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Risk Factor Analysis on Contingency Costs of Phase I Wastewater Network Project in Bogor City

Doni Triatmojo[1], Henny Pratiwi Adi[2], Hermin Poedjiastoeti[3]
Universitas Islam Sultan Agung, Semarang, Indonesia
Email: triatmojo.doni@gmail.com

*Correspondence

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ABSTRACT

Contingency cost estimation is essential for construction project management to anticipate cost uncertainty due to various risks. This study analyzes risk-based contingency cost estimation in the Bogor City Phase I wastewater network system project. The background of this research is based on the need for accurate cost planning to avoid budget overruns and ensure project sustainability. The study aims to identify risk factors that affect contingency costs, group risks based on their degree of influence, and build a more accurate estimation model using the Partial Least Squares-Structural Equation Modeling (PLS-SEM) approach. This study uses a mixed method, namely qualitative analysis through interviews and literature studies to identify risk factors and a quantitative approach by distributing questionnaires to project stakeholders. The data was analyzed using SPSS 25 and SmartPLS software to test the validity and reliability of the contingency cost estimation model. The study results show that the most significant risk in the pre-construction stage is licensing and design, while in the construction stage is procuring equipment/materials and force majeure factors. The highest contingency cost estimate is in the preconstruction stage, with a value of 11.02%. The study's conclusion confirms that risk mitigation in the early stages of the project is essential to reduce the impact of budget uncertainty. The implications of this study contribute to the management of construction projects by providing a more accurate risk-based contingency cost estimation model that can be used as a reference for stakeholders in planning and managing infrastructure projects.

Introduction

Cost is one of the essential elements of project management and an important element in project funding decisions. (SE et al., 2024)(Lock, 2017). It is also one of the most essential parameters for measuring the success of a project. (Hussein et al., 2015). Accurate cost estimates are crucial to project cost control. Cost estimation is a quantitative assessment, based on the information available at a given point in time, of the likely cost of the resources required to complete a project (PMI, 2017)(Desmyra, 2022) (Fauzi, 2018)(Fajar et al., 2016)(Lumentah et al., 2020).

Risks are things that may occur naturally in a situation or beyond expectations. Even though an activity has been planned as best as possible, there is still uncertainty that it will run entirely according to plan (Ambiya et al., 2021)(Maralis & Triyono, 2019)(Christin & Sihombing, 2021). The implementation of construction projects also experiences the same thing; there is no guarantee that the implementation in the field will run as planned (Ervianto, 2023). This uncertainty requires parties related to construction to be able to recognize and manage risks (Kerzner, 2021).

The relationship between contingency costs and risks on a project includes allocating additional funds intended to cover the uncertainty of estimated costs that may arise due to exposure to risk during the project's implementation. (Traynor & Mahmoodian, 2019). The total estimated cost of the project consists of the estimated base cost plus the contingency cost. Base costs are initial estimates based on typical conditions and initial project planning, while contingency costs are prepared to anticipate uncertainties and risks that cannot be explicitly predicted at the construction stage. (Sutikno & Rohman, 2022).

The city of Bogor is currently experiencing problems with sanitation. According to the Bogor SSK (City Sanitation Strategy) Document (2019), only 3.8% of Bogor residents have access to a safe sanitation system (Pangestu, 2021). This portion is tiny compared to the target set by the Government in the 2020-2024 National Medium-Term Development Plan, which is 15%. The percentage of careless defecation is also high, namely 26.1% compared to the zero percent target (0%). To overcome these sanitation problems, Bappeda Bogor, the Ministry of Public Works and Public Housing (Ministry of Public Works and Public Housing), Bogor City, and other relevant stakeholders under the guidance of WB & KEITI plan the construction of sewage systems which will be carried out in 2 phases. Phase I will serve areas with fewer pumps and higher revenue potential derived from commercial buildings and residential complexes. Meanwhile, Phase II will serve areas with more complex topography and need pumps.

It is currently in the Detail Engineering Design (DED) stage for the Phase I construction project of the Bogor City Wastewater Network System, which will be operated in the period 2027 to 2037 (Setiawan, 2020). Contingency cost analysis is critical in the preconstruction and construction stages. Without adequate contingency cost estimates, projects can experience a shortage of funds that can hinder completion or degrade the quality of the final deliverables (Sayed et al., 2023).

Contingency costs are often calculated as an overall percentage in addition to the basic estimate, usually derived from intuition, experience, and historical data. This study uses a flexible and rational approach, using SPSS 25 to check the validity and reality of research variables. Then, it was continued by simulating the contingency cost estimate based on risk management in the Bogor wastewater network project (Peginusa et al., 2020).

Previous research conducted by Yunanto (2021) With the title Risk Management Cost Analysis in the East Side Bogowonto River Estuary Safety Project (Ksn) Yia with the purpose of the East Side Bogowonto River Estuary Safety Development Project (KSN) YIA and analyze the cost and find out the risk mitigation measures. Yunanto (2021) Stated that the results of the questionnaire analysis using the mean method showed five high risks that require mitigation and cost analysis results.

This study aims to analyze risk factors, group the risks that affect contingency costs, and apply the Partial Least Squares-Structural Equation Modeling (PLS-SEM) method to produce a more accurate contingency cost estimation model. The research objectives include minimizing the risk of cost overruns, preparing unique calculation models, and improving the quality of project management. The research method approach uses related theories, namely construction projects, wastewater network systems, risk management, contingency costs, and the PLS-SEM method. This research is expected to provide input to practitioners regarding the amount of contingency value in the Bogor City Phase 1 Wastewater Network System Project based on the risks that will occur in preconstruction and construction.

This study's novelty is that it combines expert interviews as qualitative data that is converted into a quantitative model, and it makes a significant contribution to the development of a combined approach. The analysis of the contingency estimate of the wastewater network system project provides a new context for updates in the latest case study. The research results are expected to offer practical solutions for risk management and project cost control.

Method

Research on contingency cost estimates for Phase I of the Bogor City Wastewater Network will be conducted using qualitative and quantitative approaches to ensure valid and reliable estimation results. In the qualitative analysis stage, a literature study will identify the risk factors that affect the project's cost in the preconstruction and construction stages. Additionally, interviews with experts in the construction field will provide in-depth insight into best practices and empirical experience in contingency cost management. These interviews will also help confirm findings from the literature and identify specific risks that may not have been detected beforehand.

For quantitative analysis, use the distribution of questionnaires on respondents. Then, the amount of impact and probability value will be obtained. Then, the validity and reality of the variables will be checked using the SPSS 25 application, followed by impact and probability analysis to determine the risk category. Impact and probability analysis will also be modeled as an estimate of the contingency cost. Through a combination of qualitative and quantitative analysis, this study can produce a more accurate and reliable contingency cost estimation model for the Phase I project of the Bogor City Wastewater Network.

Research Location

This research was carried out on the Wastewater Network Project covering the Bogor city area, so the project boundaries are as follows:

1. North: Kemang and Bojong Gede Districts.
2. East: Sukaraja and Ciawi Districts, Bogor Regency.
3. West: Dramaga and Ciomas Districts, Bogor Regency.
4. South: Cijeruk and Caring in Districts, Bogor Regency.

Data Collection Methods are primary data and secondary data. In this study, primary data was obtained from the results of interviews and questionnaires by respondents. The questionnaire used in this study is semi-closed, where some of the questions are closed with available answer options, especially related to the likelihood scale and consequences of the risks that have been identified. In this project, several secondary data are combined as a project document. The data collection method in this study is carried out as follows:

1. **Literature Studies:** In addition to observation, the researcher also conducted a literature study to identify factors that affect the estimation of contingency costs.
2. **Project Details:** Detailed Engineering Design Report data such as the overall layout of the wastewater network, technical specifications, and cost budget plans.

Data Processing Methods

This research started with secondary data analysis and then expanded with primary data. In Phase I, a survey was carried out with the help of an initial questionnaire instrument given to 5 experts/experts for variables that could affect the estimated contingency cost of the project. The questionnaire instrument used in the early stages was an open-ended questionnaire model. The questionnaire model is presented simply so respondents can provide information according to their needs and circumstances. Experts are asked to fill in the information column stating the expert's perception of the parameters of these variables. The data from the experts is then processed so that the variables produced are a risk factor that affects the estimation of project contingency costs.

Data Analysis Methods

This research uses case studies of projects not yet running in the Detailed Engineering Design stage. The Project Plan will be implemented in 2025-2027, namely the Bogor City Phase I Wastewater Network System project, with a pipe length of 46,526.59 meters. The budget for the project is projected at 1.2 T. The budget is divided into six main components. General Costs, Procurement of Pipes and Accessories, Installation of Pipes and Accessories, MH Drops, Property (Dry Connection), Occupational Safety and Health Management System.

Phase I data analysis was carried out to answer the first research question. The variables of the literature results are generally brought to experts for validation. This expert validation aims to determine whether the questionnaire variables are feasible or not used as risk factors that affect the contingency cost estimation.

Data collection and questionnaire phase II are conducted using a closed questionnaire to stakeholders. This phase II study aims to identify risk factors affecting the estimation of contingency costs of the Bogor City Phase 1 Wastewater Network projects. The respondents in Phase II are the entire population of the Bogor City Phase 1 Wastewater Network project. The data from the phase II questionnaire was processed with qualitative analysis to produce influential risk factors, risk categories, and contingency cost estimation simulations. Before being analyzed, the relationship between indicators, latent variables, and main variables will be tested.

a. Validity and Reliability Testing

Validity tests are used to measure the validity or invalidity of a questionnaire. A questionnaire is said to be valid if the questions can reveal something that the questionnaire will measure. The reliability test is a tool to measure a questionnaire, which is an indicator of a variable or construct. A questionnaire is considered reliable if a person's answers to statements are consistent or stable over time.

b. Risk Categorization

Local values are calculated by multiplying the element's weight by the number of respondents who answered the element criteria for each risk factor variable. Each average local value of risk frequency and risk impact is used to obtain the value of the risk factor (Szymański, 2017).

Results and Discussion

Project Description

The domestic wastewater network construction project in Bogor City aims to improve the waste management system through a treatment plant with a capacity of 32,500 m^3/day. The physical implementation of this project is planned for 2026. By targeting dense urban areas, this project is expected to overcome sanitation problems and improve environmental quality through more effective waste management. The project will build a pipeline network directly connected to the centralized domestic wastewater treatment facility (SPALD-T).

a. Project Background

The Indonesian government promotes sustainable and environmentally friendly wastewater management practices to protect water resources, public health, and ecosystems. The government seeks to increase the coverage and effectiveness of wastewater treatment facilities, especially in the country's urban areas and industrial zones. It involves constructing, upgrading, rehabilitating, and upgrading wastewater treatment plants, networks, and decentralized treatment systems.

Bogor City is one of the cities in Indonesia that was designated in 2020 for the Implementation of the Pilot Project based on the Decree of the Minister of Home Affairs Number 845-208 of 2020 concerning Provincial Assistance in the Implementation of the Regency/City Sanitation Strategy in 2020.

b. Project Objectives

The general objective of the Sewage System with Citywide Inclusive Sanitation program is to construct the Bogor City Wastewater Treatment Plant and Wastewater Network Phase I to ensure effective wastewater treatment, protect public health and the environment, and comply with regulatory standards.

Specific objectives include three components of the project:

1. Wastewater and Fecal Treatment Plant. Make detailed WWTP, and IPLT designs that effectively and efficiently eliminate pollutants and contaminants in wastewater to meet water quality by effluent quality standards set in regulations. In this case, it involves applying various processing processes such as primary, primary, secondary, and tertiary.
2. Wastewater Network. Create detailed wastewater network designs using sustainability principles to accommodate future population growth, land shifting, and development Co Longitudinal Cut Drawing in Figure 4.1 and Horizontal Cut Drawing in Figure 1.

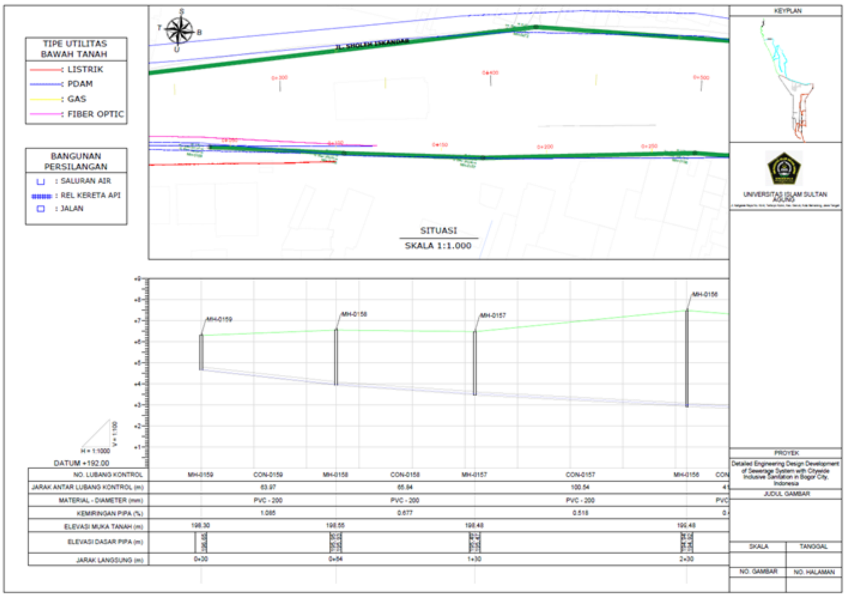

Figure 1. Drawing of an elongated cut of the wastewater network

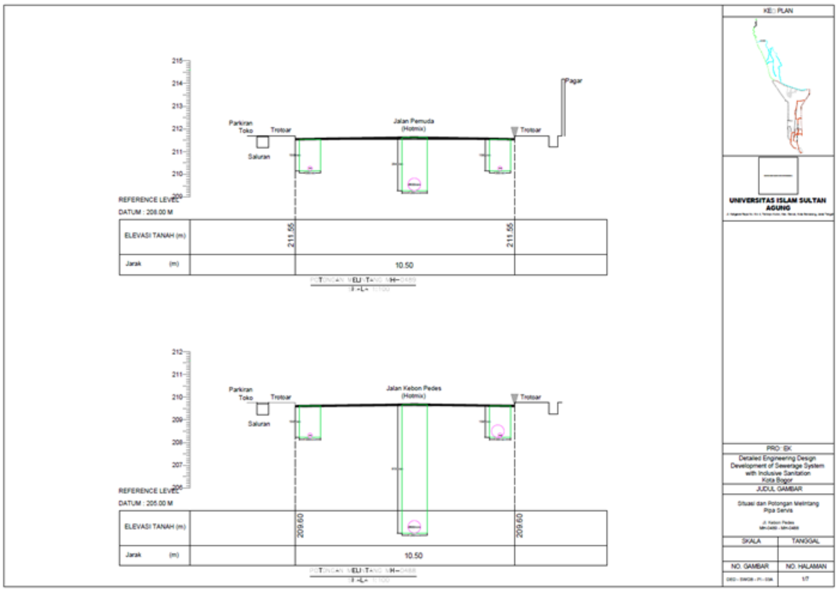

Figure 2. Drawing of a cross-cutting piece of a wastewater network

3. Prepare guidelines for operating and maintaining wastewater collection pipelines, WWTP, and IPLT.

c. Planning and Implementation of Wastewater Network Projects

A wastewater network is a system of pipes and conduits that collects and moves wastewater from a home, building, or a specific area to a wastewater treatment plant. This wastewater comes from various sources such as bathrooms, toilets, kitchens, and industries. The network is designed to efficiently drain waste to a suitable treatment site, where it can be treated and cleaned before being released into the environment. The primary purpose of the wastewater network is to avoid environmental pollution and maintain public health by ensuring that the waste produced is treated effectively before being disposed of. This system can manage wastewater efficiently and safely, reducing the risk of disease spread and environmental damage. Figure 4.3 shows the stages from the initial analysis to the operation and maintenance of the Wastewater Network system.

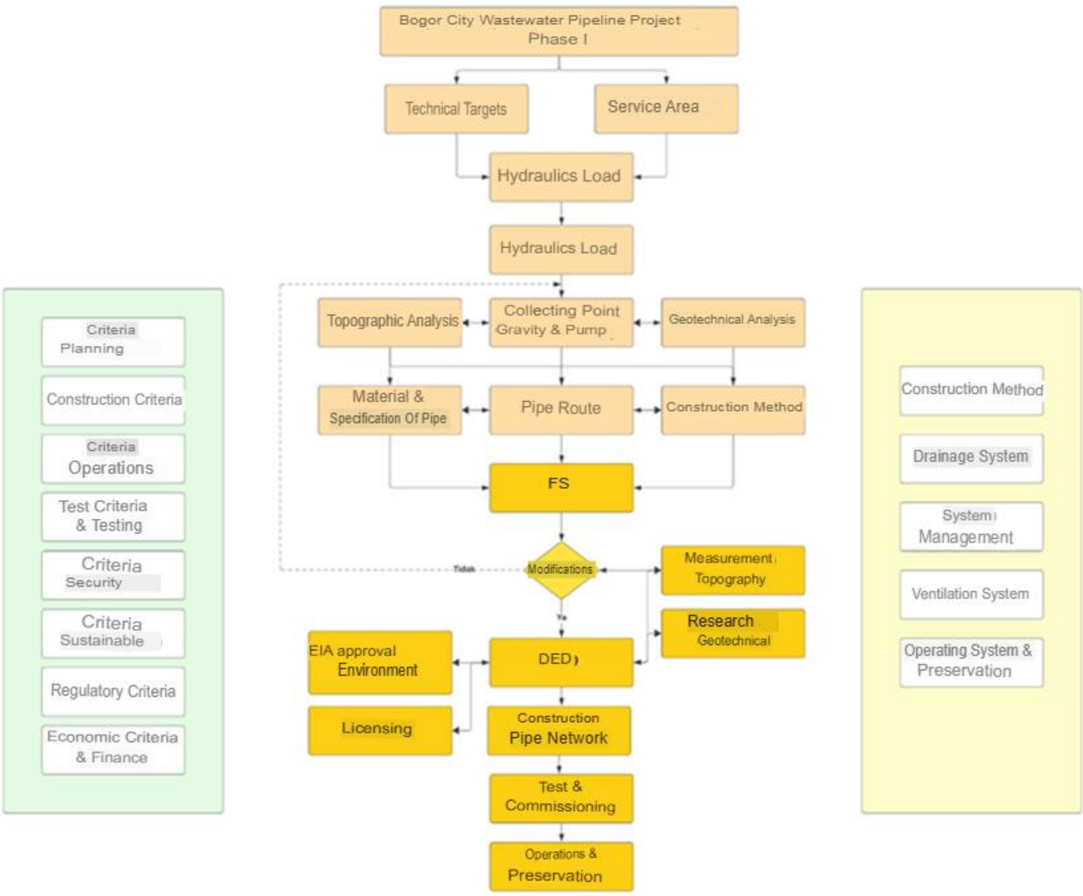

Figure 3. Wastewater Network Planning Flow Diagram

d. Basics of Wastewater Network Planning

The following are the basics of planning in the design of wastewater networks:

Table 1. Basics of Wastewater Network Planning

No.	Parameter	Unit	Basics of Planning	Information
1	Duration of Service Years until it reaches Target Capacity	-	2027-2037	Construction will be carried out starting in mid-2025
2	Project Location		Several villages in Tanah Sareal District and Central Bogor District	
3	Phase I Service Area	Ha	± 1,000	
4	Clean water discharge unit	Liters per capita per day	- Domestic : 160Non-domestic :	- Household clean water consumption is based on data from

No.	Parameter	Unit	Basics of Planning	Information
			±20% of total non-domestic	PDAM Tirta Pakuan in 2023. - Clean water consumption is assumed to remain unchanged for years, with no increase to encourage water conservation.
5	Wastewater discharge unit	Liters per capita per day	- Domestic : 128Non-domestic : ±20% of total non-domestic	- The discharge of wastewater is assumed to be 80% clean water. - The figure of 20% of non-domestic discharge is the result of the calculation of estimated discharge from commercial buildings/government agencies in the service area
6	Target SPALD-T Service Coverage at the Kayumanis city scale		- 160,709 people (± 32,142 House Connections) - 1200 Non-Home Connections (Non-domestic)	Assumption 1 House Connection = 5 people
7	Discharge Infiltration		Surface Infiltration: 10% Channel Infiltration = L/1,000×QR = 20,182(length of PVC pipe in project)/1,000×2 L/sec = 3487.44 m3/day = ±13% Total infiltration discharge = 23%	Formula for: Surface infiltration = 0.1-0.3 QR Channel Infiltration = L/1,000×QR Source: Permen PUPR
8	WWTP design capacity	m3/day	±32,500 m3	

Source : (Researcher, 2024)

Risk factors affecting contingency costs: First Stage Questionnaire Data Analysis

The first stage of questionnaire data analysis was used to help answer the first stage of research questions. The questionnaire's first stage contains variables consisting of risk factors obtained from the results of literature studies and as many as 59 factors submitted to experts for verification, clarification, and validation. Experts are asked for opinions on whether they agree with these risk variables. Experts are asked to fill in the information columns provided by adding, subtracting, giving input, and correcting the risk variables presented. (Siswoyo et al., 2023).

Initially, the number of experts appointed and sent the phase 1 questionnaire was 5 (five) people, with the criteria for experts being personnel with experience in the sanitation and wastewater networks, from the Planning Consultant, Project Owner, and Fund Provider. The following is the identity data of each respondent who was asked for information and data through interviews. The data of respondents representing the five parties are as follows:

Table 2. Phase 1 Research Respondents

No.	Expert	Age	Gender	Last Education	Position
1.	Expert 1	70	Man	S2 Engineering Civil	Advisor Consultant Planners PT Infra Tama Yakti
2.	Expert 2	48	Man	S1 Engineering Civil	President Director of Co nsultant Planner and Management Construction
3.	Expert 3	47	Woman	S1 Engineering Civil	JFT Engineering Sanitation Milieu PUPR Office Bogor
4.	Expert 4	48	Woman	S2 Engineering Civil	Head of Work Unit Implementation Pralosing Settlements Region III Java Province Middle
5.	Expert 5	59	Man	S2 Engineering Milieu	Urban Water and Sanitation Specialist World Bank

Source : (Researcher, 2024)

Table 4.5 shows 59 risk indicator variables that affect the estimation of contingency costs in the Bogor City Phase 1 Wastewater Network Project, 19 of which are considered relevant by experts, and two additional indicator variables, for a total of 22 indicator variables that will be continued in the distribution of the phase 2 questionnaire.

a. Second Stage Questionnaire Data Analysis

The questionnaire results that have been distributed to confident respondents as a pilot survey based on the results of risk variables that experts have validated are then distributed to the respondents who have been determined, namely to the parties involved in the wastewater network project. Respondents were divided into several criteria as follows:

1. Gender

Figure 2, the Respondent Graph by Gender, shows that 78% of respondents, or 19 people, were male.

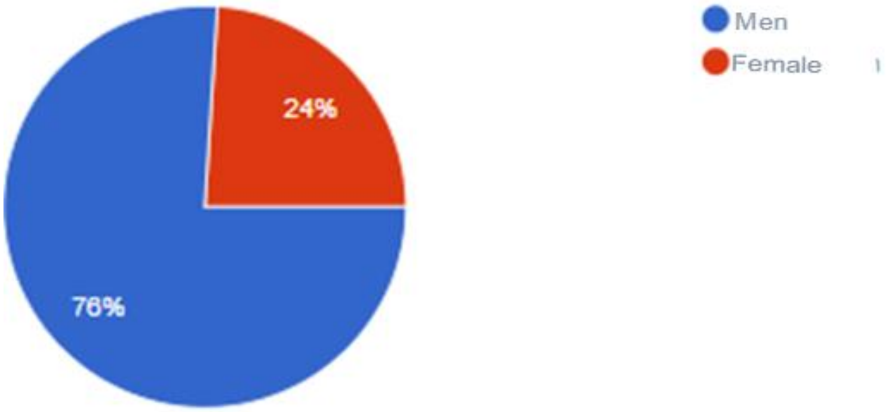

Figure 2. By Gender

2. Education

Figure 3, the Respondent Graph based on Last Education, shows that S1 Education is more than 68% or 17 people.

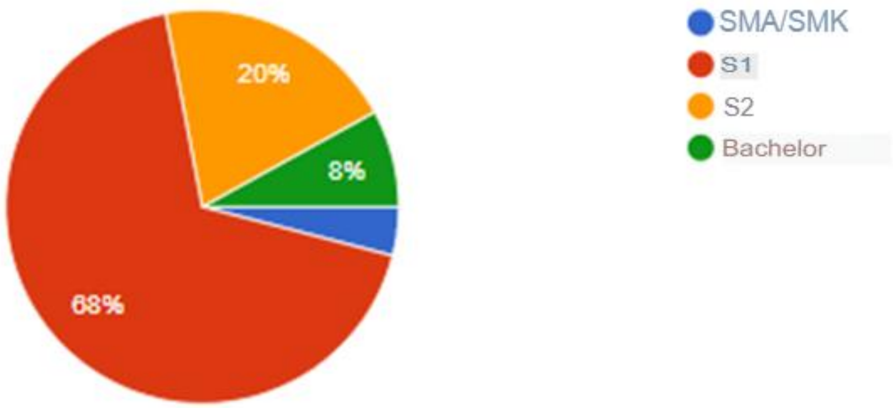

Figure 3. By Education

3. Length of Work

It can be seen in Figure 4. Respondents' Graph based on Length of Work: As many as 56% or 14 people have worked> 15 years.

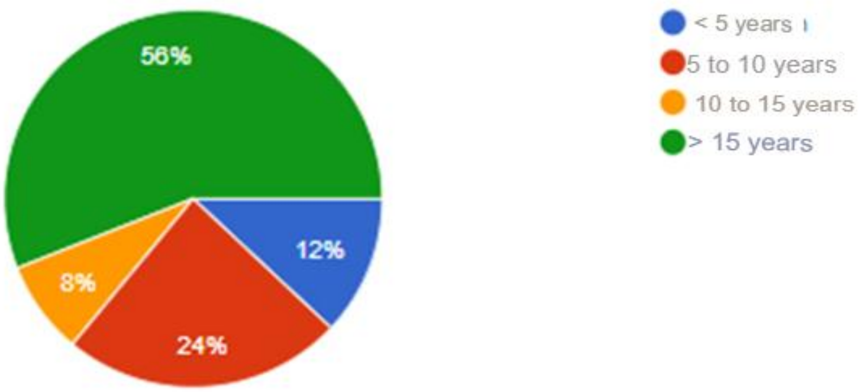

Figure 4. Based on Working Time

4. Job Title

It can be seen in Figure 5, the Respondent Graph by Job Title, Dominated by Consultants, as many as 60% or a total of 15 people, and respondents from pipe suppliers and jacking pipe vendors.

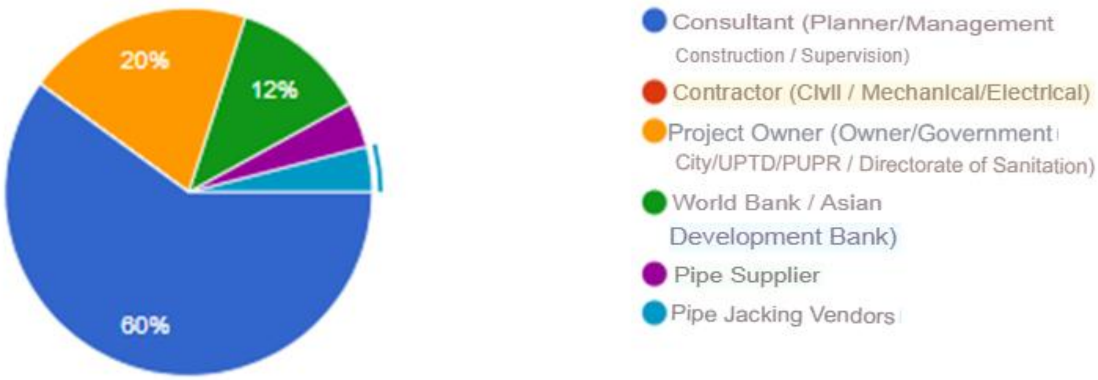

Figure 5. Based on Job Departments

The following are the variables used to distribute the Phase II Questionnaire, with 21 indicator variables. There are 13 preconstruction variables and eight construction variables.

Risk Categories

After obtaining the average value of frequency and risk impact, the value of the risk factors is examined. The Risk Factor Equation is the multiplication between the magnitude of the effects and the probability of a risk event. Risk categories divide risk categories into groups based on their level of risk.

Contingency Fee

Table 4.17 shows the risk analysis of construction projects based on two main stages: preconstruction and construction stages. Each risk component is measured based on the Impact Value and Frequency Value, which are then used to calculate the Contingency Cost. In the Pre-Construction Phase, the highest risks come from "Licensing" and "Design," with contingency costs of 11.02 and 11.01, respectively, significantly impacting project costs.

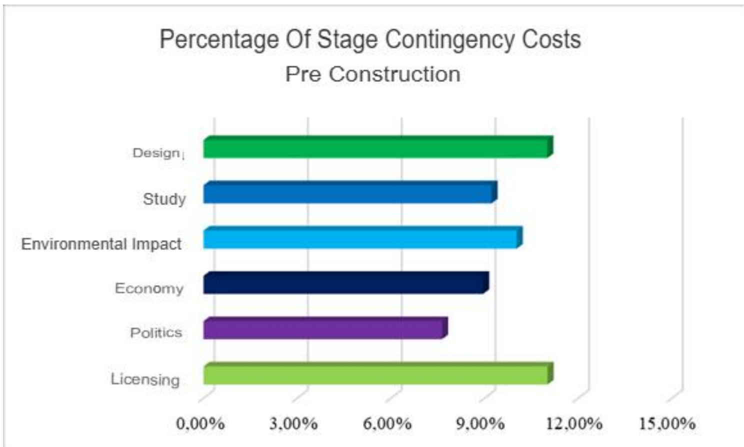

Figure 6. Contingency Costs in the Pre-Construction Stage

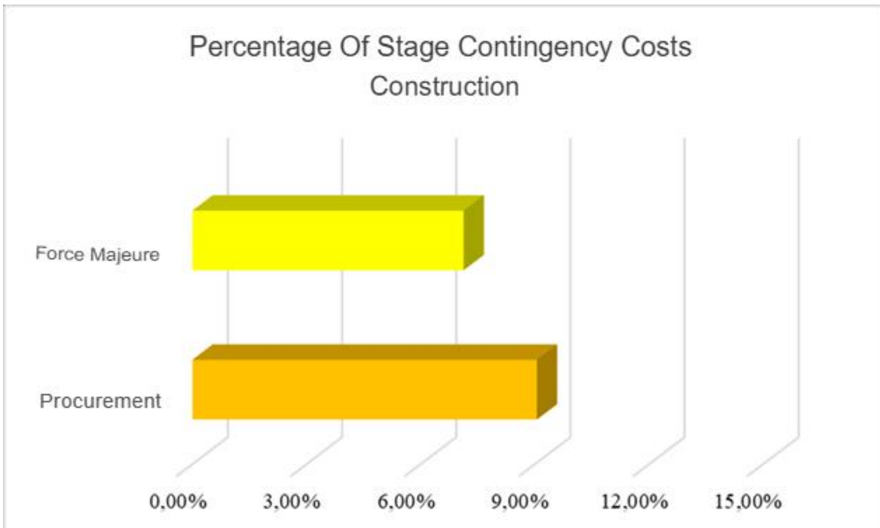

Figure 7. Contingency Costs in the Pre-Construction Stage

Conclusion

Based on the formulation of the problem that has been predetermined in the first sub-chapter, as well as the analysis of the results and discussion of the Risk-Based Contingency Cost Estimation Analysis in the Phase I Wastewater Network System Project of Bogor City, it can be concluded as follows: a) Phase I Analysis with Experts/Experts there are 21 risk variables. Furthermore, the risk variables were distributed to 25 respondents related to the Project (Saturated Sampling). In Phase II Analysis, variables with high levels of impact and frequency in the study were A1.1

(Licensing Process), A6.1 (Design Details), B3.3 (Equipment/Material Management), A4.1 (Environmental Planning) and A1.2 (Work Contract). b) Based on the research analysis, the risk variables at the preconstruction and construction stages are included in the intermediate risk category. Where these risks are known at the beginning so that they can be mitigated faster to reduce the frequency and impact. c) The highest contingency cost estimate is 11.02%. In the pre-construction process, it is necessary to consider the licensing and design process. Paying attention to the procurement process is essential in the construction process.

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