and ensuring smooth operation to extend the lifespan of components. According to manufacturer guidelines, lasers are applied to bearings, gears, chains, and other mechanical components (Wireman, 2004). Regularly cleaning hoisting systems helps prevent the accumulation of dirt, dust, and debris, which can impede performance and cause malfunctions. Components such as tracks, rollers, guide rails, and sensors should be cleaned regularly to ensure optimal operation. Cleaning schedules should be established based on usage and environmental factors (Agoos, 2011). Proper adjustment and calibration of components are necessary to maintain optimal performance and safety. It includes adjusting the tension on belts, cables, and springs, as well as calibrating sensors, brakes, and control systems. Improper adjustments can lead to operational issues or safety hazards, so it's essential to follow manufacturer specifications and industry guidelines (Choka, 2012).

Hoisting systems have various safety features, including emergency brakes, alarms, and rescue systems. These features should be regularly tested to ensure they function correctly in emergencies. Training personnel should document and conduct testing procedures to comply with safety regulations and standards. Training programs should cover equipment operation, troubleshooting, maintenance procedures, and safety protocols. Ongoing training and professional development ensure that maintenance staff stay updated on industry advancements and best practices (Kumar, 2005).

Maintenance activities, including inspections, repairs, and testing, should be systematically documented and recorded. Maintenance logs should record dates, tasks performed, findings, and any corrective actions taken. These records are valuable for tracking equipment performance, identifying trends, and demonstrating compliance with regulations

(Higgins, 1988). In addition to preventive maintenance, facilities should have an emergency response plan to address unexpected breakdowns or incidents. This plan should outline procedures for evacuating passengers safely, contacting maintenance personnel or service providers, and restoring service as quickly as possible (Moubray, 1997).

Building owners and facility managers can ensure the high-performance availability of hoisting systems by implementing a comprehensive maintenance program that encompasses these practices. Therefore, this review helps streamline the work order process in maintenance management, where preventive maintenance is particularly important in the system.

On identification of the root cause of failures, the following approaches should be understood: corrective type of maintenance is mostly and currently used in Millennium Tower II due to the lack of a proper maintenance management system that implies removing/fixing errors or faults, which might cause malfunction or error in equipment during the operation (Choka, 2012). Maintenance is frequently outsourced because contracts are too expensive; it was discovered that certain equipment wasn't being used because it wasn't getting the appropriate maintenance and services (TEMESA, 2021).

Millennium Tower II Hoisting System Maintenance

Critical equipment must be documented for the maintenance process, including procedures and frequencies, in either vendor manuals or in-house procedures, which shall be readily available for each piece of equipment. In the literature, different authors categorised maintenance differently based on the system required to maintain an ongoing process. Some authors categorised maintenance by different strategies. (White, 1979), and others categorised maintenance according to the policies that required maintenance to be performed differently (Wireman, 1986) Each Section/Unit should carry out preventative maintenance procedures (such as daily basic equipment cleaning) for each equipment or machine unless otherwise specified elsewhere, such as in the equipment manual**.** These procedures must follow a regular, predetermined schedule (Deshmukh, 2006). The maintenance records should document preventive maintenance of any hoisting system.

Identification: Root cause analysis is a strategy that breaks down issues and failures into their underlying causes. Each piece of equipment can fail for various reasons. The root cause analysis method can be used to determine what is causing a problem or unexpected occurrences (Ben-daya, 2016). The following techniques are used for root cause analysis of equipment or system failures.

Defining, identifying, and removing known and/or potential issues, errors, and so forth from the System, design, process, and/or service before they affect the customer is achieved using the engineering technique known as Failure Mode and Effectsnalysis (FMEA) (AbdulRaouf, 2006). According to Dhillon (2019), FMEA was one of the most widely used methods to evaluate design at the initial stage from the availability aspect. The technique aids in identifying the requirements for the effect of design changes, as well as the identification of how a system may fail and the consequences of such failures. FMEA reports should include failure method indicators that can identify key points for condition monitoring. Control strategies for each failure mode can be developed based on the FMEA and may include preventive, predictive, or operator tasks. These tasks are combined and serve as the foundation of a maintenance strategy (Mobley, 1957).

Fault Tree Analysis (FTA)

One of the most useful approaches for determining the frequency of occurrence of events in probabilistic risk assessment research is the fault tree, which is a logical chart of events. FTA is a top-down methodology that begins with an event at the high system level and repeats it steadily downward until it reaches the occurrences at the detailed level on the equipment (Ben-daya, 2016).

Five Whys Analysis

The five whys root cause analysis method is frequently employed to investigate workplace safety and equipment failure. The five-why technique helps identify the cause-and-effect connections in a difficulty or failure event (Kenol, 2006).

Failure Mode Effect and Cause Analysis (FMECA)

FMECA is the most widely used reliability analysis technique in the initial stages of product or system development. FMECA is typically performed during the system's conceptual and initial design phases to ensure that all potential failure modes have been considered and the necessary provisions have been made to preventhese failures, as illustrated in Figure 2.1 (Zenithia, 2018).

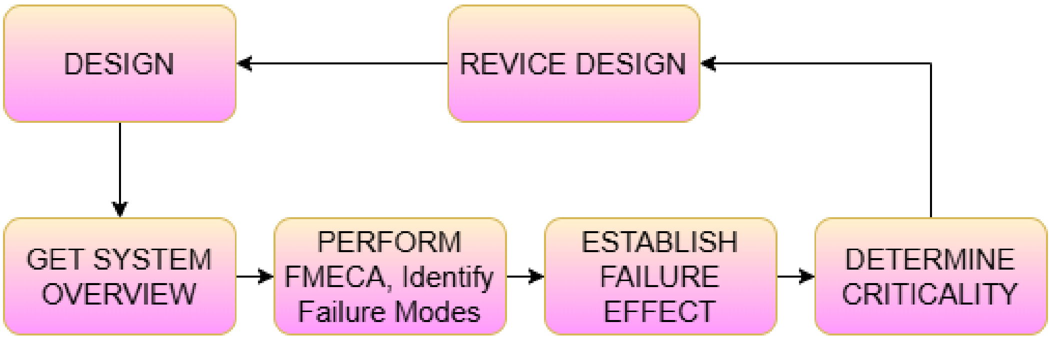

Figure 2.1 FMECA in Design (Source: Zenithia, 2018)

1.1.1 Fishbone Diagram

The Fishbone diagram (Ishikawa diagram) is a systematic analysis used to display all the possible causes of a chosen problem (ASQ, 2021). A fishbone diagram is a diagram that lists numerous potential sources for an effect or problem. It can be used to organise a brainstorming session. It categorises concepts right away into helpful groups. To categorise the probable sources of the issue and pinpoint its underlying reasons, utilise a cause-and-effect diagram, also known as an Ishikawa diagram. A fishbone diagram categorises causes into five categories: environment, people, methods, materials, and machines (ASQ, 2021).

Hence, reviewing Techniques for Root Causes of Failures during model formulation will help identify each factor, including the causes and effects, depending on the selected technique.

1.2. Maintenance Model

The input variables for the proposed conceptual model included spare parts, maintenance personnel, required maintenance tools, and the maintenance budget. In maintenance practices, the availability of spare parts reduces the Mean Time to Repair equipment when faults occur; its absence will affect MTTR and the hoisting System's reliability and overall effectiveness. Any maintenance work needs manpower to restore the faulty equipment. Since models are simplified representations of real systems, the development of a good model will lead to successful system development (Barringer, 1997). Equipment condition monitoring, inventory management, and root-cause analysis techniques were employed to optimise equipment utilisation. The output variable was reliability, and the process of the conceptual model was a maintenance management system based on preventive Maintenance, condition-based Maintenance and routine Maintenance (Scott, 2019).

Equipment condition monitoring is a process of continuously evaluating the health of the equipment. The primary purpose of equipment condition monitoring is to detect faults and abnormal indications in the respective equipment before a breakdown occurs. Equipment condition monitoring helps control the safety and economy of equipment operations. Through equipment condition monitoring, the parameters of the equipment's condition, such as temperature, input power, misbehaviour, and errors, were obtained (Onawoga, 2010).

1.2.1 Multiple Regression Model

Multiple regression is essential because it enables researchers to explore the relationships between one dependent and multiple independent variables. This technique facilitates understanding the strength and nature of these relationships, enables accurate predictions, and controls for potential confounding factors.

Cross-validation plays a critical role in model validation by assessing how well the results of a statistical analysis can be generalised to an independent dataset. It involves splitting the data into subsets, training the model on some subsets, and validating it on others. This process helps prevent overfitting, ensures the model performs well with unseen data and provides a more reliable estimate of the model's performance (Kothar, 2004).

1.3 Maintenance Management System

The fundamental approach of a maintenance management system can be viewed as a closed loop repeated in a continuous improvement program of maintenance and information procedures. This approach is based on the Plan-Do-Check-Act concept, as illustrated in Figure 2.3 (Van and Wassenhove, 1990).

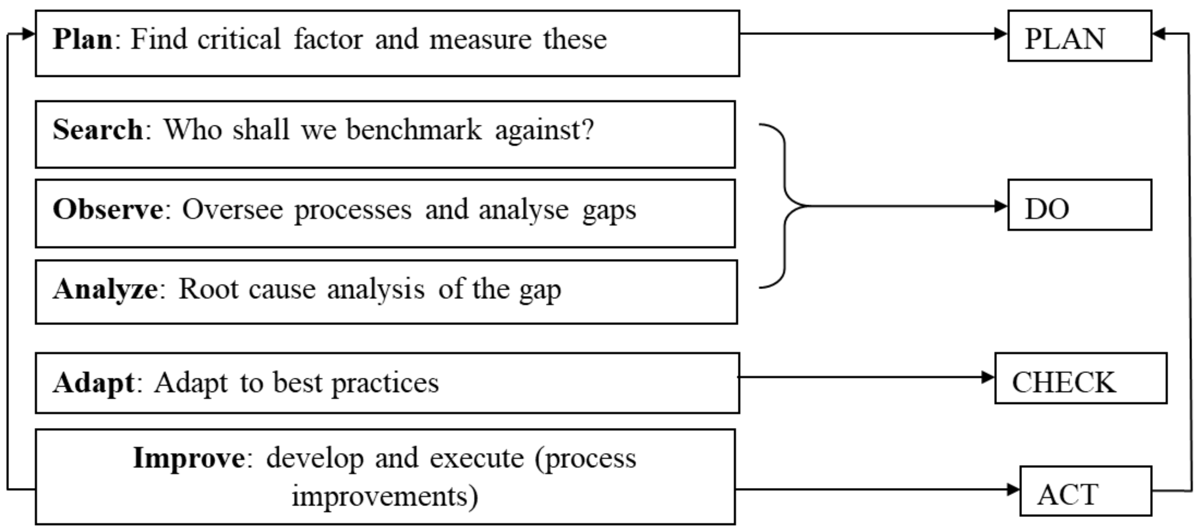

Figure 0.1 Maintenance management systems

Common Maintenance Management for Hoisting Systems

This document discusses maintenance management for hoisting systems, emphasising reliability. Here's a summary:

Maintenance Management: A systematic approach encompassing asset management, planning, scheduling, preventative and predictive maintenance, work order management, inventory control, budgeting, performance measurement (KPIS), and continuous improvement.

Reliability Factors: Hoisting system reliability depends on several factors (Evans, 2007; Zenithia, 2018; Rausand, 1998; Gronarz, 2014; Mobley,1957; Wireman, 2004; Alliance, 2022; and Kothar, 2004)

i. **Component Quality:** Durable, high-quality parts are less prone to failure.
ii. **Maintenance Practices:** Regular maintenance (inspections, lubrication, replacements) is crucial. Preventive maintenance catches issues early. Modernisation and upgrades improve reliability.
iii. **Emergency Preparedness:** Backup systems and protocols ensure operation during unforeseen events.
iv. **Manufacturing and Installation Quality:** Reputable manufacturers and qualified installers are essential.
v. **Usage and Load Management:** Prevent overloading and educate users on proper usage.
vi. **Monitoring and Diagnostics:** Real-time systems enable proactive maintenance and troubleshooting, allowing for swift and effective problem resolution. Predictive maintenance anticipates failures.
vii. The goal is to maximise uptime, minimise downtime and costs, and ensure safe and efficient operation.

Availability

Availability is the ratio of the time a system is operational to the total time it is supposed to be used. The availability of a system can be calculated using the following formula (Aibinu, 2002).:

$$Availability = \frac{MTBF + MTTR}{MTBF} x\ 100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2.2)$$

Where:

MTBF (Mean Time Between Failures) represents the average time between two consecutive system failures.

MTTR (Mean Time to Repair) is the average time required to repair and return a failed system to operational status.

This formula accounts for the time the system is operational (MTBF) and the time it takes to recover from failures (MTTR) (Elangovan, 2003).

Factors that Contribute to Low Availability Performance

Human Factor: Maintenance Staff Training on the elevator and escalator reduces the work, which may cause a rapid breakdown that will reduce the availability and performance of the equipment (Alhouli, 2011). **Spare parts,** difficulty sourcing spare parts, or long lead times for replacements can prolong elevator downtime, as most parts are shipped directly from the manufacturer. Maintaining an inventory of critical spare parts and establishing relationships with reliable suppliers can help minimise downtime due to parts unavailability (Sethia, 2016). **Maintenance planning and scheduling: Planning involves determining what maintenance tasks need to be performed, when they should be done, and how they should be executed**. It includes identifying maintenance requirements and understanding the maintenance needs of equipment or systems based on usage, age, manufacturer recommendations, and historical data (Stametis, 1947). Poor maintenance planning and scheduling result in a lack of regular maintenance, which is essential for elevators to ensure optimal performance and safety. Failure to perform routine inspections, lubrication, and component replacements can lead to increased downtime and decreased availability (White, 1979). **Technical factor:** Overloading elevators beyond their rated capacity can strain the system, leading to increased wear on components and potential breakdowns (Adam, 1992). **Environmental factor:** Elevator performance can be affected by environmental factors such as temperature extremes, humidity, and exposure to dust or debris (Alliance, 2022). Hence, the environment factor review helps to identify performance issues and errors.

Conceptual Framework

This figure shows the relationship between the variables in the study and the factors that affect the hoisting System's availability performance.

Figure **Error! No text of specified style in document.**.1 shows the conceptual framework of hoisting system maintenance management.

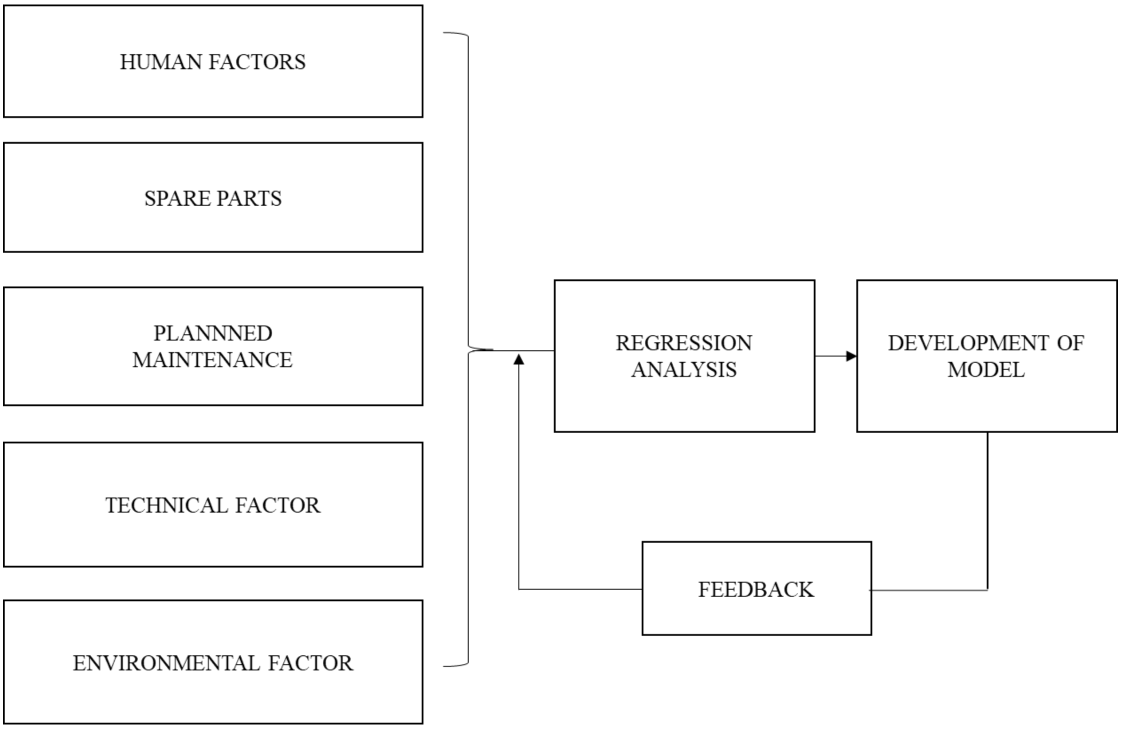

Figure **Error! No text of specified style in document.**.1: Conceptual Framework of maintenance management of the hoisting System

2. METHODOLOGY

A methodology matrix, a table outlining specific objectives, required data, methodologies, analysis tools, and expected outcomes, was used to guide the research methodology, ensuring a systematic approach to the research problem.

The survey involved 41 participants who provided valuable demographic information. The data revealed a diverse range of experience levels among the respondents. Specifically, 19.5% (8 respondents) had 1-3 years of experience, the majority (63.4%, 26 respondents) had 3-5 years of experience, and 17.1% (7 respondents) had 5-10 years of experience. It indicates that most participants had moderate expertise in their roles, suggesting a relatively experienced workforce with a solid understanding of the maintenance practices and challenges faced.

Failure modes and effects analysis (FMEA) was used to analyse the system and determine the effects of individual components on the entire assembly or system. First, the major assemblies of the system were listed, after which each assembly was broken down into its component elements. Each component was then studied to determine how it could fail, what factors could cause each type of failure, and the impact of this failure on other components, subassemblies, and the entire product.

Here is a summary of the main points from the methodology section of this dissertation:

The study aims to develop a maintenance management system to enhance availability and implement effective maintenance practices for hoisting devices at PSSSF Millennium Tower. Study Area Conducted at PSSSF Millennium Tower II, Dar es Salaam, Tanzania, featuring six elevators, two escalators, and one luggage elevator, serving a minimum of 200 users. The population of Study Respondents included engineers, technicians, supervisors, and operators associated with the tower. A sample size of 41 respondents was selected using stratified sampling, ensuring representation across different roles. Sample breakdown: Engineers 8, Technicians 20, Supervisors 5, Equipment Operators 8,

Data Collection Methods: Combined primary and secondary data through Interviews Conducted with engineers and technicians to gather relevant data. Field Observation: Observations of hoisting system operations. Documentary Reviews: Analysed various literature and reports. Questionnaires: Closed-ended questions were distributed through various methods to collect data on knowledge, beliefs, and practices. Data Analysis: - Utilised software tools like SPSS and Excel to analyse qualitative and quantitative data through descriptive statistical methods.

Model Development: Development of a multivariate regression model to assess the relationship between dependent and independent variables impacting hoisting system performance. Model validation was included through data splitting for training and testing. Maintenance Management System: Integrated the regression model into a Computerised Maintenance Management System (CMMS) for predictive maintenance scheduling, automating data processing and model updating.

3. FINDINGS

The analysis focuses on maintenance management practices that affect the availability of hoisting systems at PSSSF Millennium Tower II. It employs the Relative Importance Index (RII) and regression models to identify factors influencing performance.

Current Maintenance Management Practices

Run-to-Failure Maintenance: The current approach results in frequent breakdowns (20% system performance) and inadequate maintenance records. **Recommendations**: Focus on loss identification due to poor maintenance, Train operators in routine maintenance tasks, develop a planned maintenance system to improve availability, and implement a computerised maintenance management system (CMMS) to centralise and modernise maintenance tracking.

Relative Importance Index Results

Factors ranked by impact on performance:

Electrical System (RII = 0.985): Most critical; requires priority in maintenance, **Skilled Labor** (RII = 0.931): Essential for optimal operations, **Spare Parts** (RII = 0.926): Critical for timely repairs, **Maintenance Practice** (RII = 0.863): It is important to prevent breakdowns, **Operational Performance** (RII = 0.839): Influenced by other factors, **Mechanical Failure** (RII = 0.897): Significant disruptor; proactive maintenance needed, **Wear and Tear** (RII = 0.682): Manageable with maintenance, **Current Maintenance Procedure** (RII = 0.489): Lesser impact and **Team Communication** (RII = 0.439) and **Quality of Spare Parts** (RII = 0.400): Minimal impact.

Regression Analysis and Model Validation

Here's a concise breakdown of the provided regression analysis results related to availability performance:

Regression Coefficients: Constant (β=0.195)**: This is the model's intercept. It indicates the predicted availability value (0.195) when all independent variables are zero.** Operation Performance (β1 = 0.027): For each unit's operational performance, availability increases by 0.027 units**. It suggests a modest positive impact on availability from improvements in operational performance.** Availability of Spare Parts (β2 = 0.167): Each unit's increase in spare parts results in **a 0.167 increase in availability. It indicates a significant positive impact, more substantial than that from operational performance.** Electrical system (β3=0.242)**: The most influential factor with the highest coefficient. Each improvement in the electrical system results in a notable increase in availability.** Mechanical failure (β4 = -0.195): This negative coefficient indicate**s that mechanical failures decrease availability by 0.195 for each unit increase. Reducing these failures will be critical for enhancing overall performance.** Maintenance Practices (β5 = 0.162)**: Maintenance practices positively contribute to availability, with a 0.162 increase for each improvement, indicating a moderately strong effect.** Skilled labour (β6=0.207)**: A significant factor where each increase in the availability and quality of skilled labour enhances operational outcomes by 0.207. It underscores its critical role just after electrical system improvements.**

Overall Insights:

The model emphasises that enhancing the **electrical system** and investing in a **well-trained, skilled labour force** can significantly improve availability. Additionally, minimising **mechanical failures** is essential to prevent negative impacts on performance.

4. MODEL VALIDATION OVERVIEW

Model Fit: **R^2 Value** = 0.872, Adjusted R^2 Value = 0.850. Interpretation: These high values indicate that the regression model explains a significant portion (approximately 87.2% and 85%) of the variability in availability performance. A low standard error and a high F-statistic further validate the model's effectiveness.

Significance of Predictors: **Strong positive predictors include the Electrical System and Skilled Labour, which** are identified as having the most substantial positive impact on availability performance. **Negative Predictor**: **Mechanical Failure** is the only significant negative predictor, suggesting that higher mechanical failures detract from availability. **Other contributing factors, including operational performance, spare parts availability, and maintenance practices, also positively influence availability, albeit with varying effects that are less significant than those of** the top predictors.

No Multicollinearity: **Variance Inflation Factor (VIF)** Values: All are below 3.5. **Interpretation**: This suggests that there is no serious multicollinearity among the predictors, meaning that each independent variable contributes uniquely to the model without excessive overlap.

This regression model is statistically sound and reliable, providing valuable insights into predicting the availability performance of hoisting systems based on key factors. Enhancing the electrical system and improving the quality of skilled labour while reducing mechanical failures will improve availability and performance.

Key Features of CMMS:

Specialised Features: **Work Order Management**: Efficient handling of maintenance requests and tasks. **Preventive Maintenance Scheduling**: Automated scheduling helps ensure regular upkeep. **Inventory Control**: Manages spare parts and materials necessary for maintenance. **User Experience**: **A user-friendly interface is essential** for ease of use across different user levels. **Mobile Access**: Provides flexibility for technicians working in the field.

Critical Notifications: **Scheduled Maintenance Reminders**: Alerts for upcoming maintenance tasks to prevent downtime. I**mmediate Fault Detection Alerts**: Quick notifications when equipment issues arise, ensuring timely responses. **Access Options**: Balanced access options, including desktop, mobile, and web-based platforms, enhance operational flexibility. **Data Analytics**: Emphasising performance trend analysis and predictive maintenance forecasts enhance decision-making and reliability of hoisting systems.

Challenges and Implementation: Addressing Challenges: Anticipated obstacles, such as resistance to change and integration complexities, must be managed effectively to ensure a smooth transition to the new system. **Goal**: Implementing an advanced MMS aims to improve operational efficiency and reliability in industrial settings by leveraging the benefits of CMMS. **Conclusion:** The findings underscore the importance of adopting a CMMS tailored for hoisting systems, focusing on its ability to optimise maintenance practices and enhance overall system reliability through technological advancements and user-centred design.

5. CONCLUSION

A concise summary of the conclusions drawn from the study regarding the availability performance of hoisting systems at PSSSF Millennium Tower II:

Key Issues Identified: **Mechanical Failures and Electrical Problems**. These were identified as primary contributors to low-performance availability, indicating a need for proactive maintenance strategies. **Operational Errors**: Highlight the need for enhanced training and structured protocols to prevent errors. **Challenges in Spare Parts Availability**: Point to the importance of improved inventory management and organised maintenance schedules. **Training and Communication Gaps**: Emphasise the necessity for better training programs and communication channels to enhance reliability and efficiency.

Development of Maintenance Management Models: The regression analysis and model validation provided insights into factors affecting the availability performance, such as **Skilled Labour, Mechanical and Electrical Failures, Spare Parts Availability, Operational Performance, Maintenance Schedules, and High-Quality Spare Parts,** identified as a crucial predictor for minimising breakdowns. Addressing mechanical failures and operational errors is vital for improving overall performance. The ANOVA analysis supports the model's robustness, confirming reliability for forecasting and guiding proactive maintenance strategies.

Maintenance Management System (MMS) Development: A strong preference (80.5%) for a **Computerised Maintenance Management System (CMMS)** was observed among survey respondents. **Essential Features**: User-friendly interfaces, Automated scheduling, Mobile access, and Critical alerts for timely responses. **Data Analytics**: Emphasised for analysing performance trends and enabling predictive maintenance for better decision-making.

Implementation Challenges: Addressing resistance to change and integration issues will be essential for successful system deployment.

The study synthesises findings to guide stakeholders in adopting proactive strategies focused on optimising the efficiency and reliability of hoisting system operations. The report concludes that by recognising and addressing the identified factors affecting low performance and implementing tailored maintenance management systems, stakeholders can enhance the availability and operational efficiency of hoisting systems at PSSSF Millennium Tower II.

Recommendations

Proactive Maintenance: Transitioning from Reactive to Proactive Maintenance Strategies. Implement regular inspections, preventive maintenance, and predictive techniques utilising data analytics to reduce failures and enhance performance. **Spare Parts Management**: Optimise inventory management to ensure the availability of high-quality spare parts. Implement efficient procurement processes and closely monitor stock levels to minimise downtime caused by the unavailability of components. **Maintenance Scheduling**: Develop structured maintenance schedules aligned with equipment usage patterns. Automate these schedules through the Maintenance Management System (MMS) for improved operational efficiency. **Training and Development**: Enhance training programs to focus on technical skills, safety protocols, and troubleshooting techniques, thereby improving the capabilities and responsiveness of the maintenance team. **Implement CMMS**: Adopt a robust Computerised Maintenance Management System (CMMS) that includes mobile access, automated scheduling, and comprehensive reporting to streamline maintenance processes. **Data Analytics Integration**: Leverage data analytics for trend analysis, predictive forecasting, and informed decision-making. It will help optimise maintenance practices and resource allocation effectively. **Improve Communication**: Strengthen communication and collaboration within the maintenance team through regular meetings, clear communication channels, and MMS-supported coordination tools to enhance teamwork and overall effectiveness. **Address Integration Challenges**: Facilitate seamless integration of the MMS with existing systems by conducting compatibility tests, planning data migration strategies, and providing adequate user training to ensure smooth operations. **Monitor Performance**: Establish key performance indicators (KPIs) for tracking the effectiveness of maintenance and the overall performance of hoisting systems. It will enable ongoing assessments and drive continuous improvements. **Continuous Improvement Culture**: Foster a culture of continuous improvement by encouraging innovation, soliciting feedback from team members, and regularly updating maintenance strategies to align with new standards and technologies.

Implementing these recommendations will significantly enhance system reliability, operational efficiency, and workplace safety while reducing downtime. By prioritising proactive maintenance and leveraging advanced tools, PSSSF Millennium Tower II can achieve sustainable improvements in the performance and reliability of its hoisting systems.

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