IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

CONTRIBUTION OF MAINTENANCE MANAGEMENT PRACTICES ON NON - REVENUE WATER REDUCTION IN WATER DISTRIBUTION NETWORK

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Abstract
The main objective of this study is to assess the impact of maintenance management practices on reducing non-revenue water in the water distribution network. The specific objective of the paper is to evaluate the how DAWASA current maintenance management system practice in water distribution system contribute to overall non-revenue water of 37%. The study was conducted in Kibaha District of Tanzania. The case study design was employed. Purposive sampling of 80 representatives was included in the study. The study identified several factors influencing maintenance management practices in the water distribution network, including material vulnerability, lack of pipe and fittings, human activities (construction works), network duration, construction technology practices, material quality, water meter quality, water meter duration, technology, water project design practices, human resources, limited maintenance budget, and water pressure.

IndexTerms **- Component,formatting,style,styling,insert.**

1.0 Introduction

Many water utilities in Africa including Tanzania characterized by high non - revenue water (NRW) that exceeds the recommended limits of 15%. This challenge of high non-revenue water mainly contributed by poor maintenance management system of water distribution networks. Sub Saharan Africa water utilities have NRW value higher than 23%.
Water distributors consider the NRW as a problem, the latter is generally referred to as the water volume that does not bring revenue to the water utilities which originate from the water losses that are may or may not be used but are not accounted for (Tsitsifli, 2017). A high level of Non-Revenue Water means that the water utility is not performing well because it is mainly from the errors and flaws of the system of a water utility. The main goal of all water systems is to efficiently distribute safe water with the least level of its non-revenue water to save money and to make sure that there will be no shortage (Mclntosh, 2014).

In assessing the non-revenue water, the first thing to do is to compute the amount of non-revenue water and its components which are real loss, apparent loss, and authorize unbilled using the data provided by the water utility (Sharma, 2018). According to the Institute for Water Education, the term unaccounted-for water is the difference between the volume of water delivered into a network and the legitimate consumption of water that can be accounted for whether metered or not (Kanakoudis, 2014).

Rajasekhar (201 argued that poor maintenance of water distribution for customers will definitely cause more damage and costly repair works if left unattended. Technical knowledge and skills are necessary and essential for the identification of factors that causes poor maintenance of water equipment and the remedial measures to keep water equipment in a good condition. Limited view of the role of water conservation is changing; utilities that have pioneered the use of conservation have shown that it is a viable long-term supply option (Werick, 2005). Water conservation can yield a number of benefits for the water utility, environment, and community.

According to Tanzania Energy and Water Utilities Regulatory Authority (EWURA) a national NRW average is about (15-20) %. Dar es Salaam Water Supply and Sanitation Authority (DAWASA) is a public utility established on August 2018 with the mandate of supplying water and sanitation services in urban and rural areas entrusted to it.

DAWASA comprises a total length of about 6000km of water distribution network with more than 350,000 household connections with daily total water production of about 590 million litres per day. DAWASA produce water from Upper Ruvu production plant, Low Ruvu production plant, Wami production plant, Mtoni production plant and deferent Boreholes.Currently DAWASA Non - revenue water from last year's report of 2021/2022 is about 37% which much higher than national benchmark of (15-20) %.

Evidence from developing countries indicate misuse of equipment induced by the negligence of the operator and lack of proper training and know-how on the part 16 of equipment supervisor may result in increased frequency and cost of DT (Shahin, 2012). Lack of maintenance standard procedures is also among the challenges (Spellman, 2013). According to (Campos, 2011)all tools and equipment must be properly maintained so that workers are not endangered. Installation regulations require inspections of tools and equipment before use. Preventive maintenance is the systematic care and protection of tools and equipment in order to keep them in a safe, usable condition, limit downtime and extend life duration.

Moreover, prior studies advocate the importance of proper maintenance policy considering the operation of maintenance management (Fraser, 2014). Describe policies as guidelines that assist in achieving the defined objective of a function. A well-defined maintenance policy is essential to provide a goal and direction for maintenance management in an organization. Three main questions are considered important in establishing a comprehensive maintenance policy which is; what is to be maintained, what type of maintenance will be applied in each case and how should maintenance work be organized?

Magyar (2004) postulated that factors relate to the human aspects of crews who are involved in the equipment maintenance, operation, and production process. The factors in this category include skill level of operators and mechanics, fatigue, morale, and motivation. An operator's skill is one of the most important factors and it affects operator's performance and the direct cost of downtime (DT) through job efficiency.

An effective maintenance control system improves equipment reliability and assists in optimal utilization of resources. Maintenance control is the set of activities, tools and procedures utilized to coordinate and allocate maintenance resources to achieve the objectives of the maintenance system that are necessary for work control, quality and process control, cost control and an effective reporting and feedback system according to (Fraser, 2014)

2.0 Problem of statement.

Dar es salaam Water Supply and Sanitation Authority (DAWASA) is a public utility with higher value of non-revenue water about 37% (DAWASA 2021/2022 report) which exceeds the required limits of 15% - 20% (EWURA). Non-revenue of 37% is the major issue to the authority which imply that every month the authority lost about Tsh 10.5billion revenue collection in a monthly basis due to loss water as non-revenue water. DAWASA lost 37% of capital invested in chemicals and electricity in every month in water production as non-revenue water. Also, non-revenue water of 37% reduces the ability of the utility to provide sustainable service to customers and increasing complains to customers of leakages, water bills and lastly wasting natural resources (DAWASA 2021/2022 FINANCIAL REPORT).

There is no previous study has been done specifically in DAWASA to identify which factors contribute 37% non-revenue water, in what percentage physical and commercial non-revenue water contribute to the whole non-revenue of 37%. How maintenance management system practise contributes to the non-revenue water.

Improvement of current maintenance management practices in water distribution network will increase the availability performance for customer's satisfaction, reduction of non-revenue water that caused by poor operations and maintenance practice. The effective water distribution network maintenance management system maximizes pipe lifetime, hence reduces capital investment for replacement of the pipes and also environmental impact and increases safety, leading to the reduction of accidents and damages. Properly maintained of pipe line, contribute to highly availability of costumer's satisfaction.

3.0 Literature Review

Vermersch (2016) elaborated that commercial water losses consist of main elements namely customer meter under-registration, illegal connections, and all other forms of water theft. Based to the area to be considered in solving the problem with apparent losses are under metering, errors in data acquisition, unauthorized consumption, and poor estimate of unmetered consumption.

The European standard for maintenance terminology presents the different types of maintenance (Richard, 2001) 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. "Retention" and "restoration" are denominations for action types that are then converted into "preventive" and "corrective" maintenance types in the maintenance vocabulary.

Condition based maintenance carried out following a forecast derived from the analysis and evaluation of the significant parameters of the degradation of the equipment (Rajagopalan, 2006). According to this type of maintenance 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 (Coulibaly, 2008).

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. Corrective Maintenance can be immediate or deferred (Jaturonnatee, 2006). As explained by (Ip et al., 2000) maintenance system can be viewed as a simple input/output system. The input to the system are manpower, failed equipment, material and spare parts, tools, information, policies and procedures, and spares. The output is equipment that is up, reliable and well configured to achieve the planned operation of the plant. The system has a set of activities that make it functional. The activities include planning, scheduling, execution and control.

4.0 Study Model

A comprehensive availability performance model can be used as a practical tool when improvements are to be directed effectively, strategies tested, or alternative investment proposals compared. It is defined by (Ahuja, 2008)that, availability performance is a measure of the performance of equipment in terms of ability to operate without problems and therefore availability prediction model and assessment methods can provide 17 quantitative performance measures that may be used in assessing a given design to reduce downtime to ensuring operational availability of the treatment plant equipment. Analyses based on availability predictions help to assess design options and can lead to definition of maintenance support concepts that will increase future system availability, anticipate logistics and maintenance resource.

Maintenance support performance is measured in mean waiting time and is abbreviated as MWT. It is the average waiting time for maintenance resources when breakdown occurs and is influenced by the organization and strategies production, and operation and maintenance. Maintainability deals with duration of maintenance outages or how long it takes to achieve (ease and speed) the maintenance actions compared to a datum. The datum includes maintenance (all actions necessary for retaining an item in, or restoring an item to, a specified, good condition) is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance. Maintainability performance is measured in mean time to repair (MTTR). It is the average repair time of the failure happened and is influenced by the design of the equipment which is determined in the design phase (Humble, 1997)Mean down time (MDT) is the sum of mean waiting time (MWT) and mean time to repair (MTTR); that is:

$$MDT = MWT + MTTR \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

To increase availability performance must be able to increase reliability performance which reduce MTTF and decrease maintenance support performance and maintainability performance; the calculation of availability performance is the one among the basis of maintenance management before making any investments and every economical calculation in maintenance must be with an availability performance calculation to calculate the increase in availability performance due to planned changes (Ben-Daya, 2009).

The following useful formulas for calculations of availability performance:

$$A = \frac{MTTF}{MTTF+MWT+MTTR} X100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.2)$$

OR

$$A = \frac{MTBF}{MTBF+MBT} \text{ X } 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.3)$$

OR

$$A = \frac{Tup}{Ttotal} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.4)$$

$$MTBF= \frac{Tup}{a} \text{ Hours/failure} \ldots\ldots\ldots\ldots \quad (4.5)$$

$$MDT = \frac{Tdm}{a} \text{ Hours/ failure} \quad (4.6)$$

Where:

A is Availability performance.

MTBF is Mean time before failure (Reliability performance).

MTTR is Mean time to repair (Maintainability performance).

MWT is Mean waiting time (Maintenance support performance).

MDT is Mean down time which is given by the following equation:

$$MDT = MWT + MTTR \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.7)$$

Many researchers have used linear programming model to manage and optimize engineering activities. (Wagner, 1959)has developed a linear programming model to manage maintenance backlog; (Yusta, 2002)has used a linear programming methodology for the optimization of electric power generation schemes (Kareem, 2008) had also employed linear programming methodology to model effective maintenance and manpower planning strategy and also (Yusta, 2002) had developed a model by using linear programming technique for the optimization of the activities in maintenance projects. This study used linear programming technique for the maintenance optimization model to improve availability performance of water distribution and reduction of non-revenue water.

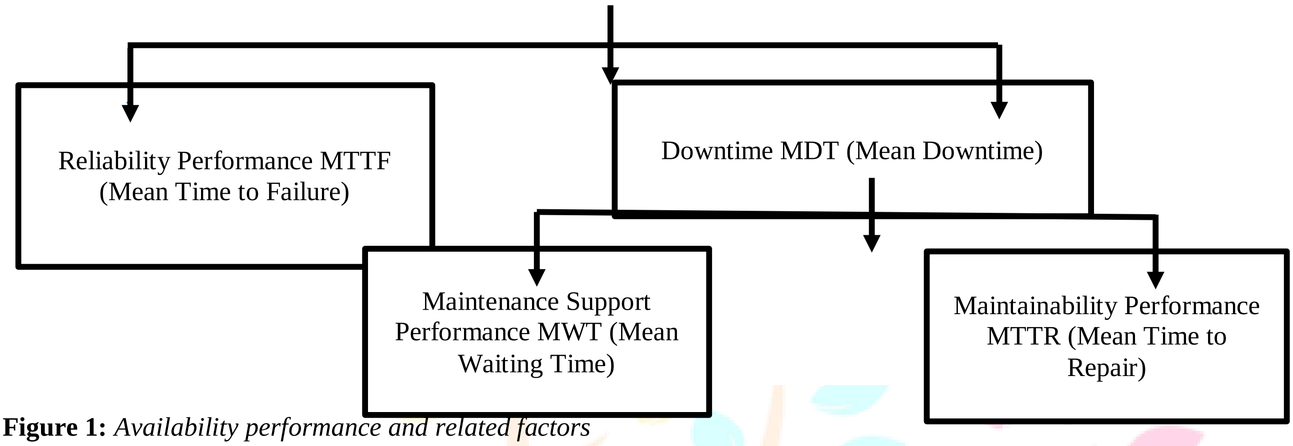

Figure 1: *Availability performance and related factors*

5.0 Methodology

This study administered the use of case study design. (Kothari, 2004) Defined the case study method as a very popular form of qualitative analysis and involves careful and complete observations. It is a method of studying in-depth rather than breadth. It places more emphasis on the full analysis of a limited number of events or conditions and their interrelations. The case study deals with the processes that take place and their interrelationship. Thus, the case study is essentially an intensive investigation of the particular unit under consideration. The object of the case study method is to locate the factors that account for the behavior-patterns of the given unit as an integrated totality.

The study was conducted at Kibaha District, particularly in all water distribution installed on different institutions within Coast Region. The study population includes 100 government officials from DAWASA. By using probability and non-probability sampling the study was executed to different personnel who met the study design. The study used a sample of respondents from each place, making a total of 100 respondents who participated in entrepreneurship program. The formula for the sample was given in equation (i) at the confidence interval of 95% with significance level of 5%

The Formula for sample size: $n = \frac{N}{1+N(e)2}$

Where:

n = Sample size to be studied

N= Population size

e = margin of error

From the formula above:

$$n = \frac{100}{1 + 100(0.05)2}$$

The sample in this study is 80

From the above formula, the required sample for this study was 80 people which will include all interested parts. The interested party had been selected by using purposive and simple random.

Descriptive statistics was used to analyze the data of the respondents while Relative Importance Index (RII) was used to analyze the respondent's scores of the maintenance factors. Respondents were asked to score factors affecting the current maintenance practice according to the degree of importance; where 1 = very low; 2 = low; 3 = high; 4= 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 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) = $\sum \frac{W}{AN}$

RII is 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 4

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). The guide for the rating is given in (Table 1)

Table 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: Vanduhe (2012)

6.0 Results and Discussion

Table 2: Respondent's Characteristics

VARIABLE	RESPONSE	FREQUENCY	PERCENT (%)
	Customer care	11	31.4
	Billing	3	8.6
	Customer care	6	17.1
Department	Operation and maintenance	10	28.6
	Planning and construction	5	14.3
	Bachelor degree	20	57.1
Level of education	Master's degree	1	2.9
	Diploma/FTC	12	34.3
	More than 5 years	14	40
Years of experience	Between (2 - 3) years	8	22.9
	Between (3 - 4) years	6	17.1
	Between (4 - 5) years	3	8.6
	Less than 2 years	4	11.4
Position of respondent	Casual labour	13	37.1
	Artisan	4	11.4
	Casual labour	3	8.6
	Engineer	2	5.7
	Principal Technician	2	5.7
TOTAL		**35**	**100**

Source: Field data results

The study examined the maintenance practices employed in the water distribution network at DAWASA. The findings revealed that out of the 35 respondents, 31.4% reported the use of preventive maintenance, which involves regular inspections and replacements to prevent equipment failures. Additionally, 5.7% stated that both preventive and corrective maintenance methods are utilized, indicating a proactive approach. Reactive maintenance, focusing on fixing issues as they occur, was reported by 22.9% of the respondents. Moreover, 17.1% mentioned the utilization of emergency maintenance for immediate repairs during critical situations. However, concerning 2.9% of the respondents, no maintenance practices were reported. These results highlight the various maintenance approaches employed by DAWASA and shed light on potential areas for improvement in maintaining the water distribution network's reliability and efficiency.

Table 3 Type of maintenance is used in water distribution network at DAWASA

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Preventive Maintenance	11	31.4	31.4	31.4
	Both Preventive and Corrective Maintenance	2	5.7	5.7	37.1
	Corrective Maintenance	8	22.9	22.9	60.0
	Emergency Maintenance	6	17.1	17.1	77.1
	Not at all	1	2.9	2.9	100.0
	Total	35	100.0	100.0	

The findings from maintenance policy and strategies indicate that the respondents' views on the presence of a maintenance policy and strategy vary. Only 20% of the participants are aware of the existence of a structured approach to maintenance, suggesting a minority acknowledges the presence of such policies and strategies. On the other hand, a significant majority (74.3%) perceive the absence of a formalized plan or strategy for maintenance. This suggests that a large portion of the respondents does not believe that there is a clear framework in place. Additionally, a small proportion (5.7%) expressed uncertainty about the existence of maintenance policies and strategies, possibly due to a lack of knowledge or information. It is important to note that these findings are specific to the surveyed group and may not reflect the views of the overall population.

Table 4 Maintenance policy and strategy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	7	20.0	20.0	20.0
	No	26	74.3	74.3	94.3
	Not sure	2	5.7	5.7	100.0
	Total	35	100.0	100.0	

The findings from computerized maintenance management system at DAWASA revealed that majority of respondents (82.9%) believe that there is no computerized maintenance management system (CMMS) at DAWASA. This indicates that a significant portion of the participants perceive the organization to lack a CMMS, which is a software-based system used for managing maintenance activities. Only a small minority of respondents (14.3%) are aware of the existence of a CMMS at DAWASA.

Additionally, a very small proportion of participants (2.9%) expressed uncertainty regarding the presence of a CMMS. These respondents may lack sufficient knowledge or information to determine whether a CMMS is in place at DAWASA.

Table 5 computerized maintenance management system at DAWASA

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	5	14.3	14.3	14.3
	No	29	82.9	82.9	97.1
	Not sure	1	2.9	2.9	100.0
	Total	35	100.0	100.0	

Results also suggest that factors affecting the current maintenance performance were include material vulnerability, lack of pipe and fittings, human activities (construction works), network duration, construction technology practice, material quality, water meter quality, water meter duration, technology, water project design practices, human resources, maintenance limited budget, and water pressure

Table 6 Descriptive Statistics for several factors related to a water project

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Material Vulnerability	35	2	5	3.26	1.120
Lack of pipe and fittings	34	1	4	2.62	1.206
Human activities (construction works)	35	3	5	4.43	.739
Network duration	34	1	4	2.62	1.206
Construction technology practice	35	3	5	4.40	.775
Material quality	34	1	4	2.06	1.347
Water meter quality	35	2	5	4.37	.843
Water meter duration	35	2	5	3.97	.707
Technology	34	1	4	2.65	1.203
Water project design practices	35	3	5	4.11	.867
Human resources	34	1	4	2.68	1.173
Maintenance limited budget	35	3	5	4.46	.741
Water pressure	35	3	5	4.03	.618
Valid N (listwise)	33				

By examining the RII values for each factor, we can assess their relative significance in relation to this issue. Several factors emerge as key contributors to non-revenue water. One such factor is material vulnerability (RII: 0.805). The relatively high RII suggests that the susceptibility of materials used in the water system plays a significant role in contributing to water losses. This vulnerability can result in leaks and failures within the infrastructure, leading to non-revenue water.

The lack of pipe and fittings (RII: 0.765) also stands out as an important factor. Inadequate or absent pipes and fittings contribute to non-revenue water by causing leakages and inefficiencies within the network. This factor underscores the significance of maintaining a robust and reliable water infrastructure to mitigate water losses.

Network duration (RII: 0.834) is another factor that strongly affects non-revenue water. The RII indicates that the age or lifespan of the water network plays a crucial role in contributing to water losses. Over time, deteriorating infrastructure can result in leaks, bursts, and other failures, leading to non-revenue water.

Material quality (RII: 0.845) is closely related to material vulnerability and further emphasizes the importance of using high-quality materials in the water system. Poor material quality can contribute to premature degradation and failures, resulting in non-revenue water.

Water meter quality (RII: 0.851) and water meter duration (RII: 0.880) highlight the significance of accurate measurement and monitoring of water consumption. Faulty or outdated water meters can lead to inaccuracies in measuring water flow, resulting in unaccounted water and non-revenue water.

Technology (RII: 0.868) and water project design practices (RII: 0.868) are additional factors that strongly influence non-revenue water. Effective technological solutions and proper design practices are essential for efficient water management, leak detection, and maintenance planning. Neglecting advancements in technology and design can exacerbate non-revenue water issues.

Human resources (RII: 0.851) and maintenance limited budget (RII: 0.840) signify the importance of skilled personnel and adequate financial resources for maintenance management. Insufficient human resources and budget constraints can hinder regular maintenance activities, leading to delayed repairs and increased non-revenue water.

Lastly, water pressure (RII: 0.988) emerges as the most influential factor contributing to non-revenue water. High water pressure within the distribution system can lead to pipe failures, leakages, and increased non-revenue water. Controlling and optimizing water pressure is crucial to minimize losses and enhance the overall efficiency of the water network.

In general, the relative importance index sheds light on the significant factors affecting maintenance management practices that contribute to non-revenue water. Addressing material vulnerability, the adequacy of pipes and fittings, network duration, material quality, water meter quality and duration, technology, water project design practices, human resources, maintenance budget, and water pressure are key considerations in reducing non-revenue water and improving the overall sustainability of water supply systems.

Table 7 Relative Importance Index (RII) of factors for NRW

FACTORS	Strongly Dis-agree	Dis-agree	Fair	Agree	Strongly Agree	∑W	A	N	A*N	RII
Material Vulnerability	1	8	6	21	105	141	5	35	175	0.805
Lack of pipe and fittings	1	8	15	60	50	134	5	35	175	0.765
Human activities (construction works)	1	8	9	24	50	92	5	35	175	0.525
Network duration	1	1	15	24	105	146	5	35	175	0.834
Construction technology practice	1	1	15	84	35	136	5	35	175	0.777
Material quality	1	0	18	24	105	148	5	35	175	0.845
Water meter quality	1	1	15	32	100	149	5	35	175	0.851
Water meter duration	0	0	21	28	105	154	5	35	175	0.880
Technology	1	0	18	28	105	152	5	35	175	0.868
Water project design practices	1	10	1	65	75	152	5	35	175	0.868
Human resources	1	1	15	32	100	149	5	35	175	0.851
Maintenance limited budget	1	6	9	36	95	147	5	35	175	0.840
Water pressure	1	6	6	70	90	173	5	35	175	0.988

Regression Model Summary presents coefficient determinant R2 − Adj. In model 6, after entering all 6 independent variables, R is equal to 0.902 which describes a strong relation between independent variables and dependent variable. R square is equal to 0.814. This is reflecting that 90.1 percent of changes in dependent variable (as competitive advantage) is describing by these independent variables (The availability performance for water system in the building). Here the point is R square didn't involve degree of freedom in analysis. Therefore, with using Adjusted R square (which it involves df) we have R2 − Adj = 0.780, which is more reliable

Table 7 Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.902a	.814	.780	.34652

a. Predictors: (Constant), Maintenance limited budget, Water pressure, Material quality, Water meter duration, Water meter quality

ANOVA test for the independent variables have significant correlation on independent variables. As it can be observed, with P-value= 0.000 it can be concluding that the F is significant in 0.05. This is reflecting that at least one of the independent variable is effective in predicting the dependent variable.

Table 8 ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.667	5	2.933	24.430	.000[b]
	Residual	3.362	28	.120		
	Total	18.029	33			

a. Dependent Variable: Contribution for non - revenue water reduction in water distribution network

b. Predictors: (Constant), Maintenance limited budget, Water pressure, Material quality, Water meter duration, Water meter quality

The magnitude of coefficients of the regression model illustrates the importance of considering factors such as human activities, budget limitations, construction technologies, and water meter quality in developing effective maintenance strategies for the water distribution network. Further analysis and consideration of these factors will be essential in devising targeted and efficient maintenance approaches.

Table 9 Magnitude of Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	3.460	.354		9.762	.000
	Material quality	-.039	.091	-.059	-.426	.673
	Water meter quality	-.125	.144	-.139	-.868	.393
	Water meter duration	.538	.118	.560	4.542	.000
	Water pressure	-.681	.120	-.531	-5.692	.000
	Maintenance limited budget	.177	.088	.251	2.003	.055

a. Dependent Variable: Contribution for non - revenue water reduction in water distribution network

According to table above, all variables and constant value are significant in 0.05 and all T-values are greater than significant in 0.05. B weights are used to predicting changes while Beta weights are used for determining amount of impacting an independent variable on dependent variable.
The regression equation was;

DEPENDENT = *f* (INDEPENDENT)

$$\boldsymbol{Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon}$$

Where;

Y is the investment which is dependent variable.

$\boldsymbol{\beta_o}$ is the intercept coefficient or is the value of dependent variable when the all independent variables are zero.

$\boldsymbol{\beta n}$ $_{(1,2,3,4,5,6)}$ is the change in dependent variable when the independent variable increases by one unit, keeping other independent variables constant.

$$\mathbf{Y= 3.460 – 0.039X_1 – 0.125X_2 + 0.538X_3 - 0.681X_4 - 0.177X_5}$$

Whereas: -

X_1-Material quality, X_2-Water meter quality, X_3-Water meter duration, X_4-Water pressure

X_5-Maintenance limited budget

7.0 Conclusion and Recommendation

Based on the results of the study, it can be concluded that, Firstly, human activities, particularly construction works, are regarded as having a significant influence on maintenance management practices, emphasizing the need to address the challenges and maintenance needs created by construction activities in the water distribution network. Additionally, the limited budget for maintenance is perceived as a crucial factor, highlighting the importance of sufficient financial resources for effective maintenance practices.

Furthermore, construction technology practices and water meter quality are considered significant factors that influence maintenance management practices. On the other hand, material quality and the lack of pipe and fittings are seen as having a relatively lesser impact on maintenance management.

In addition to these findings, the study also utilized the relative importance index (RII) to assess the significance of various factors. The analysis revealed that water pressure and water meter duration are crucial determinants with high RII values. Other factors such as material quality, water meter quality, and human resources also demonstrate notable relative importance.

Factors like network duration, construction technology practice, and technology should not be overlooked, as they can significantly impact system performance. Similarly, factors like material vulnerability, lack of pipe and fittings, and maintenance limited budget, although relatively lower in importance, should still be considered due to their implications for system functioning.

Human activities during construction and water project design practices, while ranking lower in relative importance, can still have notable effects on system performance and efficiency.

Based on the results of the study, several recommendations can be made to improve maintenance management practices in the water distribution network.

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