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Research Paper

Risk Management of Clean Water Distribution System Construction Projects in Urban Areas: Case Study of Dumai City

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ABSTRACT: *The availability of clean water is crucial for supporting regional growth, particularly with the increasing population and developments in the industrial and agricultural sectors. Therefore, the government, through Presidential Instruction No. 1 of 2024, has initiated the construction of clean water distribution networks in urban areas, including Dumai City, Riau, to ensure access to clean water for the community. This study aims to identify and analyze the dominant risks in the implementation of clean water distribution network construction projects in urban areas that affect project timelines, as well as the mitigation strategies to manage these risks. The analysis used in this research is descriptive analysis and analytic hierarchy process (AHP) and risk level analysis. From the results of the analysis, there are 5 (five) risks that fall into the high category, slow and unclear licensing, unexpected land conditions (geotechnical, weather, etc.), overlapping pipes, changes in the scope of work after signing, and addition/reduction of work.*
KEYWORDS: *Risk Management, Risk Analysis, WTP Project, Clean Water, Time Performed, AHP*

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I. INTRODUCTION

The increase in population and the intensity of development, such as in the industrial and agricultural sectors, has led to an increasing need for facilities and infrastructure, especially clean water. Clean water plays an important role in supporting public health and survival. Therefore, expanding access to clean water is a major concern in facing these challenges.

In response, the Indonesian government launched a pipeline network construction project to distribute clean water in various cities and districts, including previously underserved areas. Presidential Instruction Number 1 of 2024 on the Acceleration of Drinking Water Provision and Domestic Wastewater Management supports this initiative, with the aim of fulfilling people's basic rights, reducing water-related diseases, and supporting the SDGs and RPJMN. In the city of Dumai, which is an industrial and port center, the need for clean water is increasingly urgent, and the Presidential Instruction on Drinking Water program is prioritized to meet this need.

The implementation of drinking water infrastructure projects faces various risks, such as difficulties in pipe planting locations, licensing obstacles, social conflicts, and challenges of soil and environmental conditions. Therefore, risk analysis is very important to ensure the success of the project. With the implementation of effective risk management, it is hoped that this project can expand sustainable access to clean water, improve community welfare, and support better health quality.

II. LITERATURE REVIEW

Project Risk Management

A project is a set of activities intended to achieve a specific end result that is important enough for the interests of management [2].

There are 4 (four) main types of construction namely: Residential Construction, Building Construction, Heavy Engineering Construction and Industrial Construction [3].

Project management is the activity of organizing, planning, controlling, and directing organizational resources in a company in achieving goals with certain time and resources to achieve predetermined targets and objectives in order to obtain optimal results in terms of cost, quality and time performance [4]. In project management, the factors that greatly influence risk are failure to maintain costs, time, and achieve quality and work safety.

Project risk is defined as the uncertainty that can affect project objectives, covering everything from risks that can cause losses (negative risks) to opportunities that can provide benefits (positive risks) [6].

Project risk management includes the process of risk management planning, identification, analysis, response planning, response implementation, and monitoring of risks for a project. The goal of project risk management is to increase the likelihood and/or impact of positive risks and to reduce the likelihood and/or impact of negative risks, to optimize the chances of project success [6].

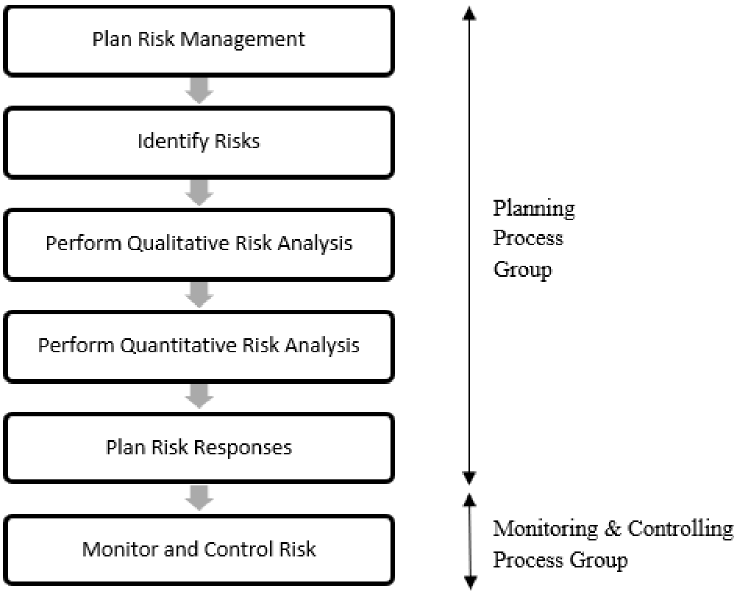

Figure 1 Risk Management Process Framework [6]

Construction of Drinking Water Supply System (SPAM)

The Drinking Water Supply System Project, hereinafter abbreviated as SPAM, is a unit of facilities and infrastructure for providing drinking water. The implementation of SPAM is a series of activities in implementing the development and management of facilities and infrastructure that follow the basic management process for providing drinking water to the community [8].

Implementation of Drinking Water Supply System [8] includes:

a. SPAM implementation
b. SPAM Management

Principles of Implementing a Drinking Water Supply System [8] include:

a. Sustainable development
b. Good governance and/or good corporate governance

The Drinking Water Supply System is organized to ensure the certainty of the quantity and quality of Drinking Water produced as well as the continuity of the flow of Drinking Water [8] which includes:

a. Raw Water Unit
b. Production Unit
c. Distribution Unit
d. Service Unit

Main Distribution Pipe

Main Distribution Pipe (JDU) or primary distribution pipe is a series of distribution pipes that form a distribution zone in a SPAM service area [8]. The diameter of the distribution pipe is determined based on the flow at peak hours with minimum remaining pressure in the distribution line, when a fire occurs the pipe network is able to flow water for maximum daily needs and three fire hydrants each with a capacity of 250 gpm with a maximum distance between hydrants of 300 m. The peak hour factor on the average discharge depends on the population of the area served.

Framework of thinking

Based on the background and literature review, a framework for thinking about risk management in the implementation of clean water distribution network construction in urban areas is described.

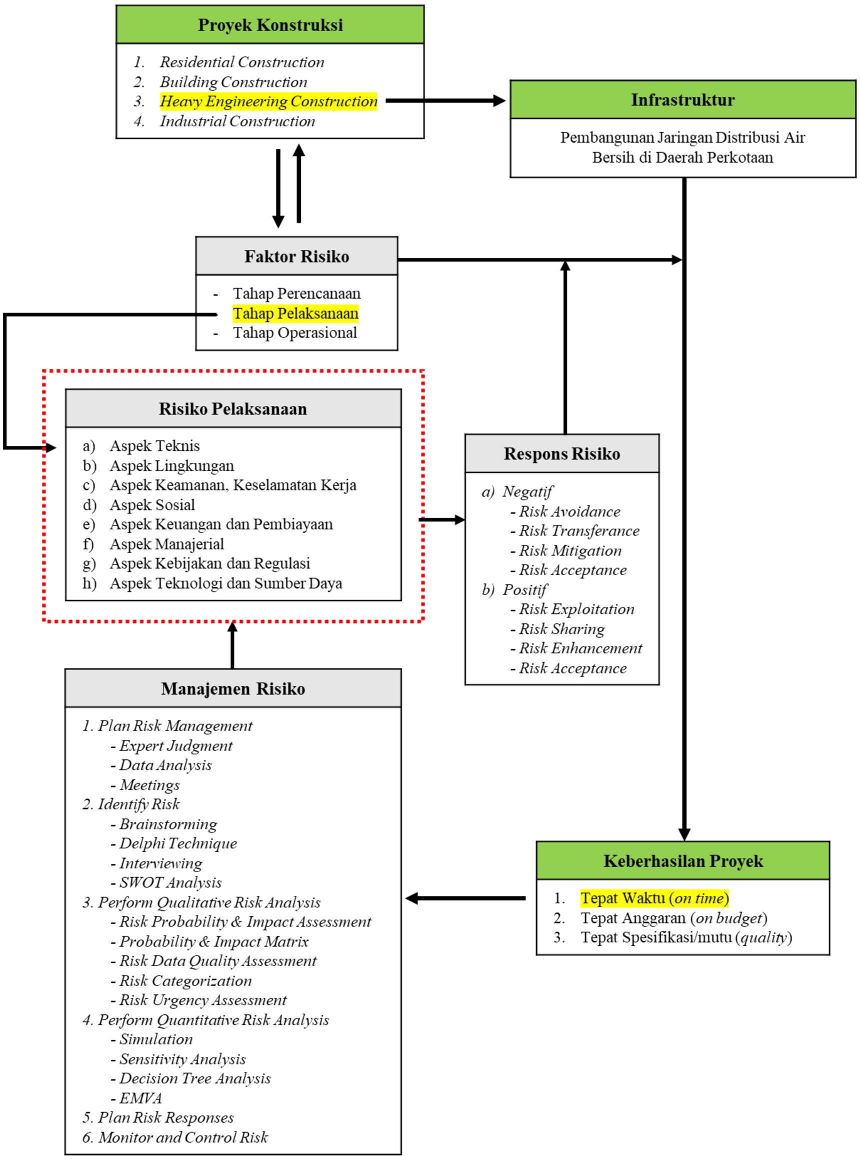

Figure 2 Thinking Framework Diagram

III. RESEARCH METHODS

The research was conducted using a qualitative approach, which collects detailed information to identify problems, as well as understand the prevailing conditions and practices. Based on the source, research data can be grouped into 2 (two) types, namely primary data and secondary data.

a. Primary Data: data obtained or collected by researchers directly from the original source, also known as original data which is up to date or current.

b. Secondary data: refers to information obtained or collected by researchers from previously existing sources.

This study uses a survey method to investigate the facts of the existing symptoms and identify risk factors that affect the construction time of the Medang Kampai SPAM pipeline network in Dumai City. Through a questionnaire filled out by respondents, this study aims to determine the dominant risk factors.

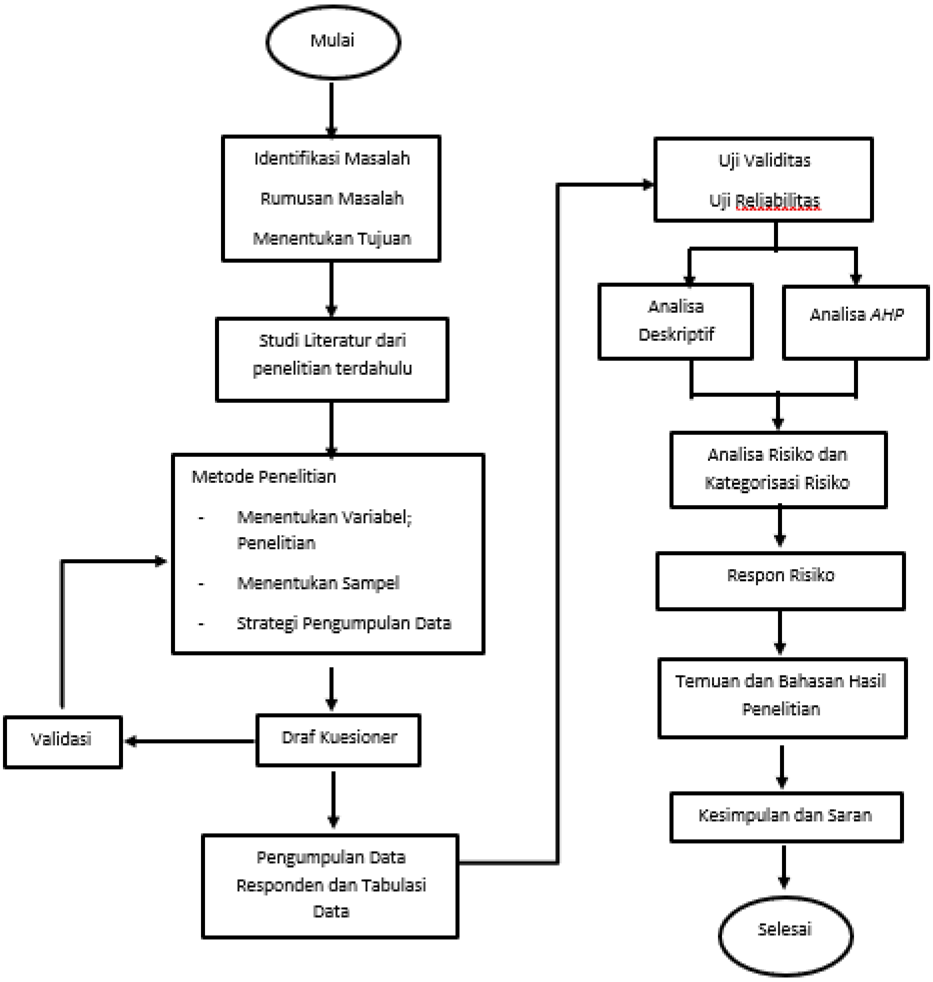

Figure 3 Research Framework Flowchart

Descriptive analysis

This analysis aims to present the characteristics of data from a particular sample, so that researchers can quickly obtain a brief and concise overview of the data that has been collected. This analysis process utilizes statistical software to process data. Some statistical analyses used include mean analysis and mode analysis. Mean analysis is used to calculate the average, which provides an overview of the high or low level of respondent response to each variable in the questionnaire. Mode analysis functions to determine the values that appear most often in respondents' assessments of the questionnaire variables.

Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a method used to support decision making in situations involving complexity and uncertainty, where the criteria used are not only numerous, but also interrelated [9].

Decisions in the AHP methodology are based on 4 principles [10], namely:

a. Decomposition
b. Comparative Judgment
c. Synthesis of Priority
d. Logical Consistency

The steps for compiling and calculating AHP [10] are:

a. Prioritization: The first step in determining the priority of criteria is to compile a pairwise comparison, which is to compare in pairs all the criteria for each sub-system of the hierarchy. The comparison is then transformed into a pairwise comparison matrix for numerical analysis.
b. Eigen value and eigen vector: Eigen Value is a value that shows the weight of the importance of a criterion to other criteria in the Hierarchical Structure. Determine the relative priority of each factor by averaging the normalized weights of each row, symbolized by Pi.

$$Pi = \sum_{i=1}^{n} = \frac{Vij}{a_{ij}}$$

Where:
Pi = Relative Priority Value of the average value – normalized weight
Vij = Number of normalized weights in row = i column – j
n = Number of sub factors

c. Consistency Ratio Calculation: aims to determine the consistency of respondents' assessments filled in the questionnaire. The Hierarchy Consistency Ratio value is obtained by dividing the hierarchy consistency index by the hierarchy random consistency index, and is said to be consistent if the Hierarchy Consistency Ratio value is <0.1

The steps to determine the Consistency Ratio are as follows:

1) Multiply each column in the pairwise comparison matrix A by the relative priorities corresponding to its respective column and sum them to obtain a matrix B of size n x 1.

$$B = \begin{bmatrix} b_1 \\ b_2 \\ . \\ . \\ . \\ b_n \end{bmatrix} : \begin{bmatrix} P_1a_{11} + P_2a_{12} + ... + P_na_{1n} \\ P_1a_{21} + P_2a_{22} + ... + P_na_{2n} \\ \\ \\ \\ P_1a_{n1} + P_2a_{n2} + ... + P_na_{nn} \end{bmatrix}$$

2) Calculating the Maximum Eigen Value (λ Max)

$$\left[\sum_{i-1}^{n} \frac{bi}{Pi} \right] : n$$

3) Calculating the Consistency Index (CI)

$$CI = \frac{\lambda \text{ Maks - n}}{\text{n - 1}}$$

4) Calculating the Consistency Ratio symbolized by CR (Consistency Ratio). If the Consistency Ratio (CR) Value < 0.1 then the results are acceptable

$$CR = \frac{CI}{RI}$$

Order	1	2	3	4	5	6	7	8	9
R.I	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45
First Order Differences		0	0.52	0.37	0.22	0.14	0.10	0.05	0.04

Figure 4 Random Index (RI) Value [9]

Risk Level Analysis

All risk identifications are searched for their causes, the level must be known in handling them. While the risk level is grouped into high (H), medium (M), and low (L). After knowing the probability and impact factors, you can continue to the risk analysis with the probability and impact matrix. Determination of the risk level, refers to the criteria [11]:

a. Frequency (probability)
b. Impact

The risk level is generated by multiplying the respondent's probability score and impact score [12]:

$$R = P * I$$

Where:
R= Risk Level
I = Risk Impact
P= Risk Probability

Probability	Likelihood									
	Threats					Opportunities				
	0.2	0.4	0.6	0.8	1	1	0.8	0.6	0.4	0.2
1	0.2	0.4	0.6	0.8	1	1	0.8	0.6	0.4	0.2
0.8	0.2	0.3	0.5	0.6	0.8	0.8	0.6	0.5	0.3	0.2
0.6	0.1	0.2	0.4	0.5	0.6	0.6	0.5	0.4	0.2	0.1
0.4	0.1	0.2	0.2	0.3	0.4	0.4	0.3	0.2	0.2	0.1
0.2	0	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0

Low Medium High

Figure 5 Risk Matrix

Risk Ranking

Risk Ranking is the acquisition of values in time-based information processing carried out during the document analysis phase using risk factor equations. Risk factor equations are interpreted as the multiplication of the magnitude of the impact and the possibility of a risk event occurring [13].

Delphi Method

The Delphi method is a qualitative approach to obtain views and descriptions of the likelihood of future events occurring [14]. This method is used to validate the dominant risks obtained and complement the respondents' opinions.

IV. RESULTS AND DISCUSSION

Project Overview

The construction project is located in Dumai City, Riau Province. Located at 01°26'50" - 02°15'40" North Latitude and 101°0'38" - 101°43'33" East Longitude. Dumai City has an area of 2,065.59 km2 with boundaries to the north bordering the Rupat Strait, to the east bordering Bandar Laksamana District, to the south bordering Bathin Solapan District and to the west bordering Tanah Putih, Bangko, Batu Hampar, Rimba Melintang, and Tanjung Melawan Districts. The name of the activity package used as a case study is the Medang Kampai Dumai City SPAM Pipeline Network Development Project (NUWSP).

Figure 6 Dumai City Area Map

Expert Validation Questionnaire

The questionnaire contained 65 risk factors from literature studies submitted to 5 experts for validation. The aim was to validate the risk variables, with the possibility of adding or reducing variables. Data analysis was clarified and validated by 5 experts for the 65 variables submitted, resulting in 61 variables agreed as significant and relevant variables.

Table 1 Expert Validation Result Risk Variable

Variables	Risk Categories and Events
A	**TECHNICAL ASPECT**
X1	Location access constraints
X2	Unforeseen land conditions (geotechnical, weather, etc.)
X3	Unexpected technical issues in the field
X4	Errors in predicting field conditions, weather, and future events
X5	Design error
X6	Drinking water quality is not as expected
X7	Raw water transmission pipes do not comply with minimum standards/technical specifications
X8	The designed raw water production unit is not yet capable of overcoming turbidity due to sedimentation.
X9	Making a delivery schedule for materials that is less accurate and precise
X10	Errors in applying construction method standards
X11	Errors in applying field work drawings
X12	The quality of installation work does not meet specifications
X13	Pipe leak
X14	Overlapping pipe
X15	The Water Treatment Plant (IPA) is not functioning according to planned capacity
B	**ENVIRONMENTAL ASPECT**
X16	There is contamination/pollution at the location
X17	Landslides and floods
X18	Noise and air pollution around residents' homes
X19	Weather disturbances
X20	Damage to the ecosystem around water sources
X21	There is unstable and previously unanticipated ground movement
C	**SECURITY ASPECTS OF WORK SAFETY**
X22	Occurrence of a work accident
X23	Insurance for every worker
X24	Difficulty in clearing the pipeline route
X25	The possibility of a strike due to dissatisfaction of project workers
X26	There are workers or implementers who are dishonest, which creates a risk of loss
X27	The presence of individuals who disrupt project implementation (eg: extortion)
D	**SOCIAL ASPECT**
X28	There was a demonstration by the community rejecting water taking.
X29	National security instability affecting project performance
E	**FINANCIAL AND FINANCING ASPECTS**
X30	Inaccurate construction cost estimates
X31	Possible increase in material prices due to inflation and cost escalation
X32	Increasing costs for non-technical factors
X33	Unit price increase
X34	Increase in land acquisition costs
X35	The compensation process is difficult to implement
X36	Slow land acquisition and compensation process
X37	Failure to complete the work contract by the contractor
F	**MANAGERIAL ASPECT**
X38	Poor project implementation management
X39	Low evaluation and decision making system
X40	Weak service provider administration and documentation systems
X41	Minimal holding of coordination meetings in the field
X42	Lack of coordination between functions within the project organization
X43	Internal conflict within project management ranks
X44	Poor performance (consultant/contractor/subcontractor)
X45	Abuse of authority (Corruption, etc.)
X46	Addition/reduction of workers
X47	There is additional work at unequal prices

Variables	Risk Categories and Events
G	**POLICY AND REGULATION ASPECTS**
X48	Replacement of officials/stakeholders in the regions
X49	Changes in scope of work after signing the contract
X50	Operating and maintenance cost estimation errors
X51	Slow or unclear licensing
X52	Time estimation error
X53	Changes in priorities in existing programs
X54	Wrong implementation method
X55	Land acquisition issues
H	**TECHNOLOGY AND RESOURCE ASPECTS**
X56	Availability of supporting facilities and utilities (electricity, etc.)
X57	Availability of raw water (continuity/quantity)
X58	Difficulty in procuring materials (locations difficult to reach)
X59	Material damage during storage process
X60	Equipment damage (heavy equipment) resulting in delays
X61	The need for adequate technology for complex work

Source: Analysis Results, 2025

Final Validation Questionnaire

A questionnaire document containing risk variables that had been validated by experts was distributed to 20 respondents to provide answers regarding the level of risk based on the respondents' experience.

Validity Test

The measurement of the level of validity is done by calculating the correlation between the question item scores and the total number of variable scores. If the correlation results of the question items have a coefficient of at least 0.444, then the item is considered valid. Conversely, if the correlation coefficient is below 0.444, the question item is considered invalid. Validity testing is carried out using the Statistical Package for the Social Sciences (SPSS) version 30 program.

Table 2 Results of the Frequency and Impact Validity Test of Risk Variables

Item-Total Statistics								
	Scale Mean if Item Deleted		Scale Variance if Item Deleted		Corrected Item-Total Correlation		Cronbach's Alpha if Item Deleted	
	Frequency	Impact	Frequency	Impact	Frequency	Impact	Frequency	Impact
X01	144.45	154.50	1360.155	1749.316	.449	.516	.960	.959
X02	144.15	154.25	1341.608	1725.461	.744	.759	.960	.959
X03	144.45	154.95	1363.945	1731.734	.510	.677	.960	.959
X04	145.05	155.15	1337.208	1766.345	.725	.308	.959	.960
X05	145.30	154.85	1362,537	1771.608	.467	.199	.960	.960
X06	145.95	155.80	1374.261	1765.116	.332	.315	.961	.960
X07	145.70	155.65	1368.537	1778.029	.373	.202	.961	.960
X08	145.50	155.50	1363.842	1757.000	.459	.361	.960	.960
X09	144.75	154.45	1326.092	1725.945	.827	.683	.959	.959
X10	145.20	155.15	1358.274	1735.818	.632	.592	.960	.959
X11	145.25	154.90	1375.145	1748.200	.388	.446	.961	.959
X12	144.85	155.00	1354.029	1748.947	.523	.485	.960	.959
X13	144.85	154.75	1392.450	1736.408	.043	.545	.962	.959
X14	144.45	154.60	1374.261	1734.779	.190	.466	.962	.959
X15	145.40	155.55	1343.305	1760.997	.601	.314	.960	.960
X16	145.40	155.75	1359.411	1763.566	.430	.355	.960	.960
X17	145.50	154.90	1367.316	1740.726	.348	.411	.961	.960
X18	145.20	155.75	1371.326	1793.671	.317	.018	.961	.961
X19	144.70	154.65	1360.853	1754.134	.432	.423	.960	.960
X20	145.70	156.00	1349.274	1762,000	.641	.402	.960	.960
X21	145.80	155.25	1368.484	1718.934	.438	.600	.960	.959
X22	145.55	155.75	1344.261	1748.092	.651	.434	.960	.960
X23	145.30	155.80	1338.432	1729.011	.599	.588	.960	.959
X24	144.65	154.45	1341.503	1705.418	.659	.722	.960	.958
X25	145.90	155.45	1354.726	1722.682	.600	.627	.960	.959

Item-Total Statistics								
	Scale Mean if Item Deleted		Scale Variance if Item Deleted		Corrected Item-Total Correlation		Cronbach's Alpha if Item Deleted	
	Frequency	Impact	Frequency	Impact	Frequency	Impact	Frequency	Impact
X26	145.45	155.70	1346.892	1747.168	.526	.530	.960	.959
X27	144.95	155.55	1349.103	1742.787	.510	.547	.960	.959
X28	145.75	155.50	1375.461	1760.263	.334	.372	.961	.960
X29	145.90	155.75	1375.779	1760.513	.291	.390	.961	.960
X30	144.85	155.00	1337.713	1747.368	.566	.363	.960	.960
X31	145.20	155.55	1336.695	1750.682	.574	.398	.960	.960
X32	144.95	155.40	1347.208	1761.200	.513	.303	.960	.960
X33	145.20	155.45	1350.168	1756.050	.596	.366	.960	.960
X34	145.05	154.80	1354.892	1714.379	.461	.682	.960	.959
X35	145.15	154.80	1356.766	1714.800	.371	.551	.961	.959
X36	144.95	154.70	1335.839	1692.011	.686	.832	.960	.958
X37	145.05	154.80	1344,576	1719.642	.605	.636	.960	.959
X38	145.15	155.05	1327.082	1719.629	.688	.711	.960	.959
X39	145.20	155.00	1319.326	1735.053	.823	.565	.959	.959
X40	144.65	155.00	1318.450	1735.158	.725	.498	.959	.959
X41	145.25	155.35	1334.829	1737.608	.614	.462	.960	.959
X42	144.85	155.00	1317.713	1722.211	.749	.628	.959	.959
X43	145.05	154.90	1333.313	1702.621	.622	.770	.960	.958
X44	144.95	154.55	1332.366	1708.155	.727	.823	.959	.958
X45	145.35	155.55	1336.450	1749.629	.626	.372	.960	.960
X46	144.35	154.30	1370.029	1725.905	.367	.696	.961	.959
X47	144.95	155.10	1366.892	1748.200	.372	.509	.961	.959
X48	145.80	155.90	1350.905	1734.832	.569	.540	.960	.959
X49	144.35	154.60	1377.924	1752.568	.168	.399	.962	.960
X50	144.90	155.50	1349.674	1751.632	.574	.467	.960	.959
X51	144.30	154.40	1350.116	1732.253	.530	.509	.960	.959
X52	145.05	154.85	1336.366	1713.082	.736	.775	.959	.958
X53	145.60	155.00	1344.463	1714.421	.583	.660	.960	.959
X54	144.90	154.55	1346.095	1724.997	.727	.738	.960	.959
X55	145.25	154.75	1364.408	1709.776	.435	.711	.960	.958
X56	144.95	154.75	1346.576	1721.461	.640	.627	.960	.959
X57	145.65	155.65	1357.608	1766.450	.612	.293	.960	.960
X58	145.25	154.90	1357.671	1715.253	.501	.661	.960	.959
X59	145.75	155.90	1352.197	1752.305	.624	.482	.960	.959
X60	144.75	154.40	1371.882	1723.937	.289	.631	.961	.959
X61	145.30	155.25	1362,537	1727.039	.467	.635	.960	.959

Source: Data Analysis, 2025

Based on the results of the validity test, several variables have a correlation coefficient value (r-count) of less than 0.444. However, because these variables are used in the Analytical Hierarchy Process (AHP) and filled in by expert respondents, all variables are considered valid and will be used for further data processing.

Reliability Test

Reliability test measures the consistency of the questionnaire as a variable indicator, where the questionnaire is considered reliable if the respondents answer stably. Reliability measurement is carried out using the one shot method using the Cronbach's Alpha (α) statistical test through the SPSS program, with an α value > 0.60 indicating good reliability [15].

Table 3 Results of the Frequency and Impact Reliability Test of Risk Variables

Reliability Statistics			
Cronbach's Alpha		N of Items	
Frequency	Impact	Frequency	Impact
.961	.960	61	61

Source: Data Analysis, 2025

The results of the reliability test using SPSS showed a Cronbach's Alpha (α) value of more than 0.60 for the frequency and impact on risk variables, which indicates a good level of consistency of respondents' answers, so that the questionnaire data can be considered reliable and reliable.

Descriptive Analysis of Time Performance

The purpose of descriptive analysis of time performance is to analyze data based on the mean and mode values at the frequency level and the risk impact according to the respondent's documents. The mean and mode values are obtained by summing up all respondents' answers related to the frequency and impact of each variable. The measurement scale used requires researchers to group subjects into categories or continua in the form of numbers in the category.

Table 4 Risk Value Scale - Frequency versus Time Performance

Scale	Possibility	Frequency	Information
1	Very rarely	The chance of this happening is very small (0-1 occurrence in a project)	The probability is very small approaching zero
2	Seldom	The chance of it happening is quite moderate (2-3 times it happens in a project)	Low probability but greater than zero
3	Sometimes	Chance of occurrence is medium (4-5 occurrences in a project)	Probability is less than 50% but quite high
4	Often	Opportunities occur quite frequently (6-7 occurrences in a project)	Chance of occurrence 50%
5	Very often	Opportunity occurs very often (>7 occurrences in a project)	The probability is above 50%

Source: Data Analysis, 2025

Table 5 Risk Value Scale – Impact on Time Performance

Scale	Level of Consequences	Description
1	Very small	Not to the point of causing delays
2	Small	There is a delay of between 1 to 9 calendar days
3	Currently	There is a delay of between 10 to 18 calendar days
4	Big	There was a delay of between 19 to 27 calendar days
5	Very large	Delay Occurred ≥28 days

Source: Data Analysis, 2025

The following table shows the results of the descriptive analysis of risk against time performance.

Table 6 Results of Descriptive Analysis of Risk on Time Performance Frequency Level and Impact

No	Risk Factors	Mode		Mean		Mean (Rounding)	
		F	D	F	D	F	D
A	**TECHNICAL ASPECT**						
X1	Location Access Constraints	3	3	3,100	3,200	3	3
X2	Unforeseen land conditions (geotechnical, weather, etc.)	3	3	3,400	3,450	3	3
X3	Unexpected Technical Issues in the Field	3	2	3,100	2,750	3	3
X4	Errors in predicting field conditions, weather, and future events	3	2	2,500	2,550	3	3
X5	Design error	2	3	2,250	2,850	2	3
X6	Drinking water quality is not as expected	1	1	1,600	1,900	2	2
X7	Raw water transmission pipes do not comply with minimum standards/technical specifications	1	1	1,850	2,050	2	2
X8	The designed raw water production unit is not yet capable of overcoming turbidity due to sedimentation.	2	1	2,050	2,200	2	2
X9	Making a delivery schedule for materials that is less accurate and precise	3	3	2,800	3,250	3	3
X10	Errors in applying construction method standards	2	2	2,350	2,550	2	3
X11	Errors in applying field work drawings	2	3	2,300	2,800	2	3
X12	The quality of installation work does not meet specifications	2	2	2,700	2,700	3	3
X13	Pipe leak	2	3	2,700	2,950	3	3
X14	Overlapping pipe	2	3	3,100	3,100	3	3
X15	The Water Treatment Plant (IPA) is not functioning according to	1	1	2,150	2,150	2	2

No	Risk Factors	Mode		Mean		Mean (Rounding)	
		F	D	F	D	F	D
	planned capacity						
B	**ENVIRONMENTAL ASPECT**						
X16	There is contamination/pollution at the location	1	1	2,150	1,950	2	2
X17	Landslides and floods	1	1	2,050	2,800	2	3
X18	Noise and air pollution around residents' homes	2	1	2,350	1,950	2	2
X19	Weather disturbances	2	4	2,850	3,050	3	3
X20	Damage to the ecosystem around water sources	1	1	1,850	1,700	2	2
X21	There is unstable and previously unanticipated ground movement	1	1	1,750	2,450	2	2
C	**SECURITY ASPECTS OF WORK SAFETY**						
X22	Occurrence of a work accident	1	1	2,000	1,950	2	2
X23	Insurance for every worker	1	1	2,250	1,900	2	2
X24	Difficulty in clearing the pipeline route	2	5	2,900	3,250	3	3
X25	The possibility of a strike due to dissatisfaction of project workers	1	1	1,650	2,250	2	2
X26	There are workers or implementers who are dishonest, which creates a risk of loss	1	1	2,100	2,000	2	2
X27	The presence of individuals who disrupt project implementation (eg: extortion)	2	2	2,600	2,150	3	2
D	**SOCIAL ASPECT**						
X28	There was a demonstration by the community rejecting water taking.	1	1	1,800	2,200	2	2
X29	National security instability affecting project performance	1	1	1,650	1,950	2	2
E	**FINANCIAL AND FINANCING ASPECTS**						
X30	Inaccurate construction cost estimates	1	1	2,700	2,700	3	3
X31	Possible increase in material prices due to inflation and cost escalation	1	1	2,350	2,150	2	2
X32	Increasing costs for non-technical factors	1	1	2,600	2,300	3	2
X33	Unit price increase	2	1	2,350	2,250	2	2
X34	Increase in land acquisition costs	3	2	2,500	2,900	3	3
X35	The compensation process is difficult to implement	1	1	2,400	2,900	2	3
X36	Slow land acquisition and compensation process	4	1	2,600	3,000	3	3
X37	Failure to complete the work contract by the contractor	2	2	2,500	2,900	3	3
F	**MANAGERIAL ASPECT**						
X38	Poor project implementation management	1	2	2,400	2,650	2	3
X39	Low evaluation and decision making system	1	2	2,350	2,700	2	3
X40	Weak service provider administration and documentation systems	1	1	2,900	2,700	3	3
X41	Minimal holding of coordination meetings in the field	1	1	2,300	2,350	2	2
X42	Lack of coordination between functions within the project organization	3	1	2,700	2,700	3	3
X43	Internal conflict within project management ranks	1	1	2,500	2,800	3	3
X44	Poor performance (consultant/contractor/subcontractor)	2	4	2,600	3,150	3	3
X45	Abuse of authority (Corruption, etc.)	1	1	2,200	2,150	2	2
X46	Addition/reduction of workers	3	4	3,200	3,400	3	3
X47	There is additional work at unequal prices	2	3	2,600	2,600	3	3
G	**POLICY AND REGULATION ASPECTS**						
X48	Replacement of officials/stakeholders in the regions	1	1	1,750	1,800	2	2
X49	Changes in scope of work after signing the contract	3	2	3,200	3,100	3	3
X50	Operating and maintenance cost estimation errors	3	1	2,650	2,200	3	2
X51	Slow or unclear licensing	4	2	3,250	3,300	3	3
X52	Time estimation error	2	2	2,500	2,850	3	3
X53	Changes in priorities in existing programs	1	2	1,950	2,700	2	3
X54	Wrong implementation method	2	4	2,650	3,150	3	3
X55	Land acquisition issues	3	3	2,300	2,950	2	3
H	**TECHNOLOGY AND RESOURCE ASPECTS**						
X56	Availability of supporting facilities and utilities (electricity, etc.)	3	2	2,600	2,950	3	3
X57	Availability of raw water (continuity/quantity)	2	1	1,900	2,050	2	2
X58	Difficulty in procuring materials (locations difficult to reach)	2	1	2,300	2,800	2	3
X59	Material damage during storage process	1	1	1,800	1,800	2	2
X60	Equipment damage (heavy equipment) resulting in delays	2	3	2,800	3,300	3	3
X61	The need for adequate technology for complex work	2	2	2,250	2,450	2	2

Source: Data Analysis, 2025

Analysis of the Analytical Hierarchy Process (AHP) Method

The risk analysis process using the AHP method begins with the following steps:

1) Matrix Normalization: The risk frequency and impact data matrices are normalized.
2) Matrix Consistency Calculation: Calculates consistency on a matrix to ensure the accuracy of comparisons between elements.
3) Hierarchical Consistency: Ensures that consistency is also applied to the AHP hierarchical structure.
4) Accuracy Calculation: Assesses the extent to which analysis results can be trusted based on consistency.
5) Calculate Local Value: Determine local values for risk frequency and impact.
6) Final Result: From this calculation, the final risk value (goal) and ranking are obtained based on the calculated weight.

Table 7 Frequency Weight Value and Impact of Risk Variables

No	Risk Factors	Very rarely/ Very small		Seldom/ Small		Sometimes/ Currently		Often/ Big		Very often/ Very large		Local Values	
		0.069		0.135		0.267		0.518		1,000			
		F	I	F	I	F	I	F	I	F	I	F	I
A	**TECHNICAL ASPECT**												
X1	Location Access Constraints	1	0	5	6	7	7	5	4	2	3	7,201	7,749
X2	Unforeseen land conditions (geotechnical, weather, etc.)	0	1	4	2	7	8	6	5	3	4	8,515	9,064
X3	Unexpected Technical Issues in the Field	0	1	5	10	9	4	5	3	1	2	6,666	6,039
X4	Errors in predicting field conditions, weather, and future events	5	4	4	6	7	5	4	5	0	0	4,826	5,009
X5	Design error	4	4	9	4	6	6	0	3	1	3	4,093	6,972
X6	Drinking water quality is not as expected	13	11	2	2	5	5	0	2	0	0	2,506	3,402
X7	Raw water transmission pipes do not comply with minimum standards/technical specifications	9	7	7	7	2	4	2	2	0	0	3,136	3,532
X8	The designed raw water production unit is not yet capable of overcoming turbidity due to sedimentation.	6	8	9	4	3	5	2	2	0	1	3,465	4,464
X9	Making a delivery schedule for materials that is less accurate and precise	3	1	5	5	6	6	5	4	1	4	6,073	8,417
X10	Errors in applying construction method standards	2	4	11	7	5	4	2	4	0	1	3,992	5,360
X11	Errors in applying field work drawings	2	3	11	5	6	8	1	1	0	3	3,742	6,537
X12	The quality of installation work does not meet specifications	2	2	8	9	5	3	4	5	1	1	5,623	5,741
X13	Pipe leak	2	3	7	4	7	7	3	3	1	3	5,505	7,170
X14	Overlapping pipe	3	4	5	3	4	6	3	1	5	6	8,503	8,802
X15	The Water Treatment Plant (IPA) is not functioning according to planned capacity	8	8	4	5	6	5	1	0	1	2	4,214	4,564
B	**ENVIRONMENTAL ASPECT**												
X16	There is contamination/pollution at the location	8	9	4	5	5	4	3	2	0	0	3,982	3,401
X17	Landslides and floods	8	6	6	4	3	1	3	6	0	3	3,717	7,327
X18	Noise and air pollution around residents' homes	5	8	6	6	6	5	3	1	0	0	4,311	3,216
X19	Weather disturbances	2	2	6	5	6	4	5	8	1	1	6,138	7,022
X20	Damage to the ecosystem around water sources	9	11	7	6	2	1	2	2	0	0	3,136	2,873
X21	There is unstable and previously unanticipated ground movement	9	7	8	6	2	1	1	3	0	3	2,754	6,113
C	**SECURITY ASPECTS OF WORK SAFETY**												
X22	Occurrence of a work accident	9	11	4	4	5	0	2	5	0	0	3,534	3,889
X23	Insurance for every worker	8	12	4	3	4	1	3	3	1	1	4,715	4,055
X24	Difficulty in clearing the pipeline route	2	3	6	4	5	4	6	3	1	6	6,389	9,368
X25	The possibility of a strike due to dissatisfaction of project workers	12	8	4	5	3	3	1	2	0	2	2,689	5,065
X26	There are workers or implementers who are dishonest, which creates a risk of loss	8	8	7	7	1	2	3	3	1	0	4,317	3,585

No	Risk Factors	Very rarely/ Very small		Seldom/ Small		Sometimes/ Currently		Often/ Big		Very often/ Very large		Local Values	
		0.069		0.135		0.267		0.518		1,000			
		F	I	F	I	F	I	F	I	F	I	F	I
X27	The presence of individuals who disrupt project implementation (eg: extortion)	2	6	11	9	3	2	1	2	3	1	5,940	4,198
D	**SOCIAL ASPECT**												
X28	There was a demonstration by the community rejecting water taking.	9	7	6	5	5	5	0	3	0	0	2,768	4,047
X29	National security instability affecting project performance	12	9	4	5	3	4	1	2	0	0	2,689	3,401
E	**FINANCIAL AND FINANCING ASPECTS**		**0**		**0**		**0**		**0**		**0**		
X30	Inaccurate construction cost estimates	5	6	5	5	3	1	5	5	2	3	6,410	6,944
X31	Possible increase in material prices due to inflation and cost escalation	8	9	4	4	2	3	5	3	1	1	5,215	4,517
X32	Increasing costs for non-technical factors	5	8	5	3	4	5	5	3	1	1	5,677	4,847
X33	Unit price increase	5	7	6	6	6	3	3	3	0	1	4,311	4,648
X34	Increase in land acquisition costs	5	4	5	5	6	3	3	5	1	3	5,176	7,340
X35	The compensation process is difficult to implement	8	7	3	2	3	3	5	2	1	6	5,348	8,591
X36	Slow land acquisition and compensation process	5	5	4	2	5	5	6	4	0	4	5,327	8,022
X37	Failure to complete the work contract by the contractor	4	4	7	5	5	3	3	5	1	3	5,109	7,340
F	**MANAGERIAL ASPECT**												
X38	Poor project implementation management	7	4	5	6	2	5	5	3	1	2	5,281	5,974
X39	Low evaluation and decision making system	7	4	5	6	2	3	6	6	0	1	4,798	5,993
X40	Weak service provider administration and documentation systems	5	5	3	5	4	4	5	3	3	3	7,407	6,642
X41	Minimal holding of coordination meetings in the field	7	8	6	5	3	1	2	4	2	2	5,130	5,565
X42	Lack of coordination between functions within the project organization	6	6	2	2	7	6	2	4	3	2	6,591	6,358
X43	Internal conflict within project management ranks	6	6	5	2	4	4	3	6	2	2	5,711	6,859
X44	Poor performance (consultant/contractor/subcontractor)	4	3	6	3	5	4	4	8	1	2	5,492	7,821
X45	Abuse of authority (Corruption, etc.)	8	11	5	1	3	3	3	4	1	1	4,582	4,768
X46	Addition/reduction of workers	1	2	3	2	8	5	7	8	1	3	7,234	8,884
X47	There is additional work at unequal prices	3	4	7	5	5	6	5	5	0	0	5,075	5,142
G	**POLICY AND REGULATION ASPECTS**												
X48	Replacement of officials/stakeholders in the regions	12	14	3	0	3	3	2	2	0	1	3,072	3,806
X49	Changes in scope of work after signing the contract	3	2	3	5	5	5	5	5	4	3	8,536	7,736
X50	Operating and maintenance cost estimation errors	3	7	6	5	7	5	3	3	1	0	5,440	4,047
X51	Slow or unclear licensing	1	2	5	6	5	2	6	4	3	6	8,184	9,552
X52	Time estimation error	4	3	7	6	4	4	5	5	0	2	4,877	6,673
X53	Changes in priorities in existing programs	9	5	7	6	1	2	2	4	1	3	3,869	6,760
X54	Wrong implementation method	2	2	7	4	7	4	4	9	0	1	5,023	7,404
X55	Land acquisition issues	5	4	6	4	7	5	2	3	0	4	4,060	7,705
H	**TECHNOLOGY AND RESOURCE ASPECTS**												
X56	Availability of supporting facilities and utilities (electricity, etc.)	4	3	4	6	8	4	4	3	0	4	5,024	7,638
X57	Availability of raw water (continuity/quantity)	7	8	9	6	3	4	1	1	0	1	3,017	3,949
X58	Difficulty in procuring materials (locations difficult to reach)	5	5	7	4	5	4	3	4	0	3	4,178	7,024
X59	Material damage during storage	10	11	5	4	4	3	1	2	0	0	2,953	3,138

No	Risk Factors	Very rarely/ Very small		Seldom/ Small		Sometimes/ Currently		Often/ Big		Very often/ Very large		Local Values	
		0.069		0.135		0.267		0.518		1,000			
		F	I	F	I	F	I	F	I	F	I	F	I
	process												
X60	Equipment damage (heavy equipment) resulting in delays	2	2	7	4	5	5	5	4	1	5	6,006	9,084
X61	The need for adequate technology for complex work	5	5	7	8	6	1	2	5	0	1	3,928	5,280

Source: Data Analysis, 2025

Risk Level Analysis

Risk level analysis is conducted to identify the impact of risk on project objectives and the chances of risk occurring, by grouping using probability and impact matrices into low, medium, or high categories, so that risk assessment is conducted objectively based on calculated data. The main focus of project risk is on variables that have a high risk level.

Table 8 Results of Analysis of Frequency Risk Level and Impact on Time Performance

No	Risk Factors	Mark (%)		Final ValueRisk Factor		Risk Level
		Frequency	Impact	(%)	Results	
A	TECHNICAL ASPECT					
X1	Location Access Constraints	7,201	7,749	55,805	0.558	Medium
X2	Unforeseen land conditions (geotechnical, weather, etc.)	8,515	9,064	77,179	0.772	High
X3	Unexpected Technical Issues in the Field	6,666	6,039	40,256	0.403	Medium
X4	Errors in predicting field conditions, weather, and future events	4,826	5,009	24,176	0.242	Medium
X5	Design error	4,093	6,972	28,539	0.285	Medium
X6	Drinking water quality is not as expected	2,506	3,402	8,526	0.085	Low
X7	Raw water transmission pipes do not comply with minimum standards/technical specifications	3,136	3,532	11,078	0.111	Low
X8	The designed raw water production unit is not yet capable of overcoming turbidity due to sedimentation.	3,465	4,464	15,470	0.155	Low
X9	Making a delivery schedule for materials that is less accurate and precise	6,073	8,417	51,111	0.511	Medium
X10	Errors in applying construction method standards	3,992	5,360	21,397	0.214	Medium
X11	Errors in applying field work drawings	3,742	6,537	24,461	0.245	Medium
X12	The quality of installation work does not meet specifications	5,623	5,741	32,282	0.323	Medium
X13	Pipe leak	5,505	7,170	39,471	0.395	Medium
X14	Overlapping pipe	8,503	8,802	74,845	0.748	High
X15	The Water Treatment Plant (IPA) is not functioning according to planned capacity	4,214	4,564	19,232	0.192	Low
B	ENVIRONMENTAL ASPECT					
X16	There is contamination/pollution at the location	3,982	3,401	13,542	0.135	Low
X17	Landslides and floods	3,717	7,327	27,235	0.272	Medium
X18	Noise and air pollution around residents' homes	4,311	3,216	13,865	0.139	Low
X19	Weather disturbances	6,138	7,022	43,100	0.431	Medium
X20	Damage to the ecosystem around water sources	3,136	2,873	9,010	0.090	Low
X21	There is unstable and previously unanticipated ground movement	2,754	6,113	16,833	0.168	Low
C	SECURITY ASPECTS OF WORK SAFETY					
X22	Occurrence of a work accident	3,534	3,889	13,741	0.137	Low
X23	Insurance for every worker	4,715	4,055	19,119	0.191	Low
X24	Difficulty in clearing the pipeline route	6,389	9,368	59,850	0.598	Medium

No	Risk Factors	Mark (%)		Final ValueRisk Factor		Risk Level
		Frequency	Impact	(%)	Results	
X25	The possibility of a strike due to dissatisfaction of project workers	2,689	5,065	13,620	0.136	Low
X26	There are workers or implementers who are dishonest, which creates a risk of loss	4,317	3,585	15,476	0.155	Low
X27	The presence of individuals who disrupt project implementation (eg: extortion)	5,940	4,198	24,939	0.249	Medium
D	**SOCIAL ASPECT**					
X28	There was a demonstration by the community rejecting water taking.	2,768	4,047	11,203	0.112	Low
X29	National security instability affecting project performance	2,689	3,401	9,147	0.091	Low
E	**FINANCIAL AND FINANCING ASPECTS**					
X30	Inaccurate construction cost estimates	6,410	6,944	44,510	0.445	Medium
X31	Possible increase in material prices due to inflation and cost escalation	5,215	4,517	23,556	0.236	Medium
X32	Increasing costs for non-technical factors	5,677	4,847	27,515	0.275	Medium
X33	Unit price increase	4,311	4,648	20,036	0.200	Medium
X34	Increase in land acquisition costs	5,176	7,340	37,994	0.380	Medium
X35	The compensation process is difficult to implement	5,348	8,591	45,942	0.459	Medium
X36	Slow land acquisition and compensation process	5,327	8,022	42,731	0.427	Medium
X37	Failure to complete the work contract by the contractor	5,109	7,340	37,503	0.375	Medium
F	**MANAGERIAL ASPECT**					
X38	Poor project implementation management	5,281	5,974	31,550	0.315	Medium
X39	Low evaluation and decision making system	4,798	5,993	28,755	0.288	Medium
X40	Weak service provider administration and documentation systems	7,407	6,642	49,196	0.492	Medium
X41	Minimal holding of coordination meetings in the field	5,130	5,565	28,551	0.286	Medium
X42	Lack of coordination between functions within the project organization	6,591	6,358	41,906	0.419	Medium
X43	Internal conflict within project management ranks	5,711	6,859	39,172	0.392	Medium
X44	Poor performance (consultant/contractor/subcontractor)	5,492	7,821	42,954	0.430	Medium
X45	Abuse of authority (Corruption, etc.)	4,582	4,768	21,849	0.218	Medium
X46	Addition/reduction of workers	7,234	8,884	64,270	0.643	High
X47	There is additional work at unequal prices	5,075	5,142	26,095	0.261	Medium
G	**POLICY AND REGULATION ASPECTS**					
X48	Replacement of officials/stakeholders in the regions	3,072	3,806	11,693	0.117	Low
X49	Changes in scope of work after signing the contract	8,536	7,736	66,035	0.660	High
X50	Operating and maintenance cost estimation errors	5,440	4,047	22,016	0.220	Medium
X51	Slow or unclear licensing	8,184	9,552	78,177	0.782	High
X52	Time estimation error	4,877	6,673	32,545	0.325	Medium
X53	Changes in priorities in existing programs	3,869	6,760	26,154	0.262	Medium
X54	Wrong implementation method	5,023	7,404	37,189	0.372	Medium
X55	Land acquisition issues	4,060	7,705	31,285	0.313	Medium
H	**TECHNOLOGY AND RESOURCE ASPECTS**					
X56	Availability of supporting facilities and utilities (electricity, etc.)	5,024	7,638	38,372	0.384	Medium
X57	Availability of raw water (continuity/quantity)	3,017	3,949	11,915	0.119	Low

No	Risk Factors	Mark (%)		Final ValueRisk Factor		Risk Level
		Frequency	Impact	(%)	Results	
X58	Difficulty in procuring materials (locations difficult to reach)	4,178	7,024	29,351	0.294	Medium
X59	Material damage during storage process	2,953	3,138	9,265	0.093	Low
X60	Equipment damage (heavy equipment) resulting in delays	6,006	9,084	54,555	0.546	Medium
X61	The need for adequate technology for complex work	3,928	5,280	20,738	0.207	Medium

Source: Data Analysis, 2025

It can be seen that the risk variables with a low risk level number 17 (27.87%), medium risk number 39 (63.93%) and high risk number 5 (8.20%).

Dominant Risk

These dominant risks have the potential to hinder the achievement of project time targets, thus requiring special attention and appropriate mitigation strategies.

Table 9 Dominant Risk

Rank	Var	Risk Factors	Weight Value	Risk Level
1	X51	Slow or unclear licensing	78.18%	*High*
2	X2	Unforeseen land conditions (geotechnical, weather, etc.)	77.18%	*High*
3	X14	Overlapping pipe	74.85%	*High*
4	X49	Changes in scope of work after signing the contract	66.04%	*High*
5	X46	Addition/reduction of workers	64.27%	*High*

Source: Data Analysis, 2025

Dominant Risk Management

Risk management through corrective and preventive measures is essential to prevent an increase in these risks, which have the potential to cause major losses to time performance and disrupt project implementation.

Table 10 Risk Response Matrix to Dominant Risk Factors

No	Risk Variables	Case	Risk Response		
			Preventive Actions	Corrective Action	Risk Mitigation
1	Slow or unclear licensing	- Land permit processing for the installation of distribution pipes takes a long time due to non-standardized licensing procedures.	- Coordinate early with relevant government agencies to understand the requirements and licensing process. - Prepare a realistic project schedule taking into account licensing time. - Involve experienced consultants in the licensing process to reduce the possibility of document errors.	- Contractors and owners together prepare a realistic work plan taking into account the licensing time. - Owners facilitate initial coordination with government agencies to expedite licensing processing. - Contractors involve consultants to support the completeness of licensing documents.	- Owner and contractor agree to reschedule the project in areas that already have permits to prevent further delays. - Develop a direct communication strategy with regulators to expedite the delayed permit process.
		- The land permit process for pipe installation takes a long time due to changes in regulations during implementation.	- Identify relevant regulations early on and ensure compliance with them. - Coordinate early with relevant agencies to understand potential regulatory changes.	- Readjust project schedules following regulatory changes and delayed permit processes. - Negotiate with authorities to expedite the permit process.	- Monitor regulatory changes periodically to be able to immediately adjust planning. - Prepare flexible licensing plans and anticipate unexpected regulatory changes.

No	Risk Variables	Case	Risk Response		
			Preventive Actions	Corrective Action	Risk Mitigation
2	Unforeseen land conditions (geotechnical, weather, etc.)	- Soft soil was found at the pipe excavation site which required additional stabilization.	- Conduct more detailed geotechnical investigations, such as additional sounding tests at the pipe installation site. - Allow extra time in the schedule for unforeseen ground conditions.	- Stabilizing the soil using geotextile materials or installing retaining structures. - Using faster alternative construction methods, such as soil compaction or the use of special heavy equipment. - Rescheduling the project schedule after identifying land problems.	- Develop a flexible schedule that allows extra time for unforeseen circumstances. - Develop a contingency plan to expedite affected work stages.
		- Unpredictable heavy rain hampered the excavation and pipe installation process.	- Use long-term weather forecast data to plan timing of critical work. - Reserve extra time in the schedule for inclement weather.	- Re-arrange the project schedule to accommodate unexpected weather conditions. - Add tools and manpower to speed up the work once the weather improves.	- Utilize alternative work methods that can be implemented in adverse weather conditions, such as using pumping equipment or temporary drainage systems. - Develop backup plans to expedite delayed work.
3	Overlapping pipe	- There was an overlap of pipes with existing pipes that was not previously detected.	- Conduct more detailed and accurate field surveys to ensure existing pipelines and pipes to be installed. - Better coordination between the design team and the field team.	- Moving pipes located on overlapping lines with new pipe lines. - Using heavy equipment to speed up the moving and re-excavation if necessary.	- Using digital mapping technology or underground scanning to minimize errors in pipeline planning.
		- There is an overlap between the pipe and the fiber optic cable line	- Establish better coordination between parties responsible for installing fiber optic pipes and cables. - Conduct more accurate mapping of fiber optic cable and pipe routes.	- Moving fiber optic cables or relocating pipe installation routes.- Using alternative installation techniques to avoid damage to fiber optic cables.	- Using more accurate mapping technology to identify fiber optic pipelines and cables. - Coordinating with fiber optic owners to assist in supervision.
4	Changes in scope of work after signing the contract	- Increase the length of the pipe installation path	- Conduct more thorough studies and comprehensive initial planning to ensure a clear scope. - Anticipate possible design changes in the project schedule.	- Readjust project schedules according to scope changes. - Optimize resource usage to expedite additional work.	- Prepare a clear scope change clause in the contract. - Prepare a schedule to accommodate unexpected changes.
		- There is an additional work item for installing a Flowmeter for clean water distribution.	- Identify the need for all technical components, including flowmeters, at the early planning stage. - Create contract clauses that allow for scope adjustments without significantly disrupting the project schedule.	- Adjust the project schedule by including additional time for flowmeter procurement and installation. - Add resources or optimize work time to catch up on delays.	- Prepare a comprehensive and detailed list of project components at the planning stage. - Estimate the procurement and installation time of the required materials.
5	Addition/reducti	- Reduction in	- Arrange work	- Readjust the work	- Ensure thorough

No	Risk Variables	Case	Risk Response		
			Preventive Actions	Corrective Action	Risk Mitigation
	on of workers	the number of workers during religious holidays	schedules by taking into account previous holidays. - Prepare a workforce plan that can accommodate holiday periods without disrupting project performance.	schedule by adjusting the number of existing workers. - Optimize the available workforce by adding work shifts (overtime) if necessary.	planning of the workforce schedule before the holidays. - Identify work that can be expedited or done with fewer workers.
		- Reduction in the number of workers because some workers were transferred to work on other projects	- Develop realistic schedules for workforce distribution across projects. - Ensure flexible workforce planning taking into account possible changes in worker allocation.	- Add workers from other projects if available or add work shifts (overtime) to maximize productivity.	- More flexible and adequate workforce planning so that the transfer of workers to other projects does not affect the project. - Identify work that can be prioritized or done more efficiently to minimize delays.

Source: Data Analysis, 2025

V. CONCLUSION

Based on the analysis, the dominant risks that affect the implementation time of the clean water distribution pipeline network construction project in Dumai City include slow or unclear licensing (78.18%), unexpected land conditions (77.18%), overlapping pipes (74.85%), changes in the scope of work after signing the contract (66.04%), and adding or reducing workers (64.27%).

Suggested mitigation measures to reduce the impact of dominant risks include: early coordination with relevant agencies, preparation of a realistic project schedule, and involvement of permit consultants to address slow or unclear permits (X51); detailed geotechnical investigations, schedule adjustments for bad weather, and preparation of flexible schedules and contingency plans for unforeseen land conditions (X2); detailed field surveys, digital mapping of pipeline routes, and relocation of overlapping lines to address pipeline overlaps (X14); comprehensive early planning, preparation of flexible contract clauses, and schedule adjustments for changes in the scope of work (X49); and workforce planning that takes into account critical periods such as holidays and flexible allocation to address the addition or reduction of workers (X46).

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