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Application of Spatial Technologies in the Maintenance of Water Distribution

[1]Gabriel.P, [2]Dr.Kazumb.S, [3]Dr.Oberlin.A

[1]Civil Engineer, [2]Senior Lecturer, [3]Senior Lecturer.
[1]Department of Civil Engineering,
Dar es salaam Institute of Technology.
P.O. BOX 2958.
Dar es salaam, Tanzania.

Abstract

DAWASA is a Public utility with higher value of non-revenue water about 37% which exceeds the required limits of 20% and more than 20,000 customers complains in every month (water leakage, lack of water, water meter, water bill). Non-revenue of 37% is the authority's major issue, implying that every month the authority lost about Tsh6.9 Billion monthly revenue collection due to the loss of water as non-revenue water. Dawasa lost 37% of capital invested in chemicals and electricity in monthly 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 increases complains to customers of leakages and lack of water. The research design employed in this investigation is descriptive. The study was conducted at the Ubungo Regiona of DAWASA area, with a sample size of 42 respondents. Purposive sampling was utilized to select four senior staff members, ensuring relevant information for the research objectives. Both primary and secondary data were collected to ensure accuracy. A questionnaire survey was administered to 42 operational staff, and four managerial staff were interviewed. Data analysis was performed using SPSS version 26 and Excel. The Relative Importance Index the extent to which factors affecting maintenance practices contribute to non-revenue water can be applied to spatial technology.

The Relative Importance Index (RII) was used to determine factors affecting maintenance management practices contribute to non-revenue water. The factors that show RII significance concerning to this issue are Material quality, Water project design practice, Technology indicating its critical importance. Human activities (construction work)), Network duration), Construction technology practice, Water quality, Water meter duration and Water pressure were the main variables considered in the regression model. The developed model was validated using historical data to assess its predictability and accuracy. The findings highlight the effectiveness of the developed maintenance management system, resulting in spatial technology for water distribution in DAWASA.

Qualitative pressure results in bars compared the design and operational of the water network shows the higher the pressure occurs during the operation lead to pipe burst especially at the joint.

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

1.0 Introduction

The rapid technological and economic developments of the recent century have led to the emergence and expansion of a large number of human settlements across the world. However, for a human settlement to be called a proper city, it should contain the infrastructures necessary for comfortable living. One of the basic and yet most complex infrastructures needed in every city is a water distribution system, which can be described as a multi-source and non-directional network. (Alegre and Coelho 2012) In the last few years, urban water network modelling has been boosted to face the new challenges of modern society. The challenges include, among others, leakage management of water distribution network and urban drainage systems. Despite immense progress in human technological ability, tens of thousands of one common leakage problem that regularly causes interruption in water supply is pipes bursting. Following a pipe burst, network maintenance personnel should be able to address the issue as soon as possible while keeping the number of affected citizens to a minimum. Although strong management of repair and maintenance efforts is of paramount importance, the method of choosing the fastest, and most effective way to solve the issue can also play an important role in this regard.(Jian-chuan, Yong-shu et al. 2008)

A possible solution to improve the response time to such problems is the utilization of a Geospatial Information System (GIS) as an enhanced technology in the field of water distribution management. GIS technology can be used for spatial modeling of the urban water network and as an interactive user environment for daily water management tasks (Kadhim, Abdulrazzaq et al. 2021)

1.1 Problem of statement.

Ubungo Regional is a part DAWASA which is Public utility with higher value of non-revenue water about 37% which exceeds the required limits of 20% and more than 20,000 customers complains in every month (water leakage, lack of water, water meter, and water bill). Non-revenue of 37% is the authority's major issue, implying that every month the authority lost about Tsh6.9 Billion monthly revenue collection due to the loss of water as non-revenue water. Dawasa lost 37% of capital invested in chemicals and electricity in monthly 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 increases complains to customers of leakages and lack of water.

1.2 Objectives of the study

The purpose of this study is application of spatial technologies in maintaining of water distribution network in Ubungo Regional. This done through identification of factors affecting maintenance practices in water distribution networks and development of the mathematical model for the factor affecting maintenance of the water distribution network.

2.0 RESEARCH METHODOLOGY

The methodology is described in the table below **2.1 METHODOLOGY MATRIX**

2.1 TABLE METHODOLOGY MATRIX

S/N	Specific Objective	Data required	Data collection method	Data Analysis	Output
1	To identify factors affecting maintenance practices in water distribution networks that can be applied to spatial technology.	-Northing and Easting -water pressure by zone -Water flow rate -Ages of pipe Pipe leakages	1)Google Earth,locas map 2)Literature review 3)Questionnaire s 4)Maintenance activity data 5)cms	Computer software -WaterGEMS -Arcgis/Qgis -GPS Visualiser -Microsoft Excel	Factors affecting maintenance practices in water distribution network

2	To develop the mathematical model for the factor affecting maintenance of the water distribution network that can be applied to spatial technology	Specific objective no 1	Survey 123,mlocas map/Gps	Computer software -WaterGEMS -ArcGIS/Qgis -GPS Visualizer -Microsoft Excel	Evaluate maintenance practices performance of water distribution network using special technology
3	Application and development of a system of spatial technologies in the maintenance of the water distribution network	The specific objective no 1 and no 2	Survey123, locas map/Gps	Computer software -Arcgis -WaterGEMS	Application of Spatial technologies in water network distribution.

3.0.DATA COLLECTION, ANALYSIS AND RESULTS

The purpose of this chapter is to describe the research findings, which are intended to contribute to evaluating the maintenance practices of the water distribution network using spatial technology and reducing the amount of water lost as non-revenue in the Ubungo district. The data collected from different sources during the research through questionnaires and survey 123 has been accurately recorded and analyzed, and the results have been organized into tables and graphs have been used to interpret and present. Furthermore, the analyzed data has been presented in a simplified format, expressed as percentages based on the responses provided by the participants in contrast software such as WaterGems, and Survey 123 ArcGIS evaluates the water distribution network's field survey data .On waterGems the method of analysis based on the nodes pressure and pipe size parameter, during the analysis the nodal pressure and pipe size were determined to identify the designed pressure of certain pipe size that will be compared with the actual operation found on the field that collected by using pressure gauge tool.

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3.1.0 Respondents Characteristics

The results show TABLE 3.1 RESPONDENTS CHARACTERISTICS of the study participants who were involved in evaluation maintenance practices water distribution network using spatial technology and reducing non-revenue water. In terms of gender the majority of the respondent was male (73.8%) while the female (26.2%).

The regarding the level of education, majority of the responds (42.9%) held a certificate or veta, followed by 28.6% had a Diploma or FTC, while bachelor's degree held (21.4%) and only a small percentage (7.1%) held a Master's degree,

In terms of the department, the majority of the respondents (40.5%) were from the operation and maintenance department, followed by customer care (28.6%) then planning and construction (19.0%) and billing (7.1%). Only a small percentage of respondents were from the ICT department (4.8%).

Regarding their position, the majority of respondents (42.9%) were casual labor, followed by customer care (19.0%),the followed artisan with an additional (19.0%.) and Principal technician (7.1%) A small percentage of respondents were in higher positions such as engineer (4.8%) and manager (2.4%).

Finally, years of experience, the majority of respondents (54.8%) had more than ten years of experience, followed by those with 5-10 years of experience (35.7%). Only a small percentage of less than five years (23.8%) of experience.

TABLE 3.1RESPONDENTS CHARACTERISTICS

VARIABLE	RESPONSE	FREQUENCY	PERCENT (%)
Gender	Male	31	73.8
	Female	11	26.2
Level of education	Bachelor degree	9	21.4
	Master's degree	3	7.1
	Diploma/FTC	12	28.6
	Certificate/Veta	18	42.9

Department	Operation and maintenance	17	40.5
	Planning and construction	8	19
	ICT	2	4.8
	Customer care	12	28.6
	Billing	3	7.1
Position of respondent	Casual labour	18	42.9
	Artisan	8	19
	Customer care	10	23.8
	Engineer	2	4.8
	Principal Technician	3	7.1
	Manager/Director	1	2.4
Years of experience	More than 10 years	23	54.8
	Between (5 - 10) years	15	35.7
	Less than 5 years	10	23.8
TOTAL		**42**	**100**

3.2 THE TYPE OF MAINTENANCE USED IN WATER DISTRIBUTION NETWORK AT UBUNGO REGIONAL .

The study examined the maintenance practices employed in the water distribution network at Ubungo Regional. The findings Table 3.2 Type of maintenance used in water distribution network at UBUNGO revealed that out of the 42 respondents, 42.9% reported using preventive maintenance, which involves regular inspections and replacements to prevent equipment failures. Additionally, 45.3 % stated that 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 using 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 3.2 TYPE OF MAINTENANCE USED IN WATER DISTRIBUTION NETWORK AT UBUNGO

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Preventive Maintenance	18	42.9	42.9	42.9
	Both Preventive and Corrective Maintenance	1	2.4	2.4	45.3
	Corrective Maintenance	6	14.3	14.3	59.6
	Emergency Maintenance	15	35.7	35.7	95.3
	Not at all	2	4.8	4.7	100.0
	Total	42	100.0	100.0	

3.3 COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM AT UBUNGO REGIONAL

The findings table 3.3 computerized maintenance management system at Ubungo Regional reveal that the most of respondents (90.5%) believe 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, software-based system used for managing maintenance activities. Only a small minority of respondents (7.1 %) know existence of a CMMS at DAWASA.

Additionally, a very small proportion of participants (2.4%) expressed uncertainty regarding the presence of a CMMS. These respondents may lack sufficient knowledge or information to determine whether a CMMS exist at DAWASA.

TABLE 3.3 COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM AT UBUNGO

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	3	7.1	7.1	7.1
	No	38	90.5	90.5	97.6
	Not sure	1	2.4	2.4	100.0
	Total	42	100.0	100.0	

3.4 BUDGET FOR WATER MAINTENANCE DISTRIBUTION NETWORK ADEQUATE

The findings table 3.4 budget for water maintenance distribution network adequate regarding the adequacy of the budget for water distribution network maintenance reveal diverse perspectives among the respondents. A significant majority of participants, comprising 45.2%, rated the budget as poor, indicating that they believe the allocated funds are insufficient to adequately address the maintenance needs of the water distribution network. This suggests a concern about the budgetary allocation and the potential impact on the network's maintenance.

On the other hand, a smaller percentage of respondents, 9.5%, viewed the budget as excellent, indicating that they consider the allocated funds to be more than adequate, falling within the range of 80-100% adequacy. These individuals' express confidence that the budget is substantial enough to effectively maintain the water distribution network.

Furthermore, 21.4% of respondents rated the budget as good, falling within the range of 40-60% adequacy. This group believes that the budget is moderately sufficient for maintaining the network, indicating a more balanced perception compared to those who rated it as poor or excellent.

A significant proportion, 16.7%, rated the budget as moderate, 20-40% adequacy range. These respondents express a believe the allocated funds are inadequate for maintaining the water distribution network, reflecting a more cautious assessment.

A small minority, 2.4%, rated the budget as very poor (0-20% adequacy), highlighting a severe inadequacy in their view, while another 4.8% considered it to be very good (60-80% adequacy), suggesting a perception that the allocated funds are more than sufficient.

TABLE 3.4 BUDGET FOR WATER MAINTENANCE DISTRIBUTION NETWORK ADEQUATE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Poor	19	45.2	45.2	45.2
	Excellent (80 - 100) %	4	9.5	9.5	54.7
	Good (40 - 60) %	9	21.4	21.4	76.1
	Moderate (20 - 40) %	7	16.7	16.7	92.8
	Poor (0 - 20) %	1	2.4	2.4	95.2
	Very good (60 - 80) %	2	4.8	4.8	100.0
	Total	42	100.0	100.0	

3.5 Factors affecting maintenance practices in water distribution network.

The table 3.5 presents descriptive statistics for several factors related to a water project. Each factor is characterized by the number of observations, minimum and maximum values, mean, and standard deviation. The factors 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. These statistics provide valuable insights into the various aspects of the project, such as the susceptibility of materials to damage, the impact of pipe and fitting shortages, the influence of human activities on the project, the time required for network-related activities, adherence to construction technology practices, material and water meter quality, technological implementation, design practices, availability and effectiveness of human resources, budget constraints on maintenance, and water pressure.

Table 3.5 Descriptive Statistics for several factors related to a water project

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Material Vulnerability	42	2	8	4.26	1.520
Lack of pipe and fittings	41	1	6	2.72	1.246
Human activities (construction works)	42	4	7	5.83	.939
Network duration	41	1	6	2.82	1.246
Construction technology practice	42	3	5	4.40	.895
Material quality	41	1	9	3.06	1.640
Water quality	42	2	5	4.37	.843
Water meter duration	42	2	5	3.97	.707
Technology	41	1	4	2.65	1.203
Water pressure	42	3	8	5.03	.957
Valid N (listwise)	40				

3.6.0 Factors affecting maintenance practices in water distribution networks.

The study deals into investigating the various factors that influence maintenance practices in water distribution networks and their potential applicability to spatial technology, as determined by the Relative Importance Index (RII). The RII Table 3.6 Factors affecting maintenance practices in water distribution networks offers a valuable means of assessing the significance of each identified factor. Among the factors analyzed, "Material Vulnerability" emerges as one of the key contributors, with an RII value of 0.69, signifying its moderate importance. However, it is noteworthy that another aspect of "Material Vulnerability" stands out as the most critical factor, garnering a high RII value of 0.98. This suggests that addressing material vulnerabilities in water distribution networks could have a substantial impact on maintenance practices and overall network reliability when spatial technology is applied.

Table 3.6 Factors affecting maintenance practices in water distribution networks

	Factors	SA	A	F	D	SD	∑W	A	N	A*N	RII	
I.	Material Vulnerability	40	40	57	4	3	144	5	42	210	0.69	Significant
II.	Lack of pipe and fittings	110	68	9	0	0	187	5	42	210	0.89	Mostly Significant
III.	Human activities (construction work)	80	104	0	0	0	184	5	42	210	0.88	Mostly Significant
IV.	Network duration	75	104	1*3	0	0	179	5	42	210	0.85	Mostly Significant
V.	Construction technology practice	0	0	16	38	19	73	5	42	210	0.35	Not Significant
VI.	Material quality	95	92	0	0	0	187	5	42	210	0.89	Mostly Significant
VII.	Water quality	150	48	0	0	0	198	5	42	210	0.94	Mostly Significant

VIII.	Water meter duration	0	0	0	36	24	60	5	42	210	0.29	Not Significant
IX.	Water project design practice	0	0	0	78	3	81	5	42	210	0.39	Not Significant
X.	Technology	0	0	0	34	25	59	5	42	210	0.28	Not Significant
XI.	Water pressure	60	64	42	0	0	166	5	42	210	0.79	Mostly Significant

The study also highlights the importance of factors such as "Lack of pipe and fittings," "Human activities (construction work)," "Network duration," and "Construction technology practice," all of which are assigned an RII value of 0.85, designating them as highly influential. These factors play crucial roles in determining the frequency and intensity of maintenance activities in the water distribution network. Leveraging spatial technology to monitor and manage these aspects can lead to more efficient and targeted maintenance practices.

On the other hand, the study identifies some factors with relatively lower RII values, suggesting their less pronounced influence on maintenance practices. For instance, "Material quality" is considered a less significant factor with an RII value of 0.35, while "Water project design practice" and "Technology" are also found to have limited impact, with RII values of 0.39 and 0.28, respectively. Though these factors may not be as crucial in isolation, they should not be entirely disregarded, as they might still interact with other influential factors and affect maintenance practices when spatial technology is applied.

Furthermore, the study underscores the substantial impact of "Water quality" and "Water meter duration," both deemed highly significant with RII values of 0.89 and 0.94, respectively. Water quality directly affects the condition and lifespan of distribution system components, while the duration of water meters can have implications for maintenance planning and resource allocation. Integrating spatial technology to monitor water quality and meter durations can optimize maintenance efforts and promote more sustainable practices.

Finally, "Water pressure" is identified as another important factor with an RII value of 0.79. Monitoring water pressure through spatial technology can aid in identifying areas with potential leakages or pressure-related issues, enabling proactive maintenance measures to reduce system losses and enhance network performance.

3.7.0 DEVELOPMENT OF THE MATHEMATICAL MODEL FOR THE FACTOR AFFECTING THE MAINTENANCE TO WATER DISTRIBUTION NETWORK THAT CAN BE APPLIED TO SPATIAL TECHNOLOGY.

Multiple regression model is a statistical technique that uses several explanatory variables to predict the outcome of a response variable. The goal of multiple regression equation is to model the linear relationship between the explanatory (independent) variable and response (dependent) variable. It is a function that allows an analyst statistician to make a prediction about one variable based on the information that is known about another variable.

Multiple regression model is one of the useful models that can be used in the managing maintenance. It is a mathematical model which shows the progression of a regression model with two or more independent variables. They are the methods of studying the effect and magnitude of more than one independent variable into its established dependent variable by using correlation and regression (Kothari 2017)

There are three (3) major uses of the multiple regression analysis.

(i) It might be used to identify the strength of the effect that the independent variables have on a dependent variable.
(ii) It can be used to forecast the effect or impact of changes. That is multiple regression analysis helps us to understand how much changes happens when we change the independent variable.

(iii) Multiple regression analysis enables to predict the trend and future values. The mltiples regression analysis can be used to get point estimates.

Maintenance Practices = $\beta_0 + \beta_1$ * Material Vulnerability + β_2 * Lack of pipe and fittings + β_3 * Age + ... + β_n * Water pressure + ε

Where:

Maintenance Practices are the dependent variable representing maintenance practices like maintenance frequency, repair costs, etc..

Lack of pipe and fittings Water pressure, Material Vulnerability and other variables are the independent variables.

The regression coefficients $\beta_0, \beta_1, \beta_2, \ldots \beta_n$ representing the impact of each independent variable on the dependent variable. And ε is the error term, representing the unexplained variance or noise in the model.

3.7.1 Model summary

The second table generated in a linear regression test in SPSS is Model Summary. It provides detail about the characteristics of the model. In the present case, Material quality, Water meter duration, Human activities (construction work), Material Vulnerability, Water pressure, Lack of pipe and fittings, Network duration and Water quality were the main variables considered. The model summary table looks like below.

Table 3.7.1 Model summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.911a	.829	.794	.47588

a. Predictors: (Constant), Material quality, Lack of pipe and fittings, Material Vulnerability, Human activities (construction work), Water pressure, Network duration, Water quality

Elements of this table relevant for interpreting the results:

- R-value represents the correlation between the dependent and independent variable. A value greater than 0.4 is taken for further analysis. In this case, the value is .911, which is good.
- R-square shows the total variation for the dependent variable that could be explained by the independent variables. A value greater than 0.5 shows that the model is effective enough to determine the relationship. In this case, the value is .829, which is good.
- Adjusted R-square shows the generalization of the results i.e. the variation of the sample results from the population in multiple regression. It is required to have a difference between R-square and Adjusted R-square minimum. In this case, the value is .836, which is not far off from .794, so it is good.

Therefore, the model summary table is satisfactory to proceed with the next step

3.7.2 ANOVA TABLE

This is the third table in a regression test in SPSS. It determines whether the model is significant enough to determine the outcome. It looks like below

Table 3.7.2 ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	37.443	7	5.349	23.620	.000b
	Residual	7.700	34	.226		
	Total	45.143	41			

a. Dependent Variable: Spatial technologies in the maintenance of water distribution network

b. Predictors: (Constant), Material quality, Lack of pipe and fittings, Material Vulnerability, Human activities (construction work), Water pressure, Network duration, Water quality

Elements of this table relevant for interpreting the results are:

- **P-value/ Sig value:** Generally, 95% confidence interval or 5% level of the significance level is chosen for the study. Thus the p-value should be less than 0.05. In the above table, it is .000. Therefore, the result is significant.
- **F-ratio:** It represents an improvement in the prediction of the variable by fitting the model after considering the inaccuracy present in the model. A value is greater than 1 for F-ratio yield efficient model. In the above table, the value is 67.2, which is good.

These results estimate that as the p-value of the ANOVA table is below the tolerable significance level

3.7.3 Coefficient

Below table shows the strength of the relationship i.e. the significance of the variable in the model and magnitude with which it impacts the dependent variable.

Table 3.7.3 Coefficient table

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	.190	2.921		3.146	.003
Material Vulnerability	.163	.105	.169	1.560	.000
Lack of pipe and fittings	.036	.237	.022	.153	.000
Human activities (construction work)	.005	.250	.471	4.017	.000
Network duration	.056	.359	.028	.156	.000
Water quality	.175	.447	.076	.391	.000
Water pressure	.411	.116	.513	3.529	.001
Material quality	.031	.272	.015	.114	.000

a. Dependent Variable: Spatial technologies in the maintenance of water distribution network

According to the table above, all variables and constant values are significant at 0.05 and all T-values are greater than significant at 0.05. B weights are used to predict changes while Beta weights are used for determining the amount of impact an independent variable has on the dependent variable.

The regression equation was;

DEPENDENT = *f* (INDEPENDENT)

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

Where;

Y is the investment which is the dependent variable.

β_o is the intercept coefficient or the value of the dependent variable when all independent variables are zero.

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

3.8 Model Validation

Model validation is the process of deciding whether the numerical results quantifying the predicted relationship between a dependent variable and independent variables obtained from regression analysis are acceptable as a description of the data. The table below summarizes data from the documentary review recorded in the Ubungo Regional for the period of 12-month different sessions which are used in the development of the model; the data were used to validate the model Table 3.8.0 and Figure 3.8

Table 3.8.0 calculated using Microsoft Excel Spreadsheet (see Table below), the validation shows the average predicting accuracy of the model is to be 82.4%

Monthly	Downtime	Uptime (per Hours,hrs)	(Constant)	Material Vulnerability	Lack of pipe and fittings	Human activities (construction work)	Network duration	Water quality	Water pressure	Material quality	Actual (A.P)	Model PREDICTION
	Model		**0.55**	**0.41**	**0.71**	**0.43**	**0.71**	**0.27**	**0.11**	**0.82**		

Jan	0	30	0.55	12.300	21.300	12.900	21.300	8.100	3.300	19.680	100%	99.43
Feb	6	24	0.55	9.840	17.040	10.320	17.040	6.480	2.640	19.680	80%	83.59
Mar	0	30	0.55	12.300	21.300	12.900	21.300	8.100	3.300	24.600	100%	104.35
April	0	30	0.55	12.300	21.300	12.900	21.300	8.100	3.300	24.600	100%	104.35
May	6	24	0.55	9.840	17.040	10.320	17.040	6.480	2.640	19.680	80%	83.59
Jun	0	30	0.55	12.300	21.300	12.900	21.300	8.100	3.300	24.600	100%	104.35
Jul	6	24	0.55	9.840	17.040	10.320	17.040	6.480	2.640	19.680	80%	83.59
Aug	3	27	0.55	11.070	19.170	11.610	19.170	7.290	2.970	22.140	90%	93.97
Sep	1	29	0.55	11.890	20.590	12.470	20.590	7.830	3.190	23.780	97%	100.89
0ct	7	23	0.55	9.430	16.330	9.890	16.330	6.210	2.530	18.860	77%	80.13
Nov	3	27	0.55	11.070	19.170	11.610	19.170	7.290	2.970	22.140	90%	93.97
Dec	5	25	0.55	10.250	17.750	10.750	17.750	6.750	2.750	20.500	83%	87.05
	Material Vulnerability										90%	93.84

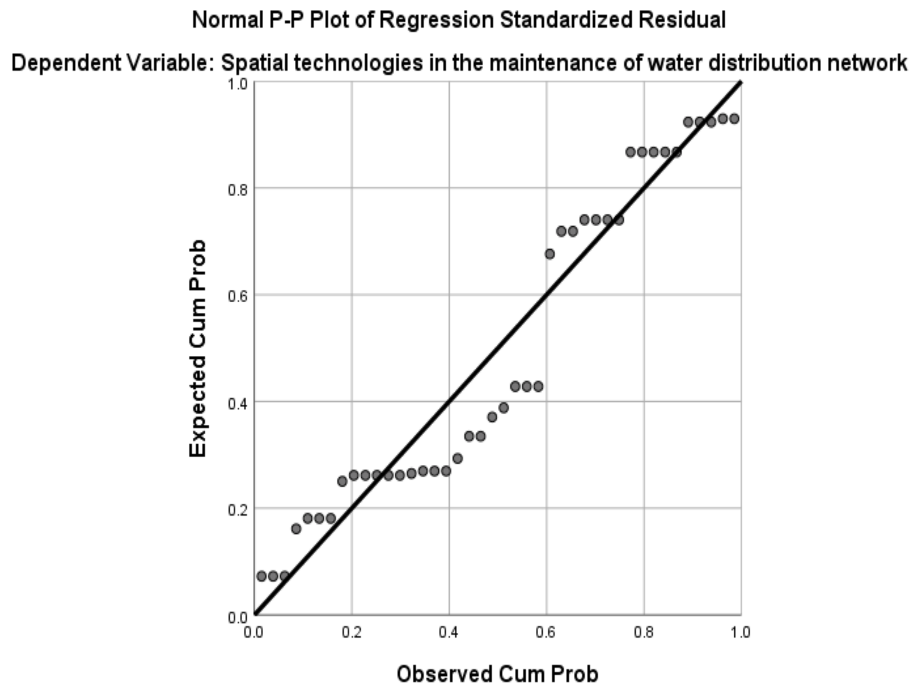

Figure 3.8 Trending Line for Multiple Regression

3.9.0 APPLICATION SPATIAL TECHNOLOGIES IN THE MAINTENANCE OF THE WATER DISTRIBUTION NETWORK

3.9.1 Introduction

In order to achieve the specific objectives no 2 data collection of this studies were collected by using Survey 123 ArcGIS and the analysis of data done by both survey 123 ArcGIS and water Gems.

The tool for leakage and pipe replacement data collection is Survey 123 ArcGIS the window is indicated below figure 3.9.1, figure 3.9.2 and figure 3.9.3

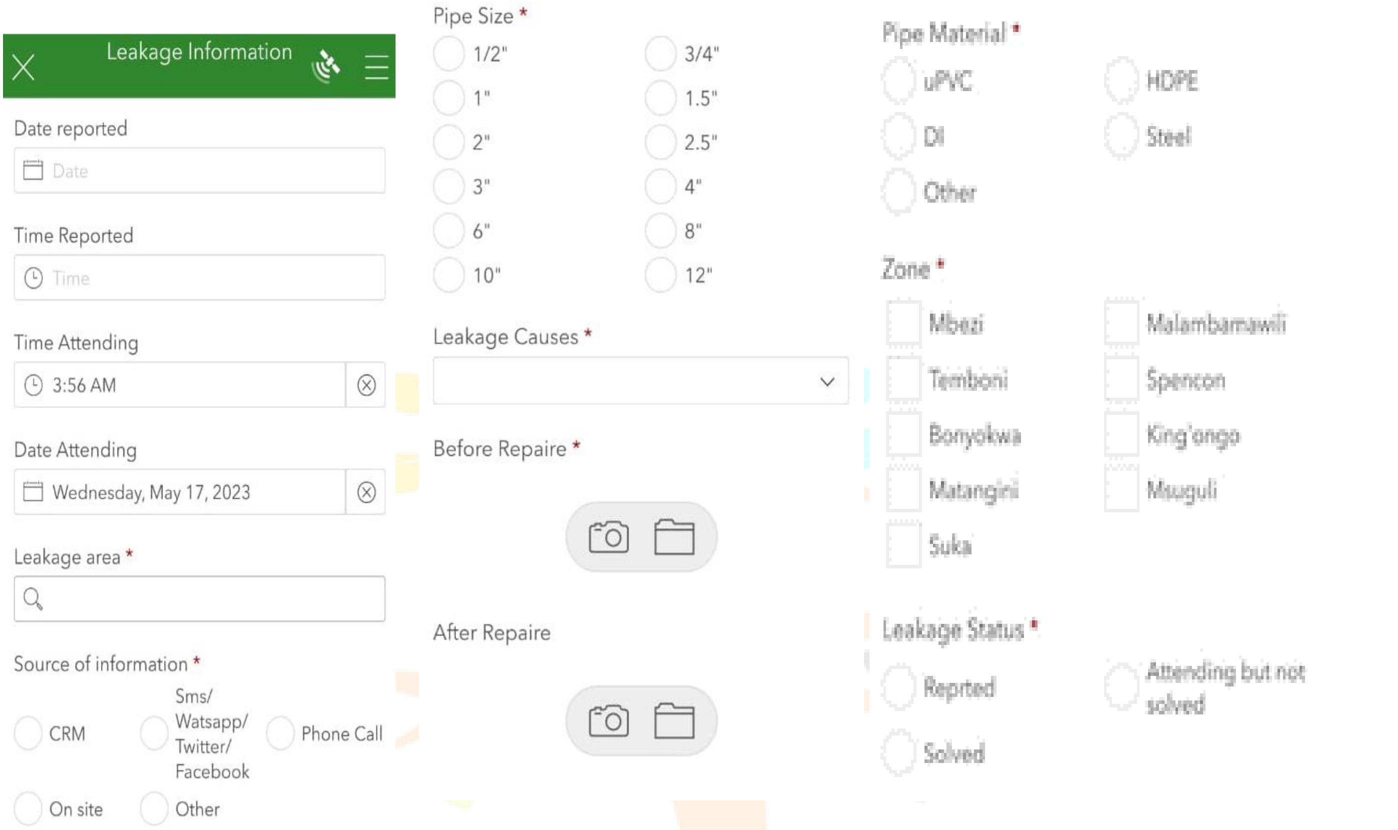

Figure 3.9.1: Show The tool for leakage data collection is Survey 123

Pipe replacement data collection tool (survey 123)

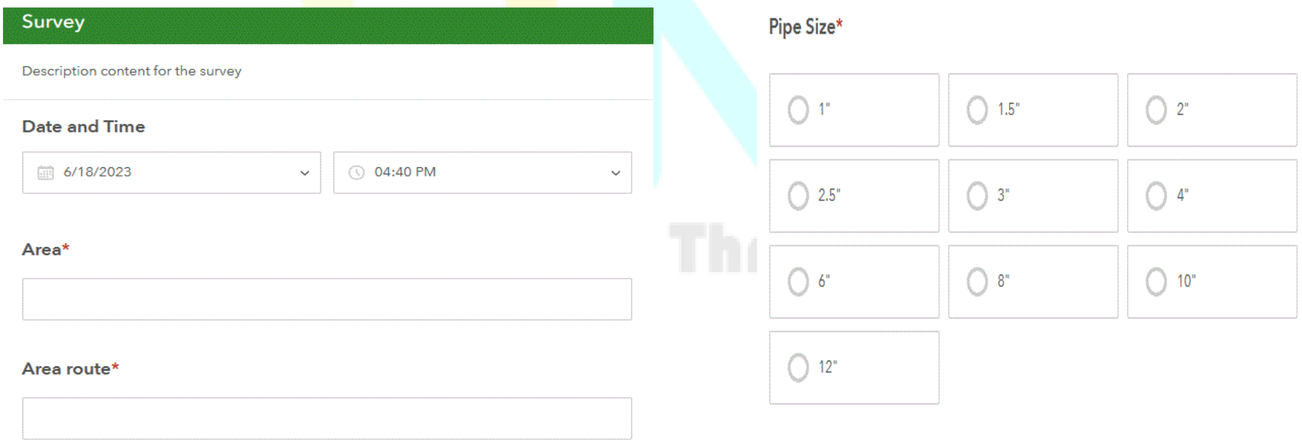

Figure 3.9.2: Show Pipe replacement data collect tool (survey 123)

Pipe route*

Figure 3.9.3: Show Pipe route

3.9.2 SOURCE OF INFORMATION

The Table 3.9.2 for source of information below show the information of leakage (non-revenue water) from different sources example the leaks that reported by phone call tend to be high (34.26%) while on site tend to be (32.09%),watsup/sms/twitter /face book tend to be followed by (30.4%) and then minimum percent tend to be reported by other means of communication (1.57%) and CRM (0.84%) of whole non-revenue water (leaks) reported.

Table 3.9.2 for source of information

Answers	Count	Percentage
Phone Call	284	34.26%
On site	266	32.09%
Sms/Watsapp/Twitter/Facebook	252	30.4%
Other	13	1.57%
CRM	7	0.84%

The above graph show Figure 3.9.2 the number of leakages (non-revenue water) reported from different sources example ,the leaks that found on site tend to be 266 and phone call 284.sms/Twitter/Facebook 252,other 13 and CRM 7 of the total number (829) of non -revenue water reported .

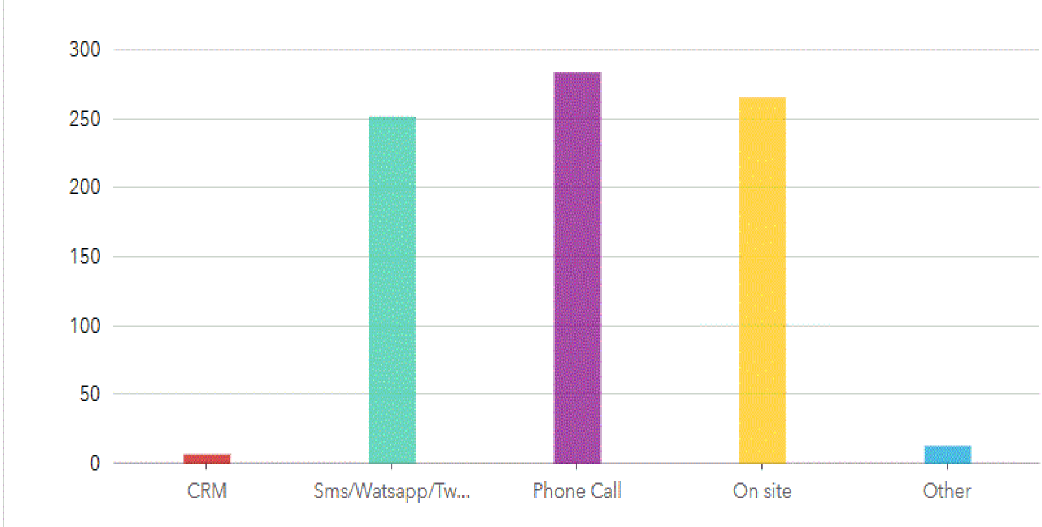

Figure 3.9.2: Graph source of information

The below Figure 3.9.**3** spatial image shows the distribution of different non-revenue water reported (leakage)in the Ubungo regional.

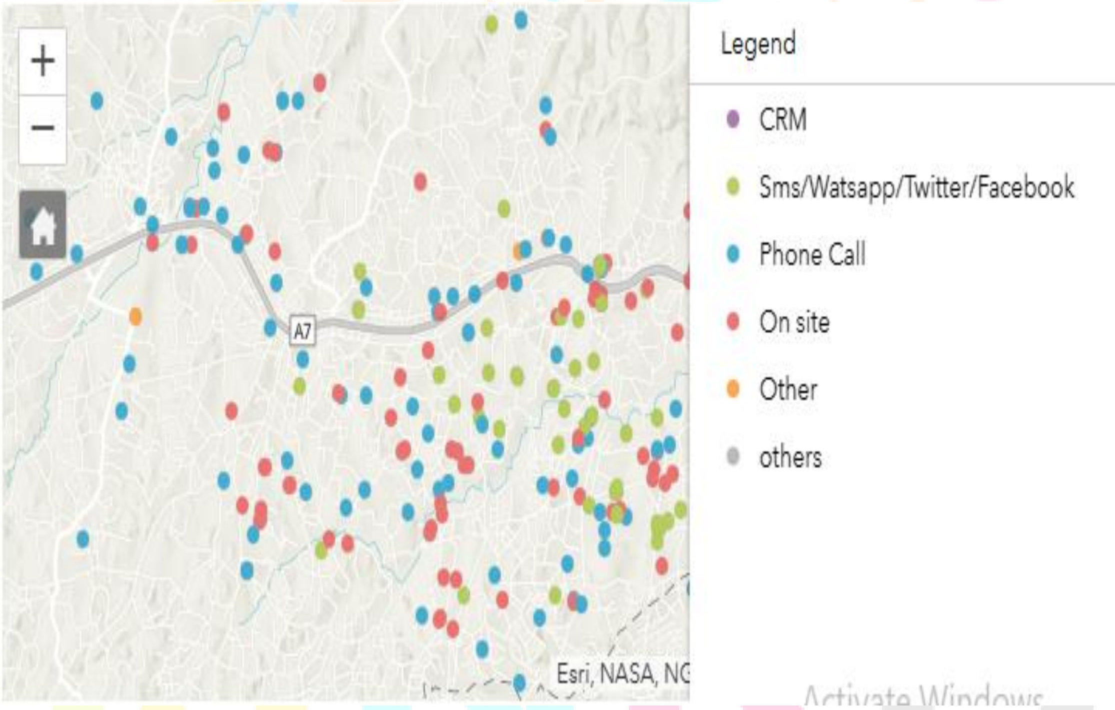

Figure 3.9.3: Spatial images for information

3.9.4 LEAKAGE STATUS

The Table 3.9.4.1 and Figure 3.9.4.1 shows the status of leakage control (non-revenue water) the leakage repaired (Solved) tend to be 79.73% while attending but not solved (that means the problem are either partially or not solved completely but the responsible personnel knows the problem well) the reported leaks tend to be 18.46%and the leakage reported only but not well known by the responsible personnel tend to be 0.97%

Table 3.9.4.1: Show Leakage Status

Answers	Count	Percentage
Reprted	8	0.97%
Attending but not solved	153	18.46%
Solved	661	79.73%

LEAKAGE STATUS PIE CHART

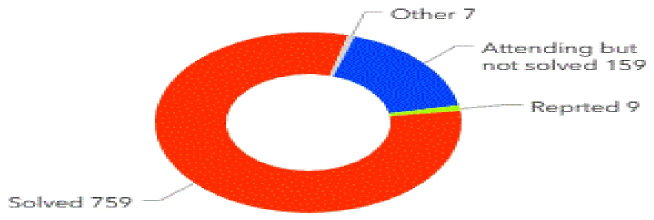

Figure 3.9.4.1: Leakage status pie chart.

SPATIAL LEAKAGE IMAGE

Spatial image leakages

The Figure 3.9.4.2 Spatial image shows how the leakage is distributed in different zones along the water pipe network by status (reported, attending but not solved and solved).

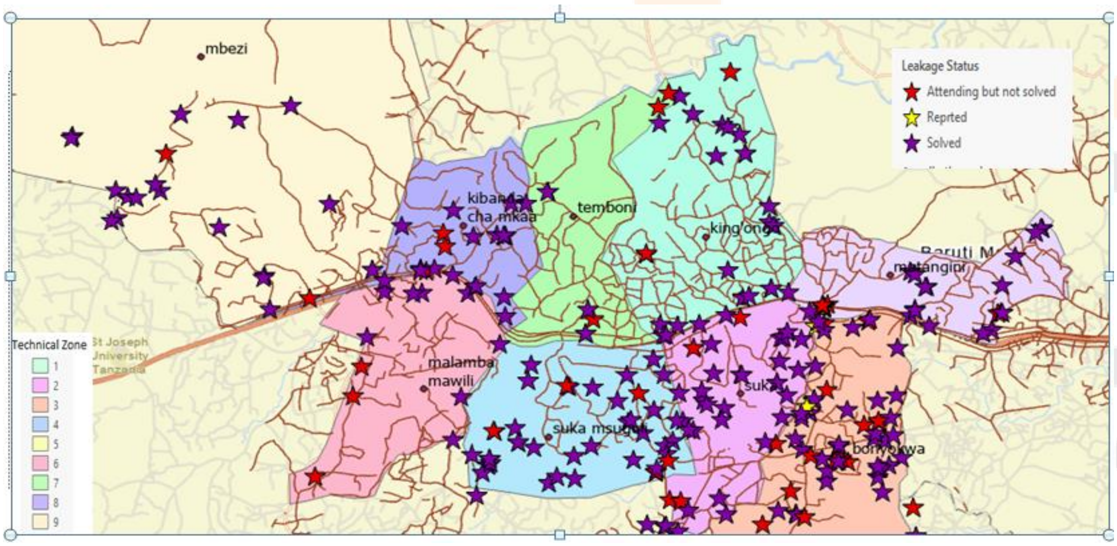

Figure 3.9.4.2 Spatial image leakages

3.9.5 LEAKAGE REASONS

The Table 3.9.5,. Figure 3.9.5A and Figure 3.9.5.B an: above shows the different causes of leakage at particular area (zone) example most of the leakages tend to be caused by the aged pipe which tend to have 250 leaks, followed by high pressure which count 192 while human activities 166 followed by low quality of material which count 121, worn out of fittings 57, other 27 and floods tend to count 9and**.**

Table 3.9.5.: LEAKAGE REASONS

Answers	Count	Percentage
Aged Pipe	250	30.16%
Human Activities	166	20.02%
High pressure	192	23.16%
Low Quality Mterial	121	14.6%
Floods	9	1.09%
Worn out of fitting	57	6.88%
Other	27	3.26%

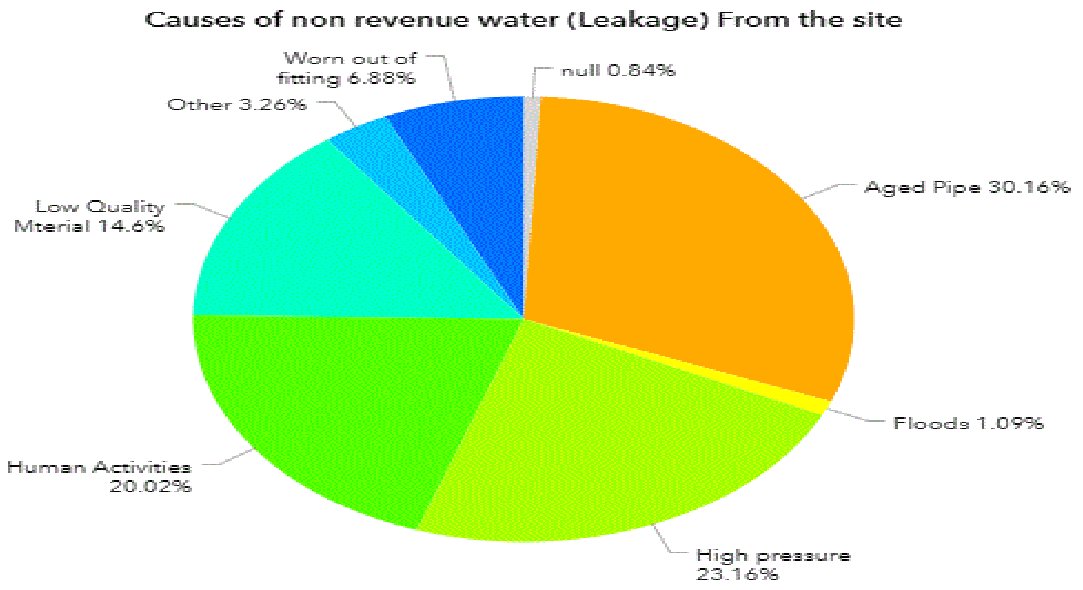

Figure 3.9.5A: Pie chart for water reasons

SPATIAL IMAGE OF LEAKS REASONS

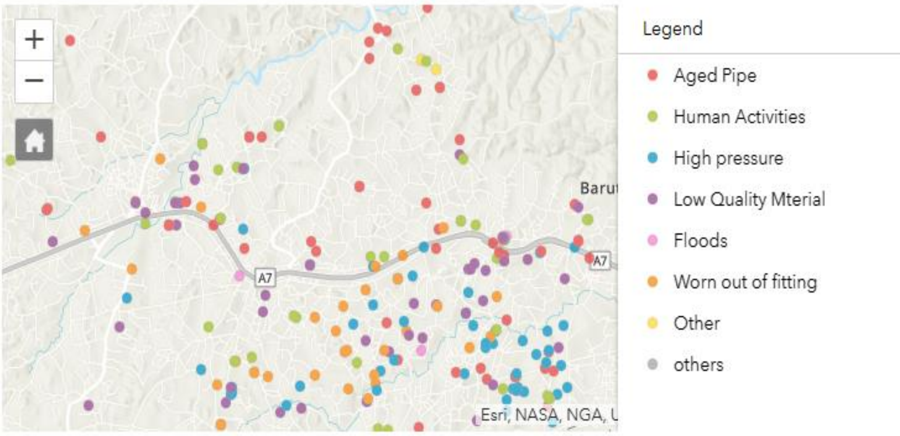

Figure 3.9.5.B: Spatial image for leaks reasons

Simulation of the water network by using WaterGems software

The below Figure 3.9.5C, Table 3.9.5A, Table 3.9.5B Table 3.9.5.AB, to shows the results generated by the waterGems during the design of the project. The nodes tend to provide the pressure required reach to the customers also the result collected during the operation of the water distribution network.

The simulation of the water project which was done by using waterGems software tend to show the result as shown above in which the pressure tends to be 2bars in diameter of 174.9mm (6") during the operation

Pressure results were obtained as shown on the Table 3.9.5BC below ,by 19 May 2023 the pressure tended to be higher as the results the pipe tended to leaks at the joint in which male and female pipe joined

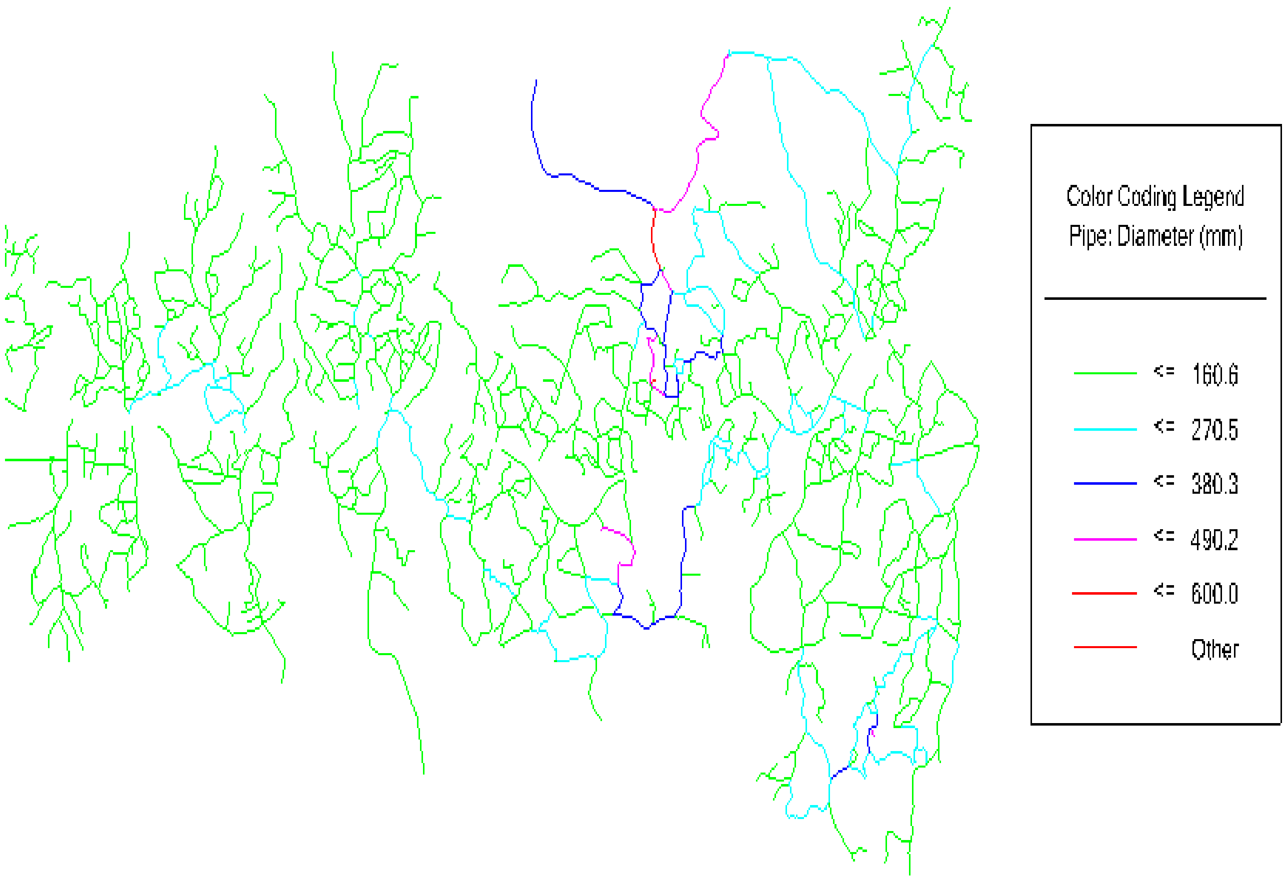

Figure 3.9.5C: Simulation of the water network

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Table 3.9.5A: results generated

ID	Elevation (m)	Demand (L/s)	Hydraulic Grade (m)	Pressure (bars)
918	164.00	0	180.11	2
919	163.20	0	181.30	2
920	164.00	0	182.67	2
921	163.20	0	181.59	2
922	163.70	0	181.78	2
923	164.00	0	181.93	2
924	164.00	0	181.98	2
925	163.30	0	182.18	2
926	163.50	0	182.43	2
927	158.50	0	183.65	2
928	158.00	0	183.65	3
929	158.00	0	183.65	3
930	160.00	0	183.65	2
931	161.00	0	183.65	2
932	164.00	0	183.65	2
933	164.80	0	183.65	2
934	166.60	0	183.70	2
935	184.70	0	195.05	1
936	184.50	0	194.96	1
937	184.00	0	194.87	1
938	183.60	0	194.78	1
939	184.00	0	194.63	1
940	184.00	0	194.42	1
941	186.00	0	194.31	1
942	184.00	0	194.17	1
943	184.00	0	194.12	1
944	182.00	0	194.03	1
945	162.00	0	192.92	3
946	178.00	0	193.86	2
947	161.00	0	192.88	3
948	174.00	0	193.66	2
949	160.00	0	192.79	3
950	167.00	0	193.31	3

Table 3.9.5B: diameter of the pipe

ID	Length (Scaled) (m)	Diameter (mm)	Velocity (m/s)	Headloss Gradient (m/m)
9381	5	174.9	0.37	0.001
9382	5	174.9	0.37	0.001
9383	10	174.9	0.37	0.001
9384	58	174.9	0.37	0.001
9385	18	174.9	0.37	0.001
9386	41	174.9	0.37	0.001
9387	66	174.9	0.37	0.001
9388	18	174.9	0.37	0.001
9389	39	174.9	0.37	0.001
9390	18	174.9	0.37	0.001
9391	23	174.9	0.37	0.001
9392	16	174.9	0.37	0.001
9393	20	174.9	0.37	0.001
9394	33	174.9	0.37	0.001
9395	13	78.5	0.58	0.005
9396	16	78.5	0.58	0.005
9397	19	78.5	0.58	0.005
9398	31	78.5	0.58	0.005
9399	26	78.5	0.58	0.005
9400	52	78.5	0.58	0.005
9401	6	78.5	0.58	0.005
9402	13	78.5	0.58	0.005

Table 3.9.5.AB: Designed by using wateGems

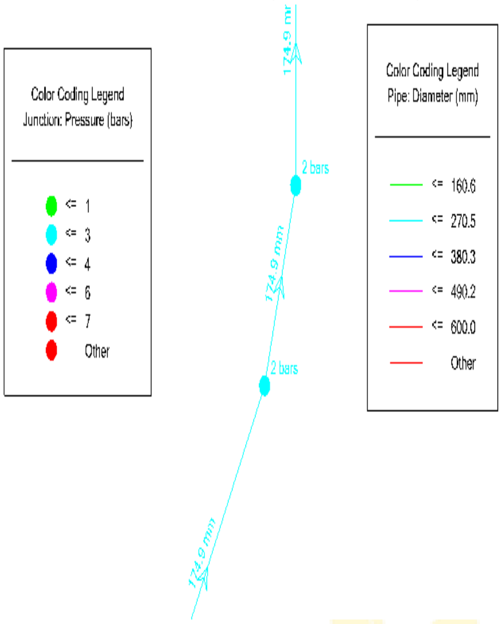

Table 3.9.5.BC: Operation reading pressure

Date	Time	Bar Reading	Technician Name
13 May 2023	7:10am-6:25pm	2.0	Hamis juma
14 May 2023	7:31am-7:50pm	2.6	Hamis juma
16 May 2023	6:55am-6:05pm	2.8	Hamis juma
18 May 2023	7:17am-6:23pm	2.4	Hamis juma
19 May 2023	7:02am-6:12pm	3.9	Hamis juma
22May 2023	7:15am-7:09pm	2.7	Hamis juma

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4.0. PIPE REPLACEMENT

The Table 4.0 and Figure 4.0 below shows the data collected and spatial distribution for pipe replacement for planning in which (44.44%) of 6" pipe size of PVC class C where 22.22% of 4" ,8" of 22.22% and then followed by 3" of which tend to have 11/11%.

Proposed pipe spatial replacement map

Table 4.4.7: Pipe Replacement

Answers	Count	Percentage
6"	4	44.44%
4"	2	22.22%
8"	2	22.22%
3"	1	11.11%

Figure 4.0.2: Proposed pipe spatial replacement map

4.1 UBUNGO REGIONAL DASHBOARD

The Ubungo Regional Dashboard Leakage Dashboard Figure 4.3.0 enables staff to monitor solved leaks, attending but not solved and other by day, week, month, or year as well as repairs in zonal wise. Dashboards are also used to understand leakages per pipe diameter, material, and location.

ArcGIS Dashboards is used to create dashboards that manage the work and visualize data being collected. The progress of inspections is easily tracked, providing a view of leakage status. Ubungo Regional can quickly identify the areas or zones with many leakages with the reason causes.

The use of dashboards has raised awareness among staff and improved operation and maintenance management of daily operations. Engineers and other staff are able to access dashboards using their smart phones and desktop or personal computers.

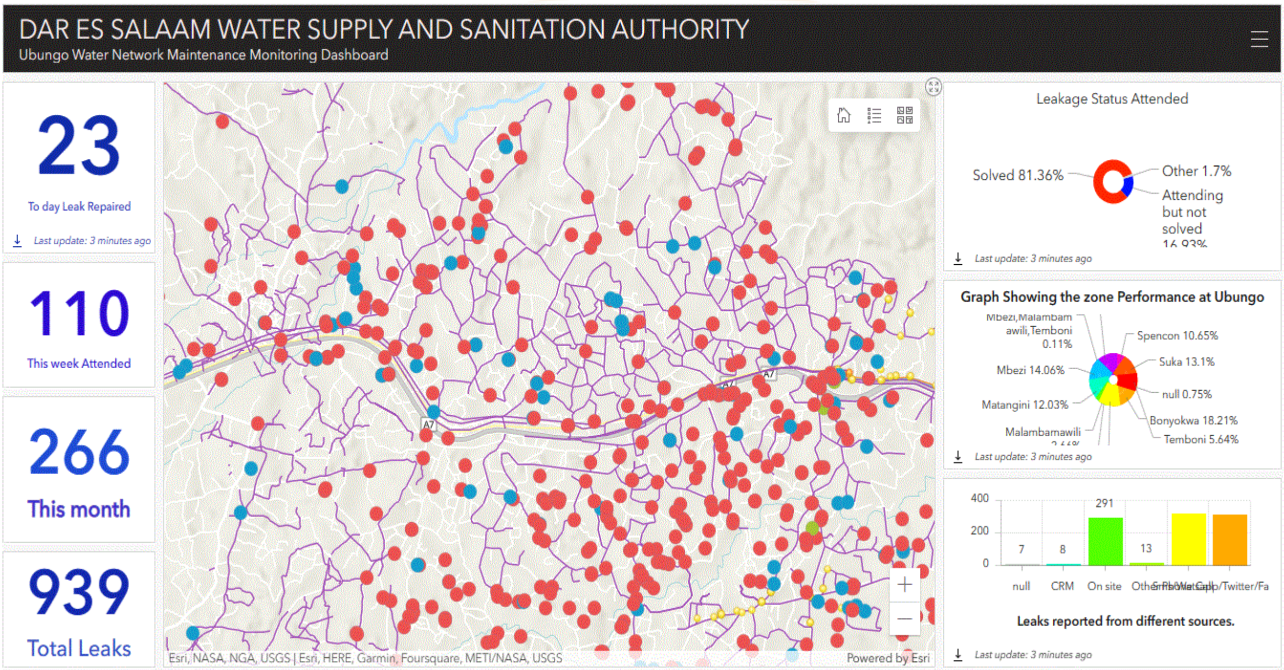

Figure 4.1: Dashboard for leakage control activities.

5.0 DISCUSSION OF RESULTS

5.1 Introduction

In this chapter, the study results are examined and analyzed in connection with the research questions. The main discoveries, importance, and potential consequences of the findings are emphasized. The discussion is focused on addressing the specific objectives of the study.

5.2.0 Identified factors affecting maintenance practices in water distribution networks

The results of the study provide valuable insights into the factors affecting maintenance practices in water distribution networks and their potential application to spatial technology. The descriptive statistics table presents information on various factors related to a water project, including material vulnerability, lack of pipe and fittings, human activities (construction works), network duration, construction technology practice, material quality, water quality, water meter duration, technology, water project design practices, human resources, maintenance limited budget, and water pressure. These statistics offer a comprehensive understanding of different aspects of the project and help identify areas that may require improvement in maintenance practices.

The Relative Importance Index (RII) analysis further evaluates the significance of each identified factor. "Material Vulnerability" stands out as a key contributor with an RII value of 0.69, indicating its moderate importance. However, another aspect of "Material Vulnerability" emerges as the most critical factor, garnering a high RII value of 0.98. This emphasizes the importance of addressing material vulnerabilities in water distribution networks, especially when spatial technology is applied, as it can significantly impact maintenance practices and overall network reliability.

The study highlights several other highly influential factors, such as "Lack of pipe and fittings," "Human activities (construction work)," "Network duration," and "Construction technology practice," all with an RII value of 0.85. These factors play crucial roles in determining the frequency and intensity of maintenance activities in the water distribution network. The integration of spatial technology to monitor and manage these aspects can lead to more efficient and targeted maintenance practices, ensuring the network's optimal performance and longevity.

While some factors have relatively lower RII values, they should not be disregarded, as they may interact with other influential factors to impact maintenance practices. For example, "Material quality" has an RII value of 0.35, while "Water project design practice" and "Technology" have RII values of 0.39 and 0.28, respectively. These factors still hold relevance in the context of maintenance practices and should be considered in conjunction with other significant factors.

The study also emphasizes the substantial impact of "Water quality" and "Water meter duration," both deemed highly significant with RII values of 0.89 and 0.94, respectively. Water quality directly affects the condition and lifespan of distribution system components, while the duration of water meters can influence maintenance planning and resource allocation. By integrating spatial technology to monitor these aspects, maintenance efforts can be optimized, resulting in a more sustainable and efficient water distribution network.

Lastly, "Water pressure" is identified as another important factor with an RII value of 0.79. Monitoring water pressure using spatial technology can aid in identifying areas with potential leakages or pressure-related issues, enabling proactive maintenance measures to reduce system losses and enhance network performance.

5.3 Developed the mathematical model for the factor affecting maintenance of the water distribution network that can be applied to spatial technology

The model summary for the developed linear regression test in SPSS shows the performance and characteristics of the model. The coefficient of determination (R-squared) value is 0.829, indicating that approximately 82.9% of the variation in the dependent variable can be explained by the independent variables considered in the model. The adjusted R-squared, which takes into account the number of predictors in the model, is 0.794, suggesting that around 79.4% of the variation is explained while adjusting for the number of variables.

The standard error of the estimate is 0.47588, representing the average distance between the observed values and the predicted values by the model. A lower standard error indicates a better fit of the model to the data.

The main variables considered in this model are Material quality, Water meter duration, Human activities (construction work), Material Vulnerability, Water pressure, Lack of pipe and fittings, Network duration, and Water quality. These variables are crucial in predicting the dependent variable in the context of the study.

Furthermore, the developed model appears to have a reasonably strong fit to the data, with a high R-squared value suggesting that a significant proportion of the variance in the dependent variable can be accounted for by the selected independent variables.

However, it is essential to interpret the model's results carefully and consider its limitations to make meaningful conclusions and implications for the study. Further analysis and validation may be required to ensure the model's accuracy and reliability.

5.4. Application of spatial technologies in the maintenance of the water distribution network

Application of spatial technologies played a crucial role in facilitating the creation of a computerized maintenance system integrating spatial technologies for the water distribution network. This innovative system has already been successfully developed, allowing for more efficient and advanced maintenance practices. The integration of spatial technologies has significantly improved the management and monitoring of the network, enhancing its overall performance and reliability. This advanced system represents a significant step forward in the field of water distribution network maintenance, providing valuable insights and predictive capabilities for better decision-making and resource allocation.

CONCLUSION AND RECOMMENDATION

6.0 CONCLUSION

The study emphasizes the significance of factors like "Lack of pipe and fittings," "Human activities (construction work)," "Network duration," and "Construction technology practice," which can be optimized through spatial technology integration to enhance maintenance practices.

While some factors have relatively lower RII values, they should not be ignored, as they can interact with other influential factors. "Water quality" and "Water meter duration" are identified as highly significant factors, and monitoring them through spatial technology can improve maintenance planning and resource allocation. Additionally, "Water pressure" is recognized as an important factor that can benefit from spatial technology monitoring to proactively address potential issues.

The coefficient of determination (R-squared) value of 0.829 indicates that approximately 82.9% of the variation in the dependent variable can be explained by the selected independent variables, while the adjusted R-squared value of 0.794 takes into account the number of predictors, suggesting that around 79.4% of the variation is explained while adjusting for the number of variables.

The main variables considered in the model, including Material quality, Water meter duration, Human activities (construction work), Material Vulnerability, Water pressure, Lack of pipe and fittings, Network duration, and Water quality, play crucial roles in predicting the dependent variable within the study's context.

The model demonstrates a reasonably strong fit to the data, as indicated by the high R-squared value, which suggests that a significant portion of the variance in the dependent variable can be attributed to the selected independent variables. However, it is essential to interpret the model's results with caution and acknowledge its limitations. Further analysis and validation are necessary to ensure the model's accuracy and reliability.

The model development process has been instrumental in achieving a significant milestone - the creation of a computerized maintenance system that seamlessly integrates spatial technologies into the water distribution network. This cutting-edge system has already been successfully developed, revolutionizing maintenance practices by introducing efficiency and sophistication.

The integration of spatial technologies has ushered in a new era of enhanced management and monitoring for the water distribution network. This advanced system has proven to be a game-changer, as it has substantially improved the overall performance and reliability of the network. By leveraging spatial technologies, the system can now proactively identify potential issues, predict maintenance needs, and optimize resource allocation, resulting in more effective and cost-efficient maintenance practices.

The successful development of this computerized maintenance system marks a significant advancement in the field of water distribution network maintenance. Its implementation has provided water utilities with valuable insights and predictive capabilities, empowering them to make better-informed decisions and ensure optimal functioning of the distribution network. The system's ability to foresee potential maintenance requirements and allocate resources strategically allows for a more proactive and sustainable approach to managing the water distribution network.

Moreover, the integration of spatial technologies into the maintenance system represents a remarkable step forward in the water distribution industry. It not only enhances the efficiency of maintenance practices but also contributes to the broader goal of providing reliable and uninterrupted water supply to communities. As technology continues to evolve, this system has set a strong foundation for future advancements in water distribution network maintenance and remains a crucial tool for ensuring the resilience and effectiveness of water infrastructure.

6.1 RECOMANDATION

This study conducted at ubungo regional in DAWASA area, it can be extended to other part of DAWASA area for real time monitoring non revenue water and all maintenance activities.

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