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DEVELOPMENT OF MAINTENANCE MANAGEMENT SYSTEM FOR IMPROVING BERTH PAVEMENT AVAILABILITY PERFORMANCE

The Case Study of Dares Salaam Port

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Abstract : Dar es Salaam port is Tanzania's principal port, and the availability performance of berth pavement is a challenge. The Dar es Salaam port berth pavement faces high downtime because of frequent failures and longtime repair which reduces the availability performance in the port. Therefore, this research is set out to develop a maintenance management system to improve the berth pavement availability. To achieve this goal, necessary information and data have been collected through a literature review, observation, and questionnaire survey. Data were analyzed by using a computer program: Social Science Statistics Package (SPSS) version 26, which applies multiple regression models and uses average values to classify the identified factors that influence current maintenance management practices. The results of the study identified the factors influencing the current maintenance strategy in the port of Dar es Salaam. The study identified four factors and their relative importance index, including insufficient fund (0.83), lack of pavement rehabilitation and preservation (0.79), insufficient drainage system (0.78) and inadequate pavement design (0.77). According to these factors, the availability performance has increased from the current 39% to 98.6%. Changes in the availability performance of berth pavement are explained by independent variables, and an effective berth pavement maintenance management system was developed. From the findings way to improve the effectiveness of the current maintenance management strategy, it is recommended to apply the developed availability performance and effective maintenance management system to the Port of Dar es Salaam.

Keywords: Maintenance management, Dar es salaam port authority, Availability performance.

1.0 Introduction

Dar es Salaam port is Tanzania's principal port, with a rated capacity of 14.1 million dry cargo and 6.0 million bulk liquid cargo. The Port has a total quay length of about 2,600 meters with eleven deep-water berths. Dar es Salaam port handles about 95% of the Tanzania's international trade. The port serves the landlocked countries of Zambia, Democratic Republic of Congo, Burundi, Rwanda, Malawi, Uganda and Zimbabwe. The port is strategically placed to serve as a convenient freight linkage not only to and from East and Central Africa countries but also to middle and Far East, Europe, Australia and America.

1.1 Statement of the Problem

Dar es Salaam port serves as an economic gateway and has a significant economic development impact to the government of Tanzania and its citizen. Berth pavement located at Dar es Salaam port is important for operation loading and off loading cargo. The lack of an effective maintenance management system is hindering the berth pavement availability performance, resulting in reduced operational efficiency, increase downtime and reduce revenues to the organization. A comprehensive solution is required to develop a maintenance management system that can optimize the maintenance activities, enhance the condition assessment and improve the overall reliability and availability of berth pavement.

1.2 Objectives

1.2.1 Main objective of the study

The main objective of this study is to develop a maintenance management system for improving berth pavement availability performance.

1.2.2 Specific Objectives

i. To identify factors that cause poor maintenance management practices for berth pavement at Dar es Salaam port.
ii. To assess current maintenance management practices for berth pavement at Dar es Salaam port.
iii. To develop maintenance management model for improving berth pavement availability performance at Dar es Salaam port.
iv. To develop maintenance management system for berth pavement at Dar es Salaam port.

2.0 Literature Review

2.1 Introduction

The current study literature research focuses on the development of maintenance management system for improving berth pavement at Dar es salaam port. Through four specific objectives. The literature focuses on the definition of important maintenance terminology and the factors that causes poor maintenance management practices finally, it examines the construction of a concept and methodology. The sources of literature include books, journals, articles and websites through internet.

Definitions of Key Terms

2.2 Port

Port is a maritime commercial facility which may comprise one or more wharves where ships may dock to load and discharge passengers and cargo. The port can be a natural establishment or an artificial construction, which provides a place for the loading and offloading of cargo (Brodie, 2013). Successful ports are located to optimize access to an active hinterland, such as the London Gateway. Ideally, a port will grant easy navigation to ships, and will give shelter from wind and waves (Notteboom, 2010). Brodie (2013) explains that, the ports usually have specialized functions: some tend to
cater mainly for passenger ferries and cruise ships; some specialize in container traffic or general cargo and; some play an important military role for their nation's navy.

2.3 Berth

Berth is a structure built alongside the water or perpendicular to the shore where ships berth for loading or discharging goods (Brodie, 2013). Thoresen (2003) expressed his opinion that wharf is where the transfer of containers from ship to shore and from shore to ship occurs and commonly comprises a fixed platform, often on pilling. Commercial ports may have warehouses that serve as interim storage areas, since the typical objective is to unload and reload vessels as quickly as possible. Where capacity is sufficient with a single berth constructed along the land adjacent to the water is normally used.

2.4 Maintenance

Venkataraman (2016) defines maintenance as all actions which have an objective to retain an item in, or restore it to a state in which it can perform the required function. The actions include the combination of all technical and corresponding administrative, managerial and supervision actions. In general, the term maintenance has the following meanings:

a) Maintenance relating to material means all actions taken to retain material in a serviceable condition or to restore it to serviceability. It includes inspection, testing, servicing, and classification as to serviceability, repair, rebuilding and reclamation.
b) The routine recurring work required to keep a facility (plant, building, structure, ground facility, utility system, or other real property) in such condition that it may be continuously used at its original or designed capacity and efficiency for its intended purpose.

Maintenance is any activity carried out on an asset in order to ensure that the asset continues to perform its intended function or to repair the equipment (CEN, 2001). “Retention” and “restoration” are denominations for action types that are then converted into “preventive” and “corrective” maintenance types in the maintenance vocabulary. Following this criterion, the European standard for maintenance terminology

(European, 2001)

2.4.1 Preventive Maintenance

According to European (2001), Preventive maintenance is defined as maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of the equipment. Preventive maintenance can be predetermined or condition based as follows:

Predetermined maintenance: Preventive Maintenance carried out in accordance with established intervals of time or number of units of use (i.e. scheduled maintenance) but without previous item condition investigation;

Condition based maintenance: Preventive Maintenance based on performance and/or parameter monitoring and the subsequent actions. Performance and parameter monitoring may be scheduled, on-request or continuous. Within the condition based maintenance, we include the predictive maintenance, that can be defined as the maintenance that directly monitors the condition and performance of equipment during normal operation to reduce the likelihood of failures

Condition based maintenance carried out following a forecast derived from the analysis and evaluation of the significant parameters of the degradation of the equipment (European, 2001).

2.4.2 Corrective Maintenance

Corrective Maintenance is maintenance carried out after fault recognition and intended to put the equipment into a state in which it can perform a required function (European, 2001). Corrective Maintenance can be immediate or deferred.

Immediate Maintenance is carried out without delay after a fault has been detected to avoid unacceptable consequences;

Deferred Maintenance is corrective Maintenance which is not immediately carried out after fault detection, but is delayed according to given maintenance rules.

2.5 Maintenance System

Maintenance systems are responsible for keeping equipment fit, safe to operate, and well configured to perform the specified task, then maintenance has a large effect on delivery quality and cost, this provides long-term profitability of an organization in both public and private sectors.

Maintenance systems are the results obtained from the evaluation process that help the organization to determine whether its information system is effective and efficient or otherwise. The process of monitoring, evaluating, modifying existing information systems, to make required or desirable improvements. A maintenance system is an ongoing activity, which covers a wide variety of activities, including removing program and design errors, updating documentation and test data, and updating user support. This process requires planning, scheduling, control, and the deployment of maintenance activities (Kusek and Rist, 2004).

2.6 Maintenance Management

Maintenance Management refers to the application of the appropriate planning organization and staffing, program implementation, and control methods to maintenance activity. This may pertain to the management of a maintenance organization in the commercial factory, or the management of sustaining maintenance and support activity responsible to ensure that the system is utilized by the consumer is effectively and efficiently maintained throughout its programmed life cycle (Blanchard et al., 1995).

In another way, maintenance management is a process of managing all assets owned by a company based on maximizing the return on investment in the asset. All activities of maintenance that are assigned and accepted by the management and maintenance department will characterize the process of leading and directing the maintenance organization. To maximize the availability of any machine, replacement and repairing of some components and different devices should be done so as the functionality of the machine to be maintained.

3.0 Methodology

Table 1 : Summary of Methodology

S/N	SPECIFIC OBJECTIVES	DATA REQUIRED	DATA COLLECTION METHOD	DATA ANALYSIS METHOD	OUTPUT
01	To identify factors that cause poor maintenance management practice.	Factors causing poor maintenance management practice	Literature review, Personal interviews, Questionnaires, Observations	Data using Statistical Package for Social Science (SPSSVersion. 26), excel and (RII) relative importance index	Identified factors causing poor maintenance management performance.
02	To assess current maintenance management practices.	Review various reports on maintenance work, Historical data (down time and uptime) and Interview with experts in maintenance	Literature review, Personal interviews, Questionnaires, Observations	Data using Statistical Package for Social Science (SPSSVersion. 26), excel and (RII) relative importance index	Current maintenance management practice
03	To develop maintenance management model for improving berth pavement availability performance.	Literature review, Using the specific objective No1and 2 in the development of model	Variables obtained from specific objectives No.1 and 02	SPSS software using linear regression methodology to show correlation of inputs and outputs variables	Mathematical model for improving berth pavement availability performance at Dar es Salaam port
04	To develop maintenance management system.	Input and output parameters/ from objective no.1,2 and 3	Data obtained from analysis of specific objective 1,2 and 3	Mathematical model, Statistical Package for Social Science (SPSSVersion. 26) and Ms excel	Maintenance management system for improving berth pavement availability performance

3.1 Adopted Methodology

The study employed primary as well as secondary data; the primary data were gathered directly from on-site observations, and from respondents through questionnaires. The secondary data were project reports from Berth pavement maintenance historical data and other related literature works.

3.2 Data collection tools

The purpose of these tools was to obtained information from primary source, directly from the respondents. Three tools were used during data collection. These were archival research, visual observation and questionnaire.

a. Archival research

Existing relevant documents of Project reports were identified and reviewed. These included secondary information from various publications such as journals, official documents, books and internet. Additionally review of published and unpublished researches.

b. Visual Observation

An examination of the real situation was carried out based on the specific objectives.

c. Questionnaire

Questionnaires were distributed to the people responsible for carrying out maintenance, the questionnaires covered technical questions that gave out answers to most of the research questions.

3.3 Data analysis method

Data were analyzed in the following.

a. Data coding

This is the changing of original data into a shortened version by assigning codes. Therefore, opinions from the questionnaires were systematically condensed into smaller analyzable units consistent with the assignment.

b. Approach for analysis of data.

Every response and its frequency were analyzed in terms of percentage and figures by entering data in SPSS analysis package. The use of tables was incorporated for the purpose of data interpretation.

c. Mean score Ranking Technique/Kendall's Concordance Analysis

The data were analyzed using mean score ranking technique to identify the boundary of different levels of factors. Further, investigation was done using the Kendall's concordance analysis that helped to measure the agreement of different respondents on their ranking of factors. In the Mean Score Ranking technique (MSR), five point Likert scale (1- strongly disagree, 2 - neutral, 3 - disagree, 4 - agree and 5 - strongly agree) were used. The MSR for each factor was computed by equation below

$$MSR = \frac{\sum(f \times s)}{N},\ (1 \le MSR \le 5)$$

Where:

s = score given to each defect by respondents, ranging from 1 to 5.

f = frequency of each rating (1-5) for each defect

N= total number of respondents,

d. Relative Important Index

The contribution of each of the factors was examined and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by the use of Relative Importance Index (RII) which was computed using equation below

$$RII = \frac{\sum W}{AN},\ (0 \le \mathrm{RII} \le 1)$$

Where:

W – is the weight given to each factor by the respondents and ranges from 1 to 5 , (where "1" is "strongly disagree" and "5" is "strongly agree");

A –The highest weight (i.e. 5 in this case) and;

N – The total number of respondents.

3.4 Identification of Current Maintenance

To identify the current maintenance procedures which are used the following are required

Data Collection Methods

1. Questionnaires

The questionnaires were used for employed personnel from the authority. the questions included were focused to relevant information on documentation

Maintenance Performance Model

Development of maintenance performance model as mitigating measures for availability of berth pavement in Dar es salaam port. This descriptive maintenance performance model was done to suggest the solution, which if adopted, would solve all the problems associated with the area of study. The methods involved review of the related literature and analysis of the obtained data.

4.0 Data Collection and Analysis

4.1Demographic Information

This section describes the characteristics of the respondents such as gender, age, educational level, and experience in term years of service.

Table 2: Respondents distribution by gender

Gender					
		Number of respondents	Percent	Valid Percent	Cumulative Percent
Valid	Male	39	55.7	55.7	55.7
	Female	31	44.3	44.3	100.0
	Total	70	100.0	100.0	

The gender participants that are requested for research. There were 39 Male and 31 were female. It's vital information as we can assess the views and opinions of the people that contributed to the research and analyze their views. The impact level of evaluation of existing maintenance management system, assessment, and factors.

Table 3: Respondents distribution by age

Age					
		Number of respondents	Percent	Valid Percent	Cumulative Percent
Valid	21 - 30 years	10	14.3	14.3	14.3
	31- 40 years	37	52.9	52.9	67.1
	Above 40 years	23	32.9	32.9	100.0
	Total	70	100.0	100.0	

The age of the interviewees participating in the study is by the previous regulations. Statistics show that 10 people are between 21 and 30 years old, 37 people are between 31 and 40 years old, and 23 people are over 40 years old. The information shows that people of different age groups can share their opinions and ideas, allowing us to obtain different information from the different people participating in the study.

Table 4: Respondents working experience

Working experience					
		Number of respondents	Percent	Valid Percent	Cumulative Percent
Valid	3 to 5 years	8	11.4	11.4	11.4
	5 to 10 years	51	72.9	72.9	84.3
	10 years and above	11	15.7	15.7	100.0
	Total	70	100.0	100.0	

Work experience shared by workers participating in the research. 8 people have 3 to 5 years of experience, 51 people have 5 to 10 years of experience, and 11 people have 10 years or more of experience.

Table 5: Respondents unit name

The name of the unit					
		Number of respondents	Percent	Valid Percent	Cumulative Percent
Valid	Engineering	9	12.9	12.9	12.9
	Security	5	7.1	7.1	20.0
	Grain Terminal	18	25.7	25.7	45.7
	Scanner	38	54.3	54.3	100.0
	Total	70	100.0	100.0	

The above survey results show that respondents (54.3%) were scanner unit employees, (25.7%) were grain terminals department, (7.1%) and (12.9%) are security and engineering departments respectively.

4.2 Identification of factors that cause poor maintenance management practice of berth pavement by using RII Ranking Technique

The scores assigned to each factor by the respondents were entered in SPSS and consequently the responses from the questionnaires were subjected to statistical analysis for further insight. The contribution of each factor was analyzed and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by using of Relative Importance Index (RII).

The rating of all factors for degree of significance was based on the value of their respective Relative Importance Index.

Degree of significance range rates:

a. Most significant 0.76 - Above.
b. Significant 0.67 - 0.75.
c. Less significant 0.45 - 0.67.
d. Not significant 0.44 - Below.

Through this study the factors were analyzed basing on the answered questionnaire, and the results of each stratum basing on the Relative Importance Index calculated were compared to each other. This shows how these factors were ranked by each stratum, and the RII of each factor within a stratum was used to rank its importance and show its degree of significant. The analyzed results for all factors in consideration are shown in the table 6 below.

Table 6: The table shows factors that cause poor maintenance management practice

S/NO	Factors	RII	Rank	Rating
1	Insufficient fund	0.83	1	Most significant
2	Lack of pavement rehabilitation and preservation	0.79	2	Most significant
3	Insufficient of drainage system	0.78	3	Most significant
4	Inadequate pavement design	0.77	4	Most significant
5	Lack of data and information management	0.66	5	Less significant
6	Limited training	0.64	6	Less significant
7	Aging of infrastructure	0.63	7	Less significant
8	Substandard construction practices	0.60	8	Less significant
9	Poor maintenance planning and schedule	0.42	9	Not significant

The most significant factors were:

I. Insufficient fund.
II. Lack of pavement rehabilitation and preservation.
III. Insufficient of drainage system.
IV. Inadequate pavement design.

4.3 Visual Observation

Looking at the current situation for Dar es Salaam port, it was discovered that there are several defects which needs proper attention. The damage of berth pavement occurs on particular areas of the section 2, 3, 4 and 5. On section 2, the affected area was about 6.45m^2 with an average depth of 28mm according to condition survey data. On section 3, the affected area was about 13.72m^2 with an average depth of 41mm. On section 4, the affected area was about 22.9m^2 with an average depth of 79mm and on section 5, the settled area was about 63.47m^2 with an average depth of 83mm. From condition survey data the most affected area was section 5 followed by section 4, because these areas are the most useful area for the huge portal and mobile crane of Dar es salaam port. The identification of damages and technical condition of the berth pavement was very important prior to identifying and undertaking appropriate prevention measures.


Image 1: Section 4


Image 2: Section 5

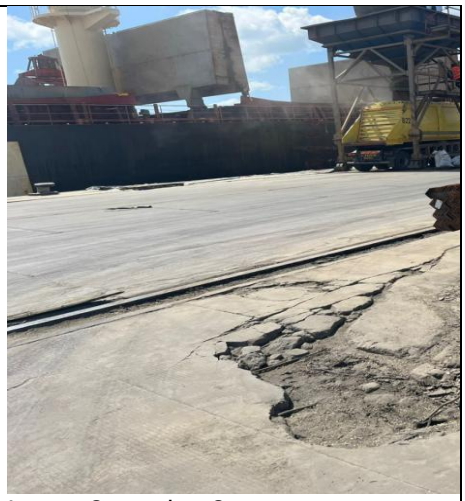
Image 3: section 3

5.0 DEVELOPING MODEL FOR IMPROVING BERTH PAVEMENT AVAILABILITY PERFORMANCE

5.1 Development of Maintenance Performance Model

The Regression equation was:

$$MAP = \beta_0 + \beta_1 IF + \beta_2 PR + \beta_3 DS + \beta_4 PD$$

Where;
MAP is Maintenance Availability Performance,
β_0 = Maintenance Performance Intercept,
IF = Insufficient maintenance fund,
PR = Pavement rehabilitation and preservation,
DS = Drainage system,
PD = Pavement design,
$\beta_1, \beta_2, \beta_3, \beta_4$ = Partial regression coefficients

The data was analyzed in SPSS software and the regression output were obtained;

5.2 Multi collinearity

The two approaches used to test for multi collinearity of a regression model are tolerance and Variance Inflation Factor (VIF) in regression analysis (Cohen et al., 2014). Tolerance is the percentage of variance in the independent variable that is not accounted for by the other independent variables. Most commonly, a tolerance value

of 0.10 or less is deemed as problematic (although 0.20 has also been suggested) also VIF value of 5 or greater is often problematic (Cohen et al., 2014).

Table 7: Collinearity Statistics

S/NO	Coefficients	Tolerance (>0.2)	VIF (<5)
1	Insufficient fund	0.977	1.024
2	Pavement rehabilitation and preservation	0.410	2.437
3	Drainage system	0.693	2.185
4	Pavement design	0.295	3.865

For this study, all the tolerance are above 0.20 and the VIF are all bellow 5. This suggest that there is no multicollinearity.

5.3 Model Summary and Autocorrelation

The table below indicates that 94.9 % of the variation in maintenance performance was explained by the independent variables,

This study was set out with testing auto correlation using the Durbin-Watson test. The result of the Durbin-Watson test was 1.873 which lies between 1.5 and 2.5, and therefore we have to assume that there is no linear autocorrelation in the data.

Table 8: Model summary

Model	R	R Square	Adjusted R Square	Durbin-Watson
1	0.974[a]	0.949	0.945	1.873[a]

5.4 Analysis of Variance

The data in the table below shows that the independent variables statistically significantly predict the dependent variable: p-value is less than 0.05, which means that the regression model is a good fit of the data at 95% level of confidence.

Table 9: Analysis Variance

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	51.523	4	12.881	248.007	0.000[a]
2	Residual	2.753	53	0.052		
	Total	54.276	57			

a. Predictors: (Constant), Insufficient fund, Lack of pavement rehabilitation and preservation, Insufficient drainage system, Inadequate pavement design.

b. Dependent Variable: Maintenance Performance

From below, all independent variables; p-values are 0.000, These variables have p-values of less than 0.05: therefore, they are contributors in Maintenance Performance which is dependent variable. The Beta coefficients for those variables: Insufficient fund (-0.044), Pavement rehabilitation and preservation (0.074), Drainage system (0.069) and Pavement design (0.0267), this suggest that Pavement rehabilitation and preservation is the highest contributor in maintenance performance followed by Drainage system, Pavement design and the least is insufficient fund.

By using the above information, the model equation is as follows: -

$$MAP = \beta_0 + \beta_1 IF + \beta_2 PR + \beta_3 DS + \beta_4 PD$$

$\beta_0 = 0.788$

$\beta_1 = -0.044$

$\beta_2 = 0.074$

$\beta_3 = 0.069$

$\beta_4 = 0.0267$

$$\boldsymbol{MAP = 0.788 - 0.044\,IF + 0.074\,PR + 0.069\,DS + 0.0267\,PD}$$

6.0 DEVELOPMENT OF EFFECTIVE MAINTENANCE MANAGEMENT SYSTEM FOR IMPROVING BERTH PAVEMENT AVAILABILITY

6.1 Development of an Effective Maintenance Management System

The maintenance management system was developed to improve the uptime of freight scanners. The developed system reduces the downtime of multiple frequent failures, thereby improving the usability performance.

An effective maintenance management system is a system designed to manage all maintenance activities within a specified period under certain operating conditions to meet operational needs. The system is developed based on a conceptual model to improve the usability performance of berth pavement by managing factors that affect current maintenance practices. The maintenance management system has formulated key maintenance strategies for

S/NO	Model	Unstandardized Coefficient		Standardized coefficient	t	Sig
1		B	Std Error	Beta		
2	(Constant)	0.788	0.444		4.031	0.000
3	Insufficient fund	-0.044	0.042	-0.033	-1.050	0.000
4	Pavement rehabilitation and preservation	0.074	0.053	0.068	1.408	0.000
5	Drainage system	0.069	0.070	0.0694	1.450	0.000
6	Pavement design	0.0267	0.063	0.0259	1.051	0.000

preventive maintenance and fault maintenance tasks. The development system user directly enters the failure information at the front end to test the nature of the failure, the location of the berth pavement, and the time the failure occurred.

After users of the system receive the failure information, they open the work order through the front end of the scan management system and, according to the urgency of the work, assign the appropriate maintenance personnel to troubleshoot, problem-solving, available resources, maintenance planning and prioritizing, to effectively adapt to planned and unplanned work. In addition to faulty or corrective maintenance measures, the system also prepares planned maintenance plans for all berth pavement and assign them to maintenance personnel along with other resources based on available inventory. The user of the system is also responsible for tracking and evaluating the implementation status of each maintenance work performed through the system.

In addition, users will be able to quickly track the status of work orders through the system. The system allows the generation of maintenance reports for management review and decision-making. Prepared reports and other maintenance records will be stored in the system database. The Authority's Information and Communications Technology Unit were responsible for maintaining the database system and ensuring its secure storage.

In addition, the system enables Dar es Salaam port managers to review the generated maintenance reports, thus performing a supervisory role. This informs them of the status of maintenance activities based on approved actions and other unplanned maintenance of the Dar es Salaam port berth pavement. This improves the availability performance of the berth pavement; because it is guided by the highest level of predictions from the developed maintenance management model.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusion

The main purpose of the study was to develop a maintenance management system to improve berth pavement availability performance. The research accomplished four specifics objectives, which were determining the factors that cause poor maintenance management practices for berth pavement at Dar es salaam port, assessing current maintenance management practices for berth pavement at Dar es salaam port, developing maintenance management model for improving berth pavement availability performance at Dar es salaam port and developing a maintenance management system.

The research findings revealed that currently Dar es salaam port uses manual maintenance approaches, which are not effective and hence lead to frequently deterioration, faults and spending longer time to repair maintenance problems, as the result the current maintenance management availability performance was found to be 39% which is practically very low.

Furthermore, the study obtained most significant factors which affect availability performance based on the relative Importance Index (RII) techniques which are insufficient fund (0.83), Pavement rehabilitation and preservation (0.79), Drainage system (0.78) and Pavement design (0.77). Based on the identified factors, the researcher developed and validated an effective Maintenance Management Model with predictability accuracy of 95% confidence level.

In addressing the above, the researcher developed a Maintenance Management System which has incorporated all the study findings and appropriate Engineering Maintenance Management strategies for both preventive and corrective maintenance for improving berth pavement availability.

Based on the developed maintenance management system the berth pavement availability has improved to 98.6% and hence improving Maintenance effectiveness at Dar es Salaam port.

7.2 Recommendations

In addressing the current availability performance of berth pavement at Dar es salaam port, the organization is advised to ensure sufficient financial support to maintenance activties.

Dar es Salaam port is advised to use the developed Maintenance Management System in managing maintenance works for berth pavement in order to improve availability performance and also extending life span of the pavement.

This study can be extended by other researchers to conduct in depth research to improve the developed system for identifying another effect of the maintenance management system at Dar es Salaam port.

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