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Development Of A Maintenance Management System For Rural Water Supply:A Case Study Of Kisarawe District

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***Abstract* :**. *Kisarawe district council is one among seven councils in Pwani Region in Tanzania. Water supply in the Kisarawe district is served by Dar es salaam Water and Sewerage Authority (DAWASA) and Rural Water Supply and Sanitation Agency (RUWASA). DAWASA supplies water in the urban area of Kisarawe and RUWASA supplies water in Rural areas. Kisarawe has been a priority district for increased infrastructure investment owning to low water access coverage of about 45% in rural areas compared to urban areas of 89%. Every year the government of Tanzania provides RUWASA with a budget for technical support, spare parts and conducting refresher courses for the community for the water supply scheme. However these is still in adequate water supply due to poor maintenance services.*

The purpose of this study is to identify the factors that affect the maintenance management system for rural water supply and to develop the maintenance management system for rural area in Kisarawe district. Data collection was done by using questionnaire and were analyzed using Statistical Package for Social Sciences (SPSS) and Microsoft excel.The Relative importance index was used to identify the factors that affect maintenance management system. The following parameters were identified as key parameters in Kisarawe district with their relative importance indices (RII): age of pipes (RII, 0.93), maintenance budget (RII, 0.84), climate change (RII, 0.84), maintenance schedule (RII, 0.91), availability of spare parts (RII, 0.92) and cultural practices (RII, 0.88) The maintenance management system was developed for improvement of water rural supply of Kisarawe district.

Keywords: Maintenance System, Relative, Importance index, Kisarawe ,RUWASA, Rural Water supply

1.0 Introduction

Kisarawe district council is one among seven councils in Pwani region. Water supply in Kisarawe district is served by DAWASA and RUWASA. DAWASA supplies water in urban area in Kisarawe. The study focuses the area served by RUWASA . The government of Tanzania's goal is to achieve 100% water access by the year 2030 to all citizens. The government invests more than Tsh. 600 billion annually in developing new water infrastructure from lakes, rivers, dams, and boreholes. Kisarawe has been a priority district for increased infrastructural investment owning to low water access coverage of about 45% in rural areas compared to urban areas of 89%. Every year the government of Tanzania provides RUWASA budget for technical support, spare parts and conduct refresher courses to community for water supply schemes. However inadequate water supply due to poor maintenance prevails.

1.1 Problem statement

RUWASA in Kisarawe has a challenge of water supply to the community due to infrastructure failure to provide intended water services to community as per designed. Water supply systems are poorly and frequent break down, leaving them with unreliable and disrupted water supply systems. Villages have a shortage of water as a result community drink unsafe water that may result to waterborne diseases.

1.2 Study objectives

The purpose of this study is to develop a maintenance management system for rural water supply at Kisarawe district served by RUWASA in order to improve water supply services .This is done through identification of factors and development maintenance model.

2.0 Literature Review

Operation and maintenance of a water supply system refer to all the activities needed to run the system and continue to provide the necessary service (Yoder et al., 1999). The two words are very frequently used together and the abbreviation 'O&M' is widely used **.**

2.1 Maintenance

Maintenance refers to planned technical activities or activities carried out in response to a breakdown, to ensure that assets are functioning effectively, and requires skills, tools and spare parts (Yoder et al., 1999).. Water supply systems must also meet requirements for public, commercial, and industrial activities. In all cases, the water must fulfil both quality and quantity requirements. Maintenance deals with the activities that keep the system in proper working condition, including management, cost recovery, repairs and preventive maintenance.

2.2 Factors affecting maintenance management system in rural water supply

The factors affecting maintenance management system practices at rural water supply schemes are discussed under the sub-headings below.

2.2.1 The technical factors

Technical factors are likely to influence operation and maintenance as well as sustainability water supply system .This include the following:,

i. **The skilled personnel**

Skilled labourers are important for water scheme infrastructure and maintenance. Skilled personnel should be competent to perform and utilize the equipment.

ii. **The age of the pipe**

The ageing of the water scheme project is a natural process. It becomes an urgent and critical problem when a long-operating of the water pipe has begun to lose reliable life.

iii. **Construction material**

Defective construction materials can result in the untimely failure of basic and other components, driving direct and indirect property harm. Contractors that employ inferior material risk premature dissatisfaction with the water infrastructure or commercial properties.

iv. **Availability of Spare parts**

Without spare parts, there is a risk of downtime, which may lower the quantity of the water supply that will be produced

v. **Maintenance schedule**

Maintenance scheduling is the process of making sure planned work is carried out Scheduled maintenance allows you to implement preventive maintenance jobs when necessary to further minimize potential downtime and increase efficiency.

vi. **Response to maintenance time.**

The respond to maintenance calls or other indications of malfunction by dispatching a service technician to the Site to repair or replace the defective component unless the trouble can be otherwise corrected through remote repair.

vii. **Availability of water tank station**

Availability of water tank station help the availability of the water average supply. The quantity of water that can be used for human purposes without significant harm to ecosystems or other users..

viii. **Pressure of water**

Low water pressure is a common home plumbing issue that can affect faucets and sinks as well as dishwashers, showerheads, toilets, and any other plumbing fixture. There are various causes of water pressure problems.

ix. **Diameter of pipe**

However, pipe diameter and water flow rate greatly affect total cost and net profit. The use of pipe with a small diameter may lead to burst if the pressure are high.

2.2.2 The community factors

The Community factor is an essential factor that influences the operating and maintenance works. This include the following factors:

i. Misuse of water infrastructure and its functionality.

Water system failures can result in service disruptions, impediments to emergency response, and damage to other types of essential infrastructure that investment is not keeping up with needs.

Income of water users.

Over 70% of households in rural communities do not have access to improved water supply due to low income. They rely solely on self-water supply (free source) such as rivers, perennial streams, water ponds and unprotected wells which is susceptible to water borne diseases such as typhoid fever, cholera, dysentery, malaria parasites. As result rural community failure to fetch water through water tapes due to lack of income. On ownership and willingness to pay, available evidence suggests while most communities can cover all costs related to minor maintenance and operation, many struggle with other aspects - particularly those related to long-term sustainability such as carrying out major maintenance and eventual asset replacement.

ii. Cultural practices.

According to their cultural and religious beliefs, many cultures adhere to the principle that water use should be free of charge.

iii. Delayed of reporting failure

A lack of or poor communication leads to misunderstanding in the workflow, weak return on investment (ROI), and even loss of revenue. In short, the level of communication can spell either the success or failure of a particular water project.

2.2.3 The environmental factors

.Based on literature (IPCC, 2014), less precipitation during the dry months can lead to drought. Changes in precipitation will ultimately affect groundwater availability. These include the following factors

i. Climate change

Climate change is likely to influence drought conditions. Climate trends in Tanzania have shown the greatestannual decrease in rainfall has occurred in the southernmost parts of Tanzania (Oberlin and Kassim, 2018).

ii. Water source location

Evidence shows that whenever proper water source analysis has not been adequately conducted, most water supply projects fall into dysfunction. In Tanzania, there are three main categories of water sources available, namely: rainwater, surface and groundwater

2.2.4 The financial factors

Financial factors are key components of the following:

i. Maintenance budget

For any rural water supply project, the financial budget of operating maintenance is a vital issue and should be planned before construction, at the designing phase.

ii. Revenue collection

Water systems facilities will only be sustainable in the long term if water users are willing to pay user charges sufficient to cover the costs of delivering the services (Kaliba, Norman, & Chang 2003).

iii. Cost recovery allocation

Water supply sustainability requires at least full O&M cost recovery from user charges.

2.5 Development of maintenance management model for rural water supply.

Modelling refers to the development of mathematical expressions that describe in some sense of behaviour of a random variable of interest (Rawlings, Pantula, & Dickey, 2001).These include the following

i. Multiple Linear Regression

. The objective can be either maximization or minimization of objectives.

A linear programming problem is a problem that requires an objective function to be maximized or minimized subject to resource constraints. The key to formulating a linear programming problem is recognizing the decision variables. The objective function and all constraints are written in terms of these decision variables (Fox & Garcia, 2013).

and Garcia (2013) further explained the conditions for a mathematical model to be a linear program (LP) were all variables continuous (i.e. can take fractional values), a single objective (minimize or maximize), the objective and constraints are linear i.e. any term is either a constant or a constant multiplied by an unknown and the decision variables must be non-negative

According to Rawlings et al. (2001) a generic of equation of the multiple regression models is given as: -

$Y=\beta 0+\beta 1X1+\beta 2X2+\beta 3X3+\cdots+\beta nXn+\varepsilon i$ (2.1)

Where:

Y is a dependent variable,

X1, X2, X3, … Xn are the independent variables,

βO is a constant,

β1, β2, β3, … βn are the coefficient of the independent variables, and

εi is the random error of dependent variable for ith observation 22

ii. Model Validation and Evaluation

It was reviewed that this phase is checking the model as a whole, it consists of validation of the assumptions and parameters of the model and the performance of the model is to be evaluated using standard performance measures such as root mean squared error and R^2 value, sensitivity analysis to test the model inputs and parameters (Kumar, 2014).

Kumar (2014) added that this phase also is an iterative process and may require returning to the model definition and formulation phase and one important aspect of this process is that in most cases data used in the formulation process should be different from that used in validation.

2.6 Development of Maintenance Management System depends on the following;

i. Leadership and Policy Deployment

Let's look at the first of these, Leadership and Policy Deployment. World Class Maintenance relies on leadership providing direction, focus and support. This involves management establishing a clear mission and vision supportive of the organization's direction and goals(Crespo Marquez, 2007). Leadership is also responsible for establishing the policies and expectations that serve to guide maintenance and the total organization in supporting maintenance activities. Once policies are developed, they must be deployed, communicated and monitored.

ii. Organizational Structure

Maintenance of organizational efficiency depends upon many interdependent variables. Some of these include organizational structure, goals and objectives, communications processes, policies and procedures, work processes (methodologies) and employee systems (Crespo Marquez, 2007).

iii. Inventory Control

The purpose of this practice area is to refine the maintenance stores and acquisition process to streamline parts appropriation. It is focused on the right parts in the right place at the right time. This may involve studying the existing flow of requested parts and improving the process to reduce wasted effort and inactivity. This would involve standardized stores and inventory practices. Minimizing poor use of the company's assets can be accomplished in many ways. (Crespo Marquez, 2007).

iv. Preventive Maintenance

PM is often defined as "those timed or meter-based service activities used to extend the life of the equipment and identify potential problems through inspection and early detection." PM may include work performed on selected equipment through service contracts, inspections, cleaning activities, testing, lubrication efforts, and scheduled shutdown service. The most significant activity to occur in PM is inspection, which should lead to early detection and correction.PM is a major component in moving from reactive to proactive through early detection and early correction(Crespo Marquez, 2007, Walters and Javernick-Will, 2015).

v. Predictive Maintenance

A sound description of PDM is "the application of technologies and early detection processes to monitor and detect changes in condition to allow more precise intervention. PDM may include vibration analysis, shock pulse methods, ultrasonic, thermographic analysis, oil analysis, electrical surge comparisons, coolant analysis, wear particle analysis, and performance trending.

vi. Planning and Scheduling

Planning is devising a process for doing, making or arranging maintenance work. It involves preparing job plans and other resources to enable the craftsperson to perform the work quicker and more efficiently. It often deals with the "what" and "how". Scheduling is creating a schedule for when the work is to be performed. Where planning deals with the "what" and "how", scheduling deals with the "when" and "who. "The lack of organized processes and standardized procedures can significantly restrict a maintenance operation from meeting its objectives of servicing the needs of the organization(Crespo Marquez, 2007). The majority of maintenance work can be planned and, for the most part, should be. Increasing productivity or value-added work of maintenance personnel depends a great deal on properly planned activities.

vii. Work Flow

The work order is an integral part of an effective maintenance operation. It serves to:

The importance of this workflow is to allow us to control and monitor work activities. One of the most significant purposes is to analyze work that has been performed to identify costs, losses, and trending of problems.

viii. Financial Control

This practice area deals with the fiscal control procedures of the maintenance organization. It may include budget control, contractor cost monitoring, and overall labour and material cost control. It may also include monitoring and affecting decisions on asset repair/replacement.

ix. Operational Involvement

It is becoming rarer to find organizations that have not broadened their level of operator involvement in basic care-type activities. The logic includes having operators assume some basic responsibilities such as routine cleaning, lubrication tasks, adjusting/tightening, inspections, and minor repair/replacement. This may be in the form of Total Productive Maintenance or some other structured process to encourage ownership, and involvement and improve equipment reliability.

METHODOLOGY

3.1 Introduction

Different data collection techniques are deployed in the collection through questionnaire

3.2Data processing and analysis

Information gathered from different data sources is processed, analyzed and compiled. Quantitative data compiled and analyzed by using Statistical Package for Social Sciences (SPSS) and Microsoft Excel software while qualitative data will be edited, coded and tabulated qualitative data will be analyzed during and after data collection by comparing results side-by-side in a discussion, transforming the qualitative data set into quantitative scores and content and trend analysis. The data will be analyzed using the SPSS and Microsoft Excel software to depict the variance of average, simple regression, descriptive statistics, and cross-tabulation and determine the degree of association between variables. Qualitative information will be presented in the form of quotations and descriptions.

3.4 Descriptive Statistics and Relative Importance Index

Descriptive statistics were used to analyze the demographic data of the respondents while Relative Importance Index (RII) was used to analyze the respondent's scores of the maintenance factors (Mishra *et al.*, 2019). Respondents were asked to score factors affecting the current maintenance practice according to the degree of importance; where 1 = very low; 2 = low; 3 = moderate; 4= high: 5=very High

In analyzing the factors, the scales were used to calculate the Relative Importance Index for further analysis. When the RII approached one (1), the factor/item has the most significant effect on current maintenance practice. The importance indices obtained were ranked in ascending order to ascertain the most frequent factor.

The relative importance index (RII) is given by equation (3.1)

Relative importance index (RII) $= \Sigma W / (A*N)$ ……………………………….(3.1)

Where:

RII = is the relative importance index which ranges between 0 and one ($0 <= RII <= 1$)

W= is the weighting given to each factor by the respondents, ranging from 1 to 5

A = is the highest weight

N = is the total number of respondents

The factors were rated to their degree of significance based on the value of their respective relative importance index (RII) (Venkataraman,2007). The guide for the rating is given in Table 3.1.

3.5 Maintenance Management Model

The diagrammatical presentation of the maintenance management model was then developed. Input data of the model were those factors affecting current maintenance practice which had a high impact on the availability of the equipment (most significant and significant factors) identified in the data collection and analysis. The model has been developed by using historical data from document review. The model has been developed by using historical data from document review. Data for five significant factors collected from Kisarawe district the area served by RUWASA were loaded into SPSS to generate the model and 2022 data was used for validation of the model.

Table 3.1: A guide for degree of significance

S/NO	Degree of significance	Rating
1	Most significant	0.76 and above
2	Significant	0.67-0.75
3	Less significant	0.45-0.67
4	Not significant	0.44 and below

Source: Venkataraman, (2007)

3.6 Conceptual Model

A conceptual model is a representation of a system made of the concept of composition which is used to help people know, understand, or simulate a subject the model represents. It is also a set of concepts; the model aims to improve equipment availability in rural water supply in the area served by RUWASA reducing downtime due to the maintenance management system. The performance was measured based on the factors affecting current maintenance identified in the specific objective number one.

4.0 Results and Analysis

S/N	Factors affecting	Rank And frequency					Total
	Maintenance management system	Very high(5)	High (4)	Moderate(3)	Low (2)	Very low(1)	Frequency
1	Skill of maintenance personnel				8	17	25
2	The age of pipe	16	9				25
3	Maintenance budget	5	20				25
4	Cost recovery allocation				6	19	25
5	Climate change	7	16	2			25
6	Delayed of failure reporting				8	17	25
7	Response time to maintenance work			2	14	9	25
8	Maintenance schedule	14	11				25
9	Availability of spare parts	15	10				25
10	Culture practices	10	15				25
11	Revenue collection			3	4	18	25
12	Construction material				12	13	25

13	Misuse of water infrastructure and functionality				13	12	25
14	Income of water users			2	17	6	25
15	Diameter of the pipe				20	5	25
15	Availability of water tank station				13	12	25
16	Water source location				11	14	25
17	Pressure of water			2	8	15	25
18							

4.1 Results and Analysis

Table 4.1 Factors affecting the maintenance management system for rural water supply

Factors	5. Very high	4. High	3. Moderate	2. Low	1. Very low	Total	A*N	RII	Comment
The skill of maintenance personnel	0	0	0	16	17	33	125	0.26	Not Significant
The age of the pipes	80	36	0	0	0	116	125	0.93	Most Significant
Maintenance budget	25	80	0	0	0	105	125	0.84	Most Significant
Cost recovery allocation	0	0	0	12	19	31	125	0.25	Not Significant
Climate change	35	64	6	0	0	105	125	0.84	Most Significant

Delayed failure reporting	0	0	0	16	17	33	125	0.26	Not Significant
Response time to maintenance work	0	0	6	28	9	43	125	0.34	Not Significant
Maintenance schedule	70	44	0	0	0	114	125	0.91	Most Significant
Availability of spare parts	75	40	0	0	0	115	125	0.92	Most Significant
Culture practices	50	60	0	0	0	110	125	0.88	Most Significant
Revenue Collection	0	0	9	8	18	45	125	0.28	Not Significant

Table 4.1 continue

Constructional material	0	0	0	24	13	37	125	0.30	Not Significant
Misuse of water infrastructure and Functionality	0	0	0	26	12	26	125	0.21	Not Significant
Income of water users	0	0	6	34	6	46	125	0.37	Not Significant

Table 4.1 Continue

Diameter of the pipe	0	0	0	26	12	38	125	0.30	Not Significant
Availability of water tank station	0	0	0	40	5	45	125	0.36	Not Significant
Water Source location	0	0	0	22	14	36	125	0.29	Not Significant
Pressure of water	0	0	6	16	15	37	125	0.30	Not Significant

5.0 Discussions

5.1 Development of Maintenance Management Model for Rural Water Supply

Table 5.1 Coefficients

Coefficients						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	0.002	4.065		2.699	.015
	The age of the pipes	-0.04	.399	-.330	-1.278	.000
	Maintenance budget	-0.05	.252	-.024	-.178	.000
	Climate change	0.01	.306	.036	.153	.000
	Maintenance schedule	0.01	.217	-.751	-5.185	.000
	Availability of spare parts	0.06	.279	-.036	-.198	.003
	Culture practices	-0.03	.235	.060	.388	.005

a. Dependent Variable: Availability performance of rural water supply

As seen in the "**Sig.**" column, all independent variable coefficients are statistically significantly different from 0 (zero). Although the intercept, B_0, is tested for statistical significance, this is rarely an important or interesting finding.

Model Specification

$$\mathbf{Y = 0.002 - 0.04X_1 - 0.05X_2 + 0.01X_3 + 0.01X_4 + 0.06X_5 - 0.03X_6}$$

Where;

Y = Rural water supply availability perfomance

X_1 = Age of the pipe, X_2 = Maintenance budget, X_3 = Climate Change, X_4 = Maintenance Schedule, X_5 = Availability of spare parts, X_6 = Cultural practices

Therefore, the model is

Rural water supply Availability Performance = 0.002 - 0.04(Age of the pipe) - 0.05(Maintenance budget) + 0.01(Climate Change) + 0.01(Maintenance schedule) +0.06(Availability of spare parts) - 0.03(Culture practices)

The upper limit of availability performance explained by the model is obtained when:

i. There is no downtime due to ineffective communication, lack of supervision of maintenance practices, and un-availability of historical maintenance data (i.e. downtime to each of these factors = 0).

ii. Effective maintenance schedule and planning are available (i.e. uptime Effective Maintenance Schedule and Planning = 24).

6.0 Conclusions

The main objective of this research was to develop a maintenance management system for rural water supply in the Kisarawe district the area served by RUWASA.

The key factors from the findings came under six main areas: age of the pipe, maintenance budget, climate change, maintenance schedule, availability of spare parts, and cultural practices. This study argues that all of the factors outlined above must be viewed together as the sum parts of one solution to a rural water supply maintenance management system. The need to improve one factor against another will vary depending on context yet, for the challenges to be overcome, no one factor should be addressed alone all need to be considered collectively to ensure services last over time.

For this study information was collected through a literature review, observation, documentary review and, questionnaires. The data collected were analyzed using computer software, Statistical package for the social sciences (SPSS) version 26 in which linear regression model was developed with coefficient of correlection of R^2=0.705.

The effective maintenance management system was developed by considering the improvement of maintenance for water supply in Kisarawe District..

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