Factors Affecting Operation and Maintenance Cost Contingency of Distribution Gas Pipeline in Indonesia

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Abstract- Operation and maintenance (O & M) activities are carried out to guarantee that the Gas Pipeline Infrastructure can operate reliably and safely. Estimated O&M Costs, which are used to generate the O&M budget for Routine, Non-Routine, and O&M Supporters, are based on a deterministic methodology, in which the components of the job and their costs are known. However, there are realizations of expenditures that have never been allocated, such as unforeseen work and handling of emergency conditions, as well as taking scheduled budget allocations for O & M activities, according to Company data for 2016-2019. These costs can be viewed as O&M Contingency Costs, which are costs that cannot be forecast or anticipated ahead of time but must occur. The long-term consequences of using the planned O&M budget allocation when the company has not set aside a special contingency budget can jeopardize gas distribution integrity and safety. This research is the initial stage of a series of studies to develop a model for estimating the O&M contingency cost of natural gas distribution. This study aims to obtain the components of the O & M Contingency Cost of Gas Pipes and the variables that affect the O & M Contingency Cost of Gas Pipes. The method used is literature study and expert validation using questionnaires. The company can carry out more actual budget planning by considering the factors that become contingency costs, in order to ensure that preventive, predictive, and corrective maintenance and corrective actions can run in accordance with the asset life time cycle, and the integrity and safety of operational activities can be maintained.

Index Terms- Costs of operations and maintenance, O&M contingency costs

I. Introduction

As one of the world's largest archipelagos, Indonesia boasts a wealth of energy resources, including natural gas.
To support energy needs in numerous sectors as well as national development, optimal natural gas usage is also required.
According to data from the Ministry of Energy and Mineral Resources gathered from the Indonesia Natural Gas Balance 2018-2027, Indonesia had natural gas reserves of 142.72 TSCF as of January 2017, which is comparable to 1.53% of global natural gas reserves [1]. The government has designated Company as a national gas sub-holding to manage the distribution and transmission of natural gas to residential, commercial, industrial, and power generation consumers, with both company-owned funds and monies from the State Revenue and Expenditure Budget (APBN), representing the Indonesian Gas Pipeline Network. According to data from company from 2016 to 2019, there are expenditures associated with unscheduled work and emergency pipe repairs (emergency). Because the expenditures incurred cannot be quantified in a deterministic or predictable manner, they have been excluded from the proposed Corporate Budget Work Plan (RKAP).
Contingency costs are costs that are integrated into project cost estimates and are described as cost reserves or cost estimates to anticipate situations of uncertainty allotted to work items based on experience and implementation of past projects [2]. According to Yunwati and Adi (2014) [2], in this study, O & M Contingency Costs are costs that arise that cannot be estimated or predicted when preparing the O & M budget but are almost certain to occur, such as unplanned work as well as emergency response to pipe repairs (emergency) and must be budgeted separately to ensure that no planned O & M budget allocations are exceeded.
The budget for RKAP Non-routine O & M (predictive, preventive, and corrective action activities) had to be used to finance contingency activities of 11.87 percent in 2016, 24.48 percent in 2017, 8.13 percent in 2018, and 11.31 percent in 2019, for a total of 13.52 percent over four years (2016-2019). The long-term consequences of the cost estimating challenge for these conditions could result in gas pipeline network damage, including leaks and possibly gas pipeline explosions.
To conduct a meta-analysis of studies related to the factors and methodologies used to identify answers that separate this research from earlier research on the calculation of gas pipeline operation and maintenance expenses, preceding research is required. The running and maintenance expenses of pipelines have been studied in journals. Gas shutdown, victims near the network, environmental pollution [3], maintenance policies, pipeline damage/pipe repair costs, external disturbances, and internal disturbances are all factors that affecting the cost of forming the O & M [4]. The first step is to identify O & M Contingency Costs through literature study and expert validation to fit the Company operating pattern. It is hoped that a special O & M contingency budget can be budgeted to overcome the problem of estimating costs for contingency events that occur and taking non-routine O & M cost allocations for planned work that has become a priority.
The goal of this research is to determine the components of the O&M Contingency Cost of Gas Pipes, as well as the variables that affectting the O&M Contingency Cost of Gas Pipes. The scope of this study is limited to company's Distribution Gas Pipeline Network and the item mentioned, which is the Gas Pipeline

Network's O&M Contingency Cost (Gas Pipe Repair, Gas Pipe Relocation, Land Rent).

II. THEORITICAL STUDY

1. Company

Company maintains more than 90% of Indonesia's gas pipeline network, which stretches from Sumatra to Papua and represents the entire gas pipeline network in the country. According to Company data, the Distribution Gas Pipeline is a route with the highest intensity of contingency events, such as Gas Pipeline Repair, Gas Pipeline Relocation, and Land Rent, because the land occupied by the Gas Pipeline Network is outside company's land. This is in contrast to the Transmission Pipeline, which owns a network located in the Right Of Way (ROW) owned by company.

2. Operating a Gas Pipeline

Company is in charge of overseeing the results and quality of O & M work, as well as O & M planning. 7 days a week, for a total of 24 hours A Contact Center, as well as a Disturbance Handling Team, is available to accept Complaint Reports and information concerning company operations.

3. Costs of Gas Pipeline Operation and Maintenance

a. Pipeline for natural gas

Natural Gas is the outcome of a natural process in the form of hydrocarbons in the form of a gas phase derived from the oil and gas mining process, and/or natural gas that has been physically processed in the form of Compressed Natural Gas or Liquified Natural Gas [5]. The gas pipeline network is a piping and supporting infrastructure system for gas distribution (Valve System, Cathodic, Offtake Station, Signs). Distribution and Transmission make up company's gas pipeline network.The focus of this research is on the Distribution Gas Pipeline Network.

b. Costs of Operation and Maintenance

The sacrifice of economic resources, defined in money units, that has occurred or may occur to attain specific aims is referred to as cost. Costs, in a strict sense, are a portion of the cost of items relinquished in order to generate money [5]. Routine O & M costs (costs incurred to manage and maintain network infrastructure assets on a regular basis in accordance with Work Reference Documents / applicable regulations that are mandatory) and Non Routine O & M costs (predictive and preventive maintenance that has been proposed to support the creation of network assets and facilities in accordance with Work Reference Documents / applicable regulations that are mandatory) are the two types of O & M costs at company (costs incurred to maintain the security and reliability of gas pipelines indirectly such as electricity, water, PBB, etc).

c. Gas Pipeline Operation and Maintenance Contingency Costs

Routine O & M costs (costs incurred to manage and maintain network infrastructure assets on a regular basis in accordance with Work Reference Documents / applicable regulations that are mandatory) and Non Routine O & M costs (predictive and preventive maintenance that has been proposed to support the creation of network assets and facilities in accordance with Work Reference Documents / applicable regulations that are mandatory) are the two types of O & M costs at company (costs incurred to maintain the security and reliability of gas pipelines indirectly such as electricity, water, property tax (PBB), etc).

1). Repairing a Pipe

Costs incurred as a result of interference from third-party operations or operational problems when handling, repairing, or relocating pipes.

There were costs for Gas Pipe Repairs that were not planned in the RKAP from 2016 to 2019 owing to external affectting, including:

1. Repairing Gas Pipeline Leaks Caused by Third-Party Activities.
2. Strengthening the Pipe Network as a result of interactions with third-party activities.
3. Landslide-damaged pipelines need to be reinforced.

Depending on the sort of work being done, different equipment is utilized to repair pipes. Inspections of the equipment's condition and the state of the calibration/validation utilized are critical to ensuring that the work was completed in line with applicable rules. The availability of manpower is a critical aspect in the success of gas pipe repair projects. As the asset owner, the Operation & Maintenance department is responsible for determining the credentials of the workers engaged. All personnel involved in every job must have integrity and competence according to their scope of work Depending on the sort of work being done, different equipment is utilized for pipe repair.

Inspections of the equipment's condition and the state of the calibration/validation used are necessary to guarantee that the job was completed in compliance with the regulations. Controlling the use of resources in pipe repair operations can significantly reduce the time it takes to complete the job.

Steel pipe, polyetheline (PE) pipe, valve, fitting, repair clamp, and coating are among the materials utilized.

The methodology, techniques, materials, and prices incurred are all determined by the environment in which the gas pipe repair operation is performed. There are four Class Locations [6] according to the Minister of Mines and Energy's Decree No. 300.K/38/M./1997.

2). *Relocation of Pipes*

The term "relocation" can be defined as "moving."

Costs incurred in the context of Moving or Handling Pipes as a result of external parties' actions requiring pipelines or facilities to be redirected from their current position.Due to external intervention, there are gas pipeline relocation costs that are not planned in the RKAP from 2016 to 2019, including:

1. Pipe relocation due to construction work in the area of the flyover.
2. Pipe Relocation as a result of Road Widening Projects.
3. Pipe relocation due to drainage channel construction / river normalization.

Pipe relocation is similar to pipe repair in terms of tools, materials, personnel, and the environment.

3). Lease of land

The recompense paid for the use of land or other natural resources with a fixed offer amount that cannot be changed is known as land rent [8]. In land resource economics, land/land rent is a crucial concept. Due to the large movement and growth with high costs, such as based on the computation of 100 percent NJOP for 1 year of land lease, the imposition of land leases on gas pipelines has become a new challenge. The fees imposed in land leases are set by each land owner's own policy. The type of land lease applied by the land owner to company is differentiated based on the owner and the basis for calculating tariffs. Land owners generally consist of

individuals/private and companies/regions. The imposition of land rental fees by the Company / Region is more commercial.

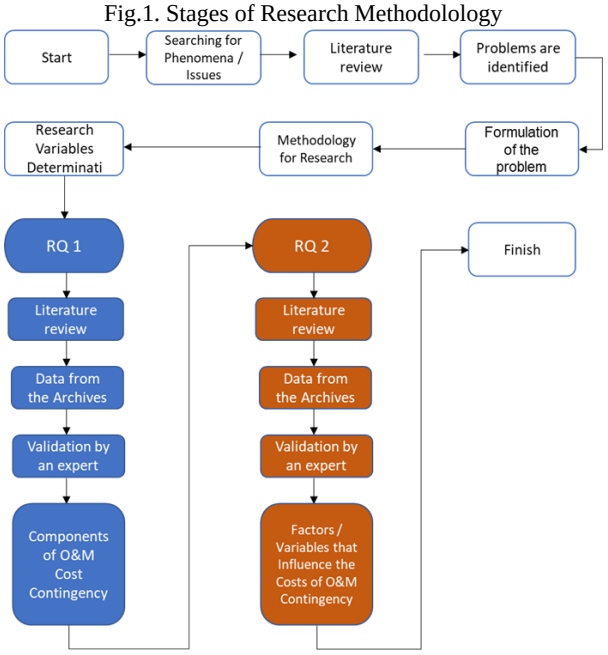
III. METHOD

1. Research Methodology

To make it easier to collect and process data for study, this research procedure starts by looking for phenomena / problems that occur in the workplace. Then, to be able to identify the problem, I conducted a literature review that discussed the phenomena and difficulties that occur. Following the identification of the problem, the problem might be formulated in order to find a solution through this research. The following step is to select a suitable research approach for each Research Question in order to arrive at an answer (RQ).

The research variables are determined by examining the literature for additional analysis in order to produce each RQ. To answer RQ 1, the input is gained by researching literature and archive data, and the output is obtained in the form of variable Y after expert validation (O & M Contingency Cost). Experts must have a Bachelor's degree and at least 15 years of experience as a Gas Pipeline O&M Midwife, with a minimum of three experts representing. RQ 1 data is utilized as input to acquire factors that affect variable Y by analyzing literature and archive data for subsequent expert validation to generate output in the form of variable X, which is then utilized to answer RQ 2. (Factors affecting Pipe Repair, Pipe Relocation and Land Rent).

Fig.1. Stages of Research Methodology



2. Research Variables

The independent variable (X) is a variable that affectting or causes the dependent variable's effect (Y). The second Research Question (RQ2) in this study is answered using this independent variable. In this study, variable X was derived from a literature review of factors that affectting pipe repair (Y1), pipe relocation (Y2), and land rent (Y3).

Table.1. Research Variables

Variable	Factors that Affecting Pipe Repair	Reference
X1	*Excavation Damage*	[9], [10], [11]
X2	Inner failure of operation (INOP)	[9]
X3	Natural disasters	[10], [11]
X4	Terrorist	[11]
X5	Vandalism	[11]
X6	Pressure outside the pipe causes damage (OUTFD)	[9]
X7	Above-ground/pipeline activities	[12]
X8	Environmental conditions	[12]
X9	Error in Design	[13]
X10	Interference by a third party (especially those that ignore signals)	[13]
X11	Failed pipe/weld/joint material	[10], [11]
X12	Corrosion	[10]
X13	Diameter of the pipe	[14]
Variable	**Factors that Affectting Pipe Relocation**	**Reference**
X14	Mudslide	[15], [16], [17]
X15	Subsidence of the Land	[15]
X16	Floating (Pipe that dangles)	[17]
X17	Erosion	[18]
X18	Changes in Land Use	[16]
Variable	**Factors that Affectting Land Rent**	**Reference**
X19	Facilities	[19]
X20	Accessibilities	[19], [20]
X21	Accessibility (Request and Offer)	[19], [21], [22]
X22	Location	[20], [21], [22]
X23	Characteristics of Rental Properties	[20]
X24	Density of the population	[23], [21]
X25	The Distance From The City Center	[23]
X26	The roadway's width	[23]
27	Condition of the Road	[23]
X28	Transportation Facilities Availability	[23]
X29	Factors in the Environment (eg Flood Free)	[22], [23]
X30	Land maturation (licensing) costs are high, and the tax object sales value is low (NJOP)	[21]
X31	Several parties hold land tenure	[21]

IV. RESULT AND DISCUSSION

The first stage in gathering data to answer the First Research Question (RQ 1) and the Second Research Question (RQ 2) was to conduct a literature review. RQ 1 is completed by searching for a literature study that discusses the O&M Cost Component in order to determine the O&M Contingency Cost Component for

Gas Pipes. RQ 2 is completed by locating a literature paper that covers the factors that affecting the O&M Gas Pipeline Contingency Cost (Pipe Repair, Pipe Relocation and Land Rent). Expert Validation was used to validate the literature study in order to gain answers to RQ 1 and RQ 2. Before filling out the Expert Validation Questionnaire using Google Forms, a discussion was held using Microsoft Teams so that the intent, purpose, and technicality of filling out the expert validation could be properly communicated to each expert. It was expected to get a variable in RQ 1 and RQ 2 that is in accordance with the operating pattern at the time. The reasons for not choosing.

A variable or question that has been collected from the literature study are not shared with the experts who are part in this expert validation when picking an answer.

Table. 2. Recapitulation of gas pipeline O&M contingency cost components resulting from expert validation

No	O & M Cost Component	Description	Reference	Conclusion
1	Shutdown	Situations that necessitate the cessation of gas distribution	[24]	Yes
2	Fatalities	Gas pipe explosions have resulted in personnel being wounded or even dying.	[3]	Yes
3	Environmental Pollution	Managing air pollution that has a negative impact on the environment	[3]	No
4	Maintenance Policy	As a result of the lack of a maintenance policy, O&M tasks are not carried out properly and safely.	[4]	No
5	Pipe Damage	There are various causes of pipe damage	[4]	Yes
6	External Interference	Interference from external parties that threaten the safety and security of distribution	[4]	Yes
7	Internal Interference	Interference from internal parties that threaten the security and safety of distribution	[4]	Yes
8	Gas Commodity Price Fluctuation	The imbalance between commodity prices that have been regulated while operating costs continue to grow	[25]	Yes
9	Geopolitics	the relationship between politics and territory on a local or international scale	[25]	Yes
10	Lack of worker competence	Workers are income tent, thus they are unable to carry out O&M without the backing of dependable activities.	[25]	Yes
11	Risk Management	Risk management and reporting	[25]	Yes
12	Compressor Fuel Cost	Purchase of compressor fuel costs	[26]	Yes
13	Permission	an agreement between authorities based on laws or government regulations to diverge from the prohibition of laws and regulations in specific circumstances	[4], [25]	Yes
Other Inputs:				
1	Macro and Micro Economic Conditions			No
2	Pandemic/Outbreak			No
3	Natural disasters			No
4	Limited Gas Supply			No

the Expert picks the response "Yes," the Expert receives a score of 1, whereas picking the answer "No," the Expert receives a score of 0. If a question receives a minimum total score of 2, it becomes the Expert's option. Results of Expert Validation

Because the overall score for expert choice is less than 2, there are Variable Components that are not utilized as variables in the study based on Expert Validation, which include Environmental Pollution and Maintenance Policies.These two items have never been included in company's O&M contingency expenditures.

Variable Y (Components of O & M Contingency Costs) is obtained in this study, which consists of Pipe Repair, Relocation Pipes, and Land Lease, based on the results of Expert Validation and the availability of Perimer data (Archive Data) related to the realization of contingency costs that occurred at company from 2016 to 2019. Table 3 summarizes the findings of the Expert Validation of Factors Affecting Pipe Repair using a questionnaire.

Table 3 Recapitulation of Factors Affecting Pipe Improvement Results from Expert Validation using a questionnaire

No	Factors Affecting Pipe Repair	Description	Reference	Conclusion
1	*Excavation Damage*	Soil excavation is carried out either by heavy equipment or by manual excavation around the gas pipeline network	[9], [10], [11]	Yes
2	Inner failure of operation (INOP)	The operating pressure is above the maximum pressure capacity of the pipe so that the pipe cracks / leaks	[9]	Yes
3	Natural disasters	Natural events that disrupt / damage pipelines such as landslides	[10], [11]	Yes
4	Terrorist	Sabotage committed by terrorists such as bombings, shootings, arso	[11]	No
5	Vandalism	Activities for destroying gas pipeline network assets (gas pipeline bridges) and theft of assets such as pipe markers	[11]	Yes
6	Pressure outside the pipe causes damage (OUTFD)	There is a load on the gas pipeline network that exceeds the maximum pressure capacity of the pipeline network so that the pipeline cracks / leaks	[9]	Yes
7	Above-ground/pipeline activities	There are activities that endanger the gas pipeline network, such as the construction of buildings above the pipeline, making it difficult for O & M and emergency handling	[12]	Yes
8	Environmental conditions	The environment in the form of roads is different from that in the form of residential areas	[12]	Yes
9	Error in Design	Pipe network conditions such as dimensions, materials, plantings that are not in accordance with applicable standards	[13]	Yes
10	Interference by a third party (especially those that ignore signals)	There are activities such as excavation, burning of waste above the pipe network while above it there are signs. Gas pipeline presence information marker keberadaan	[13]	Yes
11	Failed pipe/weld/joint material	The failure condition of the welded material / location of the pipe being welded is not strong enough to accept operating pressure and external loads	[10], [11]	Yes

Table 3 Recapitulation of Factors Affecting Pipe Repair from Expert Validation using a questionnaire (cont')

No	Factors Affecting Pipe Repair	Description	Reference	Conclusion
12	Corrosion	Corrosion of pipeline infrastructure causing leaky pipes	[9], [10], [11]	Yes
13	Diameter of the pipe	The larger the diameter of the pipe, the more fluid is channeled so that if there is damage, the greater the impact	[9]	Yes
Other Input:				
1	Citizen Compensation			No
2	Other Source Channeling Support			No

Furthermore, there are two input variables from Expert number 1 in the form of Citizen Compensation and Support for Other Sources Distribution that were not picked by other experts, received a score of less than 2, and were not included in the study as variables. The findings of the Expert Validation of Pipe Relocation Factors are presented in Table 4, while the results of the expert validation of factors that affect land rent are described in Table 5 below.

Table 4. Result of Expert Validation Findings Factors Affecting Pipe Relocation using a questionnaire

No	Factors Affecting Pipe Relocation	Description	Reference	Conclusion
1	Mudslide	Landslide events so that the pipe experiences stress due to no soil carrying capacity	[15], [16], [17]	Yes
2	Subsidence of the Land	Land subsidence that makes the pipe unsupported to support its own load and above	[15]	Yes
3	Floating (Pipe that dangles)	The condition of the pipe hanging in the absence of a safe support so that it becomes stressing / crack	[17]	Yes
4	Erosion	There is a flow of water that erodes the ground where the pipeline is embedded	[18]	Yes
5	Changes in Land Use	There is a change in use, such as what was originally a rice field into a highway / fly over	[16]	Yes

Table 5. Results of Expert Validation of Factors Affecting Land Rent by using a questionnaire

No	Factors Influence Pipe Land Rent	Description	Reference	Conclusion
1	Facilities	There are facilities in the form of electricity, water, telephone, gas	[19]	Yes
2	Accessibilities	Distance to toll, station, airport, office, hospital, education	[19], [20]	Yes
3	Accessibility (Request and Offer)	The more land that is offered, the less available it is	[19], [21], [22]	Yes
4	Location	Place of land located (City/Regency)	[20], [21], [22]	Yes
5	Characteristics of Rental Properties	Rent for a residential house is different from that for plumbing (commercial)	[20]	Yes

Table 5. Results of Expert Validation of Factors Affecting Land Rent by using a questionnaire (Cont')

No	Factors Influence Pipe Land Rent	Description	Reference	Conclusion
6	Density of the population	The number of population activities that make the area more crowded	[23], [21]	Yes
7	The Distance From The City Center	Distance to city center / economy center	[23]	Yes
8	The roadway's width	Dimensions of the width of the road to be traversed by vehicles	[23]	Yes
9	Condition of the Road	Asphalt road, concrete, stone, dirt	[23]	Yes
10	Transportation Facilities Availability	Stations, terminals, airports, ports	[23]	Yes
11	Factors in the Environment (eg Flood Free)	Free flood	[22], [23]	Yes
12	Land maturation (licensing) costs are high, and the tax object sales value is low (NJOP)	Selling Value of Tax Object	[21]	Yes
13	Several parties hold land tenure	Controlled by the State, BUMN/BUMD, Private, Individual	[21]	Yes

V. CONSLUSION

It is possible to discover the cost components of Gas Pipeline O & M contingency in Variable Y from the data analysis process using the research approach employed to answer RQ 1 as shown in table 6:

Table 6: Operation and Maintenance Recapitulation Components of the contingency budget

Variables Code	O&M Contingency Cost Components
Y1	Repairing a Pipe
Y2	Relocation of Pipes
Y3	Lease of land

After analyzing the data from the Input Data Variable Y (RQ 1) to answer RQ 2 (Variable X), the variables that affect the O & M Gas Pipeline Contingency Cost Factors that affect Pipe Repair (Table 7), Factors that affect Relocation Pipes (Table 8) and Factors affecting Land Rent (Table 9) can be identified;

Table 7. Recapitulation of Factors Affecting Pipe Repair

Variables Code	Factors Affecting Repairing a Pipe
X1	Excavation Damage
X2	Inner failure of operation (INOP)
X3	Natural disasters
X4	Vandalism
X5	Pressure outside the pipe causes damage (OUTFD)
X6	Above-ground/pipeline activities
X7	Environmental conditions
X8	Error in Design
X9	Interference by a third party (especially those that ignore signals)
X10	Failed pipe/weld/joint material
X11	Corrosion
X12	Diameter of the pipe

Table 8. Recapitulation of Factors Affecting Pipe Relocation

Variables Code	Factors Affecting Relocation a Pipe
X13	Mudslide
X14	Subsidence of the Land
X15	Floating (Pipe that dangles)
X16	Erosion
X17	Changes in Land Use

Table 9. Recapitulation of Factors Affecting Land Rent

Variables Code	Factors Affecting Land Rent
X18	Facilities
X19	Accessibilities
X20	Accessibility (Request and Offer)
X21	Location
X22	Characteristics of Rental Properties
X23	Density of the population

Table 9. Recapitulation of Factors Affecting Land Rent (Cont')

Variables Code	Factors Affecting Land Rent
X24	The Distance From The City Center
X25	The roadway's width
X26	Condition of the Road
X27	Transportation Facilities Availability
X28	Factors in the Environment (eg Flood Free)
X29	Land maturation (licensing) costs are high, and the tax object sales value is low (NJOP)
X30	Several parties hold land tenure

VI. RECOMMENDATION

This research can be developed as a basis for modeling the O&M contingency cost estimation of gas pipeline networks using an artificial intelligent approach such as the neural network method, in order to produce a precise and accurate formulation of contingency cost estimation.

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