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Original Article

Analysis of Factors Affecting Clean Water Service in Dili City

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Abstract

Availability of clean water is a basic need in Dili City, Timor Leste, but uneven distribution, inadequate infrastructure, and limited resources are the main challenges. This study aims to analyze the factors that influence clean water services. The research method included multiple linear regression analysis to identify influential factors. Data was obtained through surveys, interviews, official reports and literature review. The results showed that piping distance and number of family members positively influenced water quality and quantity, while household income tended to decrease water quality and quantity. Expenditure on clean water improves water quality and quantity. For water continuity, the number of people in the family had a strong positive effect, while other factors had a negative effect. The coefficient of determination for water quality is 5.3%, water quantity 20.9%, and water continuity 5.9%, indicating that many other factors influence water services in Dili City.

Keywords: Water Availability, Dili City, Household Income, Multiple Linear Regression, Water Resources.

1. Introduction

The availability of adequate clean water is one of the essential elements supporting the quality of life, health, social welfare, and economic development. In many cities, especially those that are developing, the issue of clean water provision has become a significant challenge, including in Dili, the capital city of Timor Leste. The city faces various obstacles in providing access to clean water for all its citizens, ranging from uneven distribution to the limited capacity of the pipeline network. Optimizing clean water services in Dili requires a reliable and integrated infrastructure system, but major challenges still persist, such as the scarcity of quality raw water sources and fluctuations in water supply due to uncertain climatic influences (Grigg, 2003). With the rapid pace of urbanization and population growth, the demand for clean water services is becoming increasingly urgent, while the existing capacity is becoming more limited (Darmawan et al., 2024).

Clean water services are not only about quantity but also involve quality, continuity, and affordability (Sutrisno, 2008). According to Kodoatie (2002), good clean water services must meet sustainability standards that consider not only technical aspects but also social factors relevant to the community's life. In Dili, areas such as Dom Aleixo and Cristo Rei show significant disparities in the coverage and quality of clean water services, which are far below the national average. Research by Darmawan (2024) highlights the importance of community-based planning in addressing geographical and social issues that hinder the provision of equitable clean water throughout the city (Darmawan et al., 2024). This emphasizes the importance of involving the community in every stage of planning and managing water resources.

As urban infrastructure develops, the pressure on the clean water supply system increases. Paradis et al. (2024) explains that factors such as the length of the pipeline network, water leakage rates, and operational efficiency of the distribution system pose major challenges in clean water management, especially in urban areas. Dili, which has hilly terrain and a dense population, requires specific solutions to address these issues. Without comprehensive improvements to the distribution and storage systems, the sustainability of clean water services will continue to be threatened, while the demand for water keeps rising. Efforts to improve and develop infrastructure must be a top priority in the city's water management policies (Sudia et al., 2021).

The availability of adequate raw water is also a major issue in optimizing clean water services. Noerbambang & Morimura (1985) note that the quality, quantity, and continuity of raw water sources are key indicators of sustainable clean water provision. In Dili, although some water sources have been utilized, the raw water supply is often affected by the dry season, which can significantly reduce water flow. In a region prone to drought, ensuring the continuity of the water supply is a unique challenge that must be addressed with more effective and efficient water resource management.

The continuous population growth in Dili also has a significant impact on the increasing demand for clean water. According to data from the Timor Leste Central Statistics Agency (2022), Dili's population has exceeded 320,000, with a relatively high population growth rate. This indicates that the demand for clean water will continue to rise, while the existing distribution capacity is insufficient to meet this need. As the population increases and mobility grows, the challenges of ensuring the sustainability of the clean water distribution system become more complex. Therefore, more careful planning is needed to increase the capacity of the clean water supply system and anticipate potential water crises in the future.

Social and economic aspects also play an important role in clean water services. Research by Sinaga et al. (2024) highlights that factors such as household income, distance to water sources, and the level of community education contribute to the success of clean water provision programs. In Dili, many residents still rely on traditional water sources such as wells and natural springs. Limited economic factors make it difficult to access modern pipeline networks, adding to the disparity in clean water services between regions. Therefore, in addition to improving infrastructure, policies should prioritize equitable access to clean water, especially for low-income communities.

Optimizing clean water services in Dili requires a holistic and integrated approach. Umaji et al. (2023) suggests that community participation in water resource management can improve the efficiency and sustainability of services. In the context of Dili, a community-based approach that emphasizes active participation in the maintenance and management of water sources needs to be strengthened. This will not only raise public awareness about the importance of maintaining sustainable water resources but also reduce the government's burden in managing limited infrastructure. Moreover, this approach will accelerate the achievement of the goal of equitable access to clean water for all residents.

The clean water distribution system in Dili faces major challenges, particularly related to the high leakage rate of the pipeline network and the inadequate storage capacity. Udin et al. (2024) stresses that improving distribution infrastructure must be a top priority to address these issues. Leaks in the pipeline network not only reduce distribution efficiency but also increase operational costs due to uncontrolled water loss. Additionally, limited storage capacity often becomes the main obstacle in meeting the needs of residents, especially during the dry season when water supply from main sources decreases significantly. Therefore, the development of adaptive distribution technologies, such as modern pumping systems and the construction of additional reservoirs, is essential to improve storage capacity and ensure more equitable distribution across the city.

In the context of the Sustainable Development Goals (SDGs), particularly related to clean water and sanitation, Dili faces significant challenges in ensuring equitable access to clean water for all its residents. The Timor Leste government has made efforts to improve clean water service coverage through policies and strategic programs. However, the effectiveness of these programs still needs to be enhanced through a thorough analysis of the factors influencing clean water services in Dili. With a data-driven and community-based approach, it is hoped that this research can contribute to improving the clean water supply system and enhancing the quality of life for the residents of Dili.

This study aims to identify and analyze the factors influencing clean water services in Dili and formulate appropriate strategies to optimize clean water provision based on local conditions. It is hoped that the findings of this study will provide valuable insights for the planning and implementation of more effective policies in managing water resources and improving the quality of life in Dili through better and more sustainable clean water access.

2. Methods

This research uses a positivistic approach with theoretical and empirical analytical methods, which focus on measured data through surveys or questionnaires and statistical analysis. Theories related to clean water services are compiled to produce research variables, which are then analyzed and generalized. This type of research is descriptive, aiming to reveal facts and phenomena related to clean water services and analyze the relationship between variables and their effects.

2.1. Data Collection Method

The methods used in this research are primary and secondary data collection.

1) Secondary Data

Secondary data was obtained from official sources, such as statistical reports from the Central Bureau of Statistics of Timor Leste, BTL.EP documents, and literature review on clean water infrastructure in Dili City. This data included information on population, water distribution networks, water demand, and socio-economic conditions of the community, which was used to provide a preliminary overview of water services in the study area.

2) Primary Data

Primary data was collected through questionnaires distributed to households in Dom Aleixo and Cristo Rei sub-districts, as well as interviews with community leaders and water service managers. The questionnaires collected information on water quality, continuity and access, while the interviews provided qualitative data on operational constraints and service improvement strategies.

2.2. Population and Sample

Determining the number of samples in a study is one of the important aspects that affect the results of the study. One way to calculate the required sample size is to use the Slovin formula, which was first introduced by Slovin (Sujarweni, 2014). This formula is used to calculate the sample size simply, especially when the population is quite large. The formula used is as follows:

$$n = \frac{N}{N.e^{2+}}$$

Where:
n = Number of Samples required
N = Total Population
e = Degree of accuracy

In this study, the sampling technique used was proportional cluster random sampling. The initial calculation was carried out using the random sampling formula, where the population of Dili City was 57,085 households, with a degree of accuracy of 6%. Based on this calculation, the number of samples to be used was 150 households. Furthermore, the number of samples was proportioned based on the number of households in each village.

2.3. Research Variables

Research variables are the main elements in research that are measured quantitatively or qualitatively. The variables of this study can be seen in Table 1.

Table 1. Research Variables and Operational Definitions

Aspect	Indicator	Variable	Sub Variable	Operational Definition
Clean Water Availability	Clean water source	Clean water source debit	-	Total debit of clean water source (liters/day)
Clean Water Demand	Domestic demand	Population count	-	Population count (persons)
		Daily consumption	-	Total water usage (1/day)
Water Leakage	Total water production	-	-	Total amount of water produced (m^3)
	Recorded accounts	-	-	Total water usage by consumers (m^3)
Clean Water Service	Piped service	Clean piped service	Quality	Quality of water received by the community, which can be visually observed based on Ministry of Health regulations in East Timor: clear, odorless, colorless, tasteless water.
			Quantity	Flow debit of water per household (smooth or interrupted)
			Continuity	Continuous water supply to customers 24/7 (24 hours or not)
Factors Affecting Clean Water Service	Distance to access clean water	Pipe distance	-	Direct use of piping per household or shared use
	Household ability to pay	Monthly household income	-	Monthly income per household (Rp/household)
		Monthly household water expenditure	-	Monthly expenditure on clean water (Rp/household)
	Population	Household size	-	Number of family members in the household

2.4. Data Analysis Technique

The data analysis method in this study was used to determine how much influence each factor has on clean water services in the study area. Each factor is given a value based on criteria obtained from respondents' statements in questionnaires distributed in the primary survey. The following are the steps used in data analysis: Regression Analysis

To determine the factors influencing the conversion of residential land into trade and service areas, regression analysis was conducted with the help of SPSS for Windows software. Regression is used to measure the relationship between variables in order to determine whether there is a functional relationship between two or more variables.

1. Types of Regression Analysis

   There are two types of regression analysis used in this study:

   a. Simple Regression Analysis: Explains the relationship between one independent variable and one dependent variable.

   b. Multiple Regression Analysis: Explains the relationship between two or more independent variables and one independent variable. The formula below:

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e}$$

   Description:

Y	=	Quality
β_0	=	Constant
$\beta_1, \beta_2, \beta_3, \beta_4$	=	Regression coefficients
X_1	=	Pipe distance
X_2	=	Average monthly income
X_3	=	Monthly water expenses
X_4	=	Number of people in the household

2. Steps in Regression Analysis

   The steps of regression analysis in this study are as follows:

Determining Research Variables: The variables used in the regression analysis to determine the factors affecting clean water services can be seen in Table 2 as follows:

Table 2. Variables in Regression Analysis

Dependent Variable (Y)	Independent Variable (X)
Clean water service (Y)	Piping distance (X1)
Quality (Y1)	Household monthly income (X2)
Quantity (Y2)	Monthly household expenditure on clean water (X3)
Continuity (Y3)	Number of people in the household (X4)

Techniques Used: Based on these variables, one dependent variable can be related to one or more independent variables. Therefore, in this study, Multiple Linear Regression Analysis was used to determine the factors that influence clean water services.

3. Results and Discussion

3.1. General Overview

The research area is located in Dili City, Timor Leste, which includes two main sub-districts, namely Don Aleixo and Cristo Rei sub-districts. Both sub-districts are located on the western side of Dili City and consist of 15 villages, with 7 villages in Don Aleixo sub-district and 8 villages in Cristo Rei sub-district. Dili City itself has an area of approximately 48,272 km² and is divided into 6 sub-districts and 31 villages. Geographically, Dili City is located between latitudes 8° and 10° S, and longitudes 124° and 128° E, with coordinates 8°34′S 125°34′E as the center point.

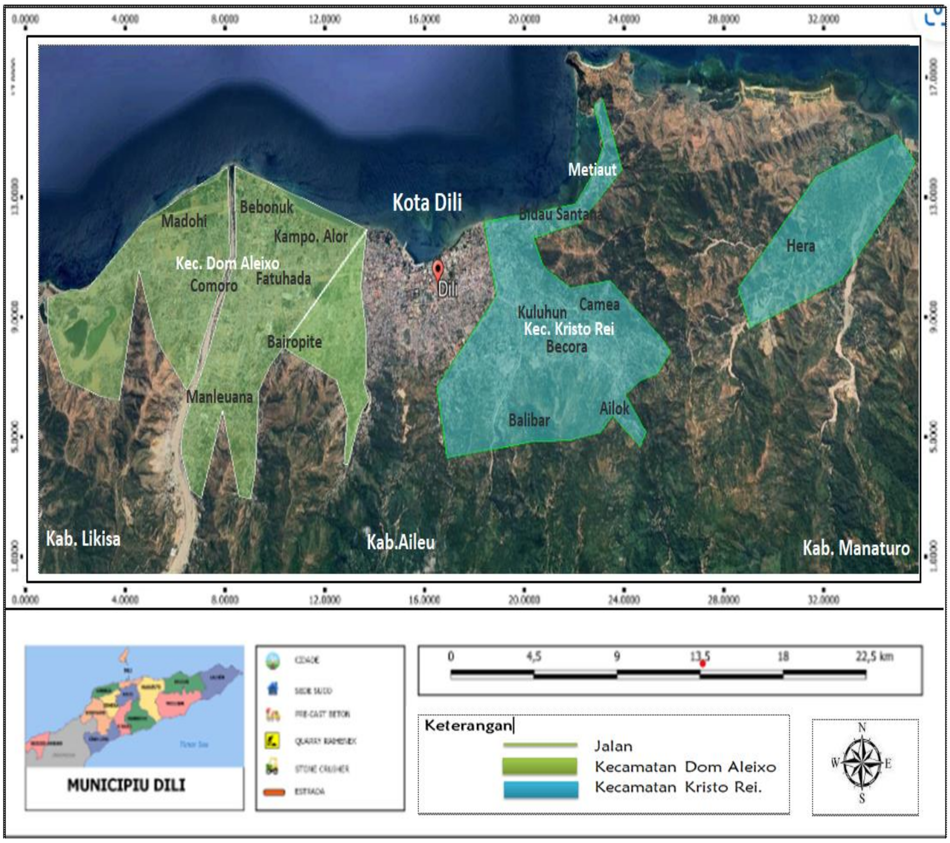

Figure 1. Map of Research Area

Administratively, the city of Dili is bordered by the Manatuto region to the north, the East Timor Sea to the east, the Tibar region to the south, and the Aileu region to the west. According to the 2000-2025 RT/RW administrative division of Dili City, the districts in Dili are grouped into Urban and Rural Areas. The Don Aleixo and Cristo Rei districts are part of the Urban Area, while other villages are included in the Rural Area. This study focuses on the urban area, specifically the villages that function as urban areas, which include 15 villages from both districts. Below is a list of the villages included in the research area, along with their respective land areas, as shown in Table 3.

Table 3. Scope of Research Area

No	Village	Area (km²)
Don Aleixo District		
1	Comoro	3.84
2	Madohi	1.38
3	Bairopite	1,53
4	Bebonuk	0,67
5	Manleuana	1,37
6	Kampo Alor	0.27
7	Fatuhada	0,36
Cristo Rei District		
8	Becora	2,32
9	Culu Hun	0,42
10	Camea	0.67
11	Bidau Santana	2,43
12	Hera	0,68
13	Metiaut	0.62
14	Ailok	0,52
15	Balibar	0.35
	Total	**7,13**

3.2. Population

3.2.1. Population Growth

Based on the data in Table 4 on the development of the population in the study area from 2021 to 2023, it can be seen that the population in each village in Don Aleixo Sub-district and Cristo Rei Sub-district shows an increase every year.

Table 4. Population Growth for 2021-2023

No	Village	Total Population		
		2021	2022	2023
Don Aleixo District				
1	Comoro	47,025	47,308	47,594
2	Madohi	12,723	12,8	12,877
3	Bairopite	25,37	25,523	25,677
4	Bebonuk	15,725	15,82	15,915
5	Manleuan	11,796	11,867	11,939
6	Kampo Alor	4,506	4,534	4,561
7	Fatuhada	9,38	9,437	9,494
Cristo Rei District				
8	Becora	23,184	23,324	23,465
9	Culu Hun	7,616	7,662	7,708
10	Camea	12,6	12,676	12,753
11	Bidau Santana	7,812	7,86	7,907
12	Hera	10,346	10,408	10,471
13	Metiaut	2,291	2,307	2,321
14	Ailok	5,02	5,05	5,086
15	Balibar	1,723	1,734	1,744
Total		**197,117**	**198,31**	**199,512**

From the table above, it can be concluded that in both Don Aleixo and Cristo Rei sub-districts, the total population has increased from 2021 to 2023. This increase indicates stable population growth in both sub-districts.

3.2.2. Total Population and Number of Households

In Table 5, data on population, number of households, and population density in 2023 can be seen. This table shows that the population is directly proportional to the number of households in each village.

Table 5. Total Population, Number of Households (KK), and Population Density in 2023

No	Subdistrict	Population	Number of Households (HH)	Population Density (people/km²)
Don Aleixo District				
1	Comoro	47.594	9.529	56.544
2	Madohi	12.877	2.524	23.112
3	Bairopite	25.677	5.965	33.323
4	Bebonuk	15.915	2.949	25.212
5	Manleuan	11.939	2.618	21.365
6	Kampo Alor	4.561	873	8.652
7	Fatuhada	9.494	2.233	13.923
Cristo Rei District				
8	Becora	23.465	4.716	32.564
9	Culu Hun	7.708	1.644	14.432
10	Camea	12.753	2.625	16.774
11	Bidau Santana	7.907	1.745	9.547
12	Hera	10.471	2.209	7.036
13	Metiaut	2.321	476	5.221
14	Ailok	5.086	945	8.533
15	Baliabr	1.744	400	2.652
Total		**199.512**	**41.451**	**278.890**

In addition, the analysis shows that the neighborhood with the highest population is Comoro, followed by Bairopite and Becora. This is also reflected in the highest number of households, where Comoro has the highest number of households, followed by Bairopite and Becora. Conversely, the neighborhood with the lowest number of residents and households is Balibar.

3.3. Types of Occupation

The livelihoods of residents in the study area show diverse socioeconomic characteristics, including agriculture, industry, construction, trade, transportation, services, and others. Based on 2023 data, the majority of the population works in the industry sector at 23%, followed by the service sector with a percentage of 21%, while other fields dominate at 42%. Details of this data can be seen in Table 6 and Figure 2.

Table 6. Livelihoods of the Population in the Study Area in 2023

No	Subdistrict	Agricul-ture	Indus-try	Cons truct ion	Trade	Transpor-tation	Services	Others
				Don Aleixo District				
1	Comoro	18	9	-	1055	256	324	1625
2	Madohi	7	-	-	432	157	154	1358
3	Bairopite	32	-	-	635	232	433	523

No	Subdistrict	Agricul-ture	Indus-try	Construction	Trade	Transpor-tation	Services	Others
4	Bebonuk	6	4	-	356	237	243	255
5	Manleuan	9	-	-	528	158	377	462
6	Kampo Alor	-	-	-	347	89	561	677
7	Fatuhada	2	-	-	215	172	322	582
	Kristo Rei District							
8	Becora	11	-	-	633	347	455	611
9	Culu Hun	-	-	-	341	196	228	523
10	Camea	9	-	-	105	215	338	479
11	Bidau Santana	16	-	-	79	165	584	769
12	Hera	4	3	-	62	48	165	352
13	Metiaut	65	-	-	78	52	109	298
14	Ailok	157	-	-	54	24	95	252
15	Balibar	232	-	-	66	42	102	185
	Total	**608**	**16**		**4977**	**2390**	4490	**8951**

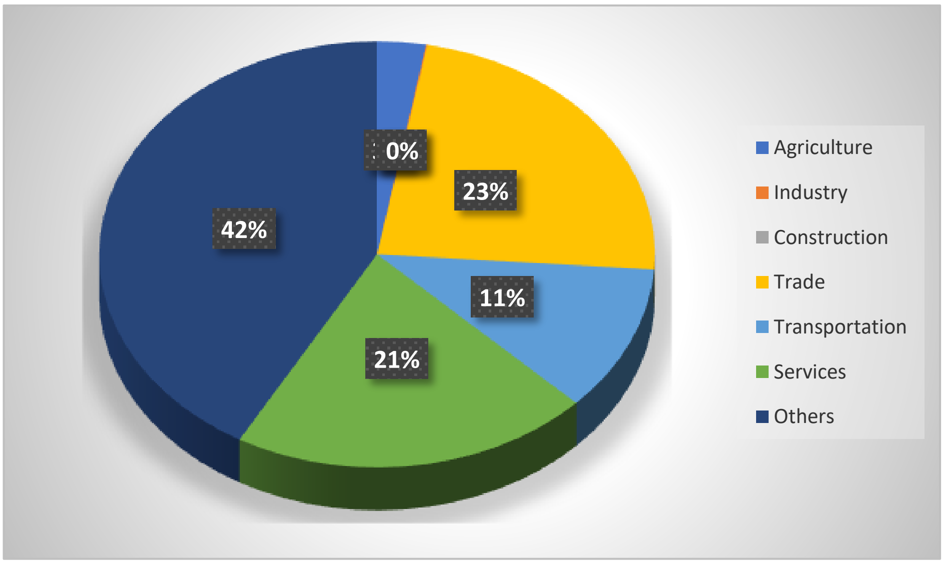

Figure 2. Total Population by Livelihood in 2023

3.4. Factors Affecting Clean Water Services

Clean water services in Dili City were analyzed using multiple linear regression with dependent variables including water quality, quantity, and continuity. The independent variables are piping distance (X1), monthly household income (X2), total monthly expenditure on clean water (X3), and number of people in the family (X4). The following table shows the variable scale of water service factors in Dili City:

Table 7. Scale of Clean Water Service Factor Variables in Dili City

	Scale	1	2	3	4
Y1	Quality	Smelly and colored (cloudy)	Colored (cloudy) and salty taste	Colorless and salty taste	Odorless, colorless, tasteless
Y2	Quantity	Dripping	Flows smoothly with pump assistance	Flows inconsistently	Flows smoothly

	Scale	1	2	3	4
				(intermittent) without pump	without pump
Y3	Continuity (Water Availability Time)	0-5 hours	6-11 hours	12-17 hours	18-24 hours
X1	Income Level	<1000000	1000001-	1500001-	2500001-
	Scale	1	2	3	4
	Monthly Household Income		1500000	2500000	3500001
X2	Number of Household Members	02-Mar	04-May	06-Jul	08-Sep
X3	Monthly Water Usage (PDAM+Well)	<20,000 liters	20,001-40,000 liters	40,001-60,000 liters	>60,000 liters
X4	Distance of Piping	Well / buy water from vendors	Well / buy water from vendors + PDAM	PDAM connection	Direct PDAM connection

3.4.1. Clean Water Quality

The results of multiple linear regression analysis show that the variables of piping distance (X1), monthly household income (X2), total monthly expenditure on clean water (X3), and number of people in the family (X4) simultaneously have a significant influence on clean water quality. The regression equation obtained is as follows:

$$Y_1 = 2{,}577 + 0{,}084X_1 - 0{,}009X_2 + 0{,}014X_3 + 0{,}124X_4$$

- The constant of 2.577 indicates that if all independent variables are zero, clean water quality is predicted to be 2.577.
- The coefficient of X1 of 0.084 indicates that a one unit increase in piping distance increases water quality by 0.084, assuming other variables remain constant.
- The coefficient of X2 of -0.009 indicates that an increase in monthly household income decreases water quality by 0.009 units, assuming other variables remain constant.
- The coefficient X3 of 0.014 indicates that an increase in monthly expenditure on clean water improves water quality by 0.014 units.
- The coefficient of X4 of 0.124 indicates that every additional one family member increases water quality by 0.124 units.

The coefficient of determination (R^2) of 0.053 indicates that only 5.3% of the variability in water quality can be explained by this model. This indicates that there are many other factors outside the study that affect water quality. The negative coefficient on income indicates a possible preference for alternative water sources by higher income households.

3.4.2. Clean Water Quantity

The regression analysis results for clean water quantity yielded the following equation:

$$Y_2 = 2{,}202 + 0{,}369X_1 + (-\,0{,}016)X_2 + 0{,}149X_3 + 0{,}122X_4$$

- The constant value of 2.202 indicates that if all independent variables are zero, the predicted clean water quantity is 2.202.

- The coefficient of X_1, at 0.369, indicates that an increase of one unit in pipe distance raises the water quantity by 0.369.
- The coefficient of X_2, at -0.016, signifies that an increase in household monthly income decreases water quantity by 0.016 units.
- The coefficient of X_3, at 0.149, indicates that an increase in monthly expenditure on clean water raises the water quantity by 0.149.
- The coefficient of X_4, at 0.122, signifies that each additional family member increases the water quantity by 0.122 units.

The determination coefficient (R^2) value of 0.209 indicates that 20.9% of the variability in clean water quantity can be explained by this model. This shows a stronger relationship compared to water quality. The pipe distance variable contributes the most to water quantity.

3.4.3. Clean Water Continuity

The regression analysis results for clean water continuity yielded the following equation:

$$Y_1 = 1{,}950 + (-0{,}003)\ X_1 + (-0{,}017)\ X_2 + (-0{,}175)\ X_3 + 0{,}276\ X_4$$

The constant value of 1.950 indicates that if all independent variables are zero, the predicted clean water continuity is 1.950.

- The coefficient of X_1, at -0.003, shows that an increase of one unit in pipe distance decreases water continuity by 0.003.
- The coefficient of X_2, at -0.017, indicates that an increase in household monthly income reduces water continuity by 0.017.
- The coefficient of X_3, at -0.175, shows that an increase in monthly expenditure on clean water reduces water continuity by 0.175.
- The coefficient of X_4, at 0.276, signifies that each additional family member increases water continuity by 0.276.

The determination coefficient (R^2) value of 0.059 indicates that only 5.9% of the variability in water continuity can be explained by this model. The variable representing the number of family members has the most positive influence, emphasizing the importance of considering the number of users in water distribution.

4. Conclusion

Based on the results and discussion, the analysis of factors affecting clean water services in Dili City shows that clean water services in Dom Aleixo Sub-district are affected by quality and continuity. The main factors influencing quality are piping distance, monthly household income, and number of members in the household, while continuity is influenced by piping distance. In Kristo Rei District, service is influenced by quality, quantity and continuity, where quality is determined by piping distance, quantity by household monthly expenditure on clean water, and continuity also by piping distance. These results indicate the importance of improved piped infrastructure and more effective distribution management. In addition, a service distribution strategy that considers the socio-economic conditions of the community is needed to ensure sustainable and inclusive water availability in all areas of Dili City.

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