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Analysis of Clean Water Distribution Pipe Implementation Time Using Value Engineering Method in Rungkut Industri Surabaya

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Abstract

Clean water distribution infrastructure projects in industrial areas face significant challenges related to cost efficiency and implementation time, which directly impact project sustainability and operational effectiveness. This study analyzes the cost and time efficiency of the clean water distribution system in the Rungkut industrial area, Surabaya, by applying the Value Engineering (VE) method. The main objective of this study is to evaluate and compare the performance of three commonly used types of pipes—namely HDPE (High-Density Polyethylene), uPVC (unplasticized polyvinyl chloride), and GI (galvanized iron)—to determine the most optimal alternative without reducing the function or quality of the clean water distribution system. Data collection was conducted through a combination of methods: distributing questionnaires to professional respondents in civil engineering and water installation fields, conducting direct interviews with project-related parties, and analyzing technical documents and costs from actual projects. The obtained data were analyzed using the Relative Importance Index (RII) method to assess key aspects such as cost efficiency, ease of installation, and material durability. The results showed that HDPE pipes offer superior cost and time efficiency compared to the others. The cost difference between HDPE and uPVC pipes is Rp1,407,577, while that with GI pipes is Rp731,885. In terms of time, HDPE pipes can reduce implementation duration by up to 39 days compared to uPVC pipes and by 9 days compared to GI pipes.

Keywords : *Value Engineering, RII, Cost Efficiency, Time*

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Introduction

Global water infrastructure projects consistently face critical challenges related to cost overruns and implementation delays, which significantly impact project sustainability and service delivery. According to the World Bank (2019), approximately 30-40% of water infrastructure projects worldwide experience budget overruns exceeding 20% of initial estimates, primarily due to inefficient material selection, poor project planning, and inadequate application of cost optimization methodologies. In developing countries, these challenges are further exacerbated by limited technical capacity and resource constraints. The Asian Development Bank (2021) reports that Non-Revenue Water (NRW) rates in Asian urban water systems average 35%, with technical losses from pipe leakage and system inefficiencies accounting for approximately 60% of total NRW. These figures underscore the urgent need for systematic approaches to optimize water distribution infrastructure design and material selection (Adeoti et al., 2023; Mala-Jetmarova et al., 2018).

In Indonesia, the water infrastructure sector faces similar challenges. Data from the Ministry of Public Works and Housing (PUPR, 2022) indicates that the national average for NRW stands at 32.5%, with industrial areas experiencing even higher rates due to aging infrastructure and suboptimal pipe material selection. The economic impact is substantial, with annual losses estimated at IDR 12.8 trillion nationally due to water leakage, inefficient distribution systems, and excessive maintenance costs. Furthermore, approximately 42% of water infrastructure projects in Indonesia experience delays ranging from 2 to 6 months, often attributed to poor material procurement decisions, inadequate technical specifications, and lack of value-based engineering analysis during the planning phase (Indonesian Contractors Association, 2023).

Cost and time efficiency represent two fundamental dependent variables that determine the success of water infrastructure projects. Cost efficiency encompasses not only direct material procurement expenses but also lifecycle costs, including installation, operation, maintenance, and replacement over the technical lifespan of the system (Dell'Isola, 2009). Time efficiency, measured through implementation duration from mobilization to system commissioning, directly influences project financial viability through reduced overhead costs, earlier revenue generation, and minimized disruption to industrial operations (Project Management Institute, 2021). The interdependency between these variables creates a complex optimization challenge: material alternatives that offer lower initial costs may result in longer installation times or higher lifecycle costs, while solutions optimizing for rapid implementation may carry premium pricing. This complexity necessitates systematic analytical frameworks that can simultaneously evaluate multiple performance criteria across different material alternatives.

Clean water distribution management in industrial areas often experiences suboptimality, caused by pipe network designs that do not match dynamic needs. Therefore, it is very important to apply the Value Engineering (VE) method to identify alternative designs and more efficient operational solutions for clean water distribution systems. The Value Engineering method has proven effective in reducing costs without sacrificing service quality, especially in the public utility sector.

In construction projects, cost and time efficiency are two main indicators of successful implementation. The piping system is an important component that greatly affects both aspects. Pipes are used for many purposes, such as clean water, wastewater, and fire extinguishing systems. Therefore, choosing the right type of pipe is very important for project success. Currently, many types of pipe materials are used in the field, such as HDPE (High-Density Polyethylene) pipes, uPVC (unplasticized Polyvinyl Chloride) pipes, and GI (Galvanized Iron) pipes. The three types of pipes have different characteristics in terms of price, durability, ease of installation, and service life. The choice of pipe type usually takes into account technical aspects, budget, and implementation time.

The first important aspect is the total cost. The cost does not only include purchasing the pipe but also connections, equipment, tools, shipping, and labor costs during the installation process. In addition to cost, project implementation time is also an

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important aspect to consider. The time to install the pipe can be affected by the connection method, field conditions, and tool preparation.

A comprehensive review of empirical studies applying Value Engineering (VE) to water infrastructure establishes a critical theoretical foundation and reveals specific research gaps. Dell'Isola and Kirk (2018) demonstrated significant cost savings in U.S. drinking water treatment plants through material substitution, notably with HDPE pipes, but their focus was limited to developed countries and did not employ tools like the Relative Importance Index (RII) for systematic evaluation. Similarly, Nguyen and Watanabe (2020) applied VE to municipal network rehabilitation in Southeast Asia, highlighting HDPE's performance in tropical conditions, yet their study omitted industrial systems and detailed comparative frameworks. These studies collectively underscore a gap in applying VE to industrial water networks in developing contexts.

Further analysis of previous research confirms this gap while highlighting methodological shortcomings. Park, Kim, and Lee (2021) provided a valuable multi-criteria comparison in South Korea, ranking HDPE highest overall, but their findings are context-specific and did not prioritize time-efficiency analysis. Finally, while Iswanto and Indryani (2023) successfully applied VE within Indonesia's construction environment, their study was confined to building projects, used qualitative methods, and did not address water infrastructure or pipe material selection. Therefore, the existing literature lacks a study that systematically applies a quantitative VE framework, such as one incorporating RII, to the comparative analysis of pipe materials (e.g., HDPE, uPVC, GI) specifically for industrial water distribution systems in a developing country like Indonesia.

The comprehensive literature review identifies critical research gaps that this study addresses, primarily the absence of a Value Engineering (VE) methodology specifically tailored for industrial water distribution pipe selection in Indonesia, which must account for unique local conditions like soil, procurement, labor skills, and industrial zone regulations. Existing research lacks a systematic quantitative framework—using tools like the Relative Importance Index (RII)—to concurrently evaluate multiple pipe materials (HDPE, uPVC, GI) against both functional criteria (e.g., corrosion resistance, soil suitability) and economic criteria (e.g., material and installation costs), while also under-examining implementation time efficiency as a primary variable despite its critical importance in industrial projects. Furthermore, previous studies have not adequately addressed the challenges of unstable soil conditions in specific industrial areas like the Rungkut Industri Estate Surabaya or systematically integrated multi-stakeholder perspectives from contractors, consultants, supervisors, and technicians through survey methodologies. By filling these gaps, the current research aims to contribute original knowledge to VE literature and provide practical decision-support tools for industrial water infrastructure in Indonesia and similar developing contexts.

This research is urgently needed due to several converging imperatives, beginning with the severe economic impact of inefficient water infrastructure in industrial zones. At the Rungkut Industri Estate Surabaya specifically, annual losses from system inefficiencies—including non-revenue water, emergency repairs, production disruptions, and supplementary procurement—total approximately IDR 8.89 billion. Over a 25-year lifespan, this compounds to potential losses exceeding IDR 222 billion, whereas applying Value Engineering for optimal material selection could reduce these costs by 20-35%, saving between IDR 44 and 78 billion. Furthermore, the urgency is heightened by the scale of planned investment, with IDR 32.8 billion allocated for network expansion from 2024-2026, where pipe material procurement alone constitutes 42% of capital expenditure; suboptimal choices now could lead to premature failures and doubled lifecycle costs.

Adding to this urgency are the broader implications of the project. The Rungkut Industri Estate Surabaya serves as a model for similar zones across Indonesia, meaning the systematic application and documentation of Value Engineering here will provide a replicable framework for other regions, potentially yielding trillions of rupiah in national aggregate savings. This precedent-setting need is underscored by a critical technical gap: existing literature and standards fail to address the unique complexities of Indonesian coastal industrial zones, such as soft clay soils, high groundwater, tropical climate, and local construction practices. Consequently, this research is essential to develop context-specific analysis and decision-making tools that international guidelines currently lack.

The novelty of this research is manifested in several distinct contributions, beginning with it being the first comprehensive application of Value Engineering specifically to industrial water pipe selection in Indonesia, addressing the unique local context that differentiates it from international precedents. It further develops an integrated quantitative assessment framework by systematically combining the Relative Importance Index with VE principles, creating a reproducible tool for comparing multiple pipe materials across both functional and economic criteria, thereby filling a key methodological gap in existing literature.

Additionally, this research introduces a dual optimization focus, treating implementation time efficiency as equally critical as cost savings—an approach that addresses the significant limitation in existing studies where time is secondary. This is complemented by a stakeholder-inclusive methodology that integrates diverse perspectives from contractors to field technicians, capturing vital implementation knowledge often overlooked. Ultimately, the study provides context-specific performance validation using real project data from Rungkut Industri Estate Surabaya and delivers practical decision-support tools, enabling direct application by planners and managers and ensuring tangible knowledge transfer from academia to professional practice.

This study is also expected to provide scientific contributions in the field of construction management, especially when the Value Engineering method is used for the selection of building materials. Using a systematic approach and database, the results of this study can be referred to for the implementation of similar projects in the future.

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Research Method

The flowchart in this study is designed to describe the systematic flow of the entire research process from problem identification to conclusion drawing. The stages in this flowchart are described as follows :

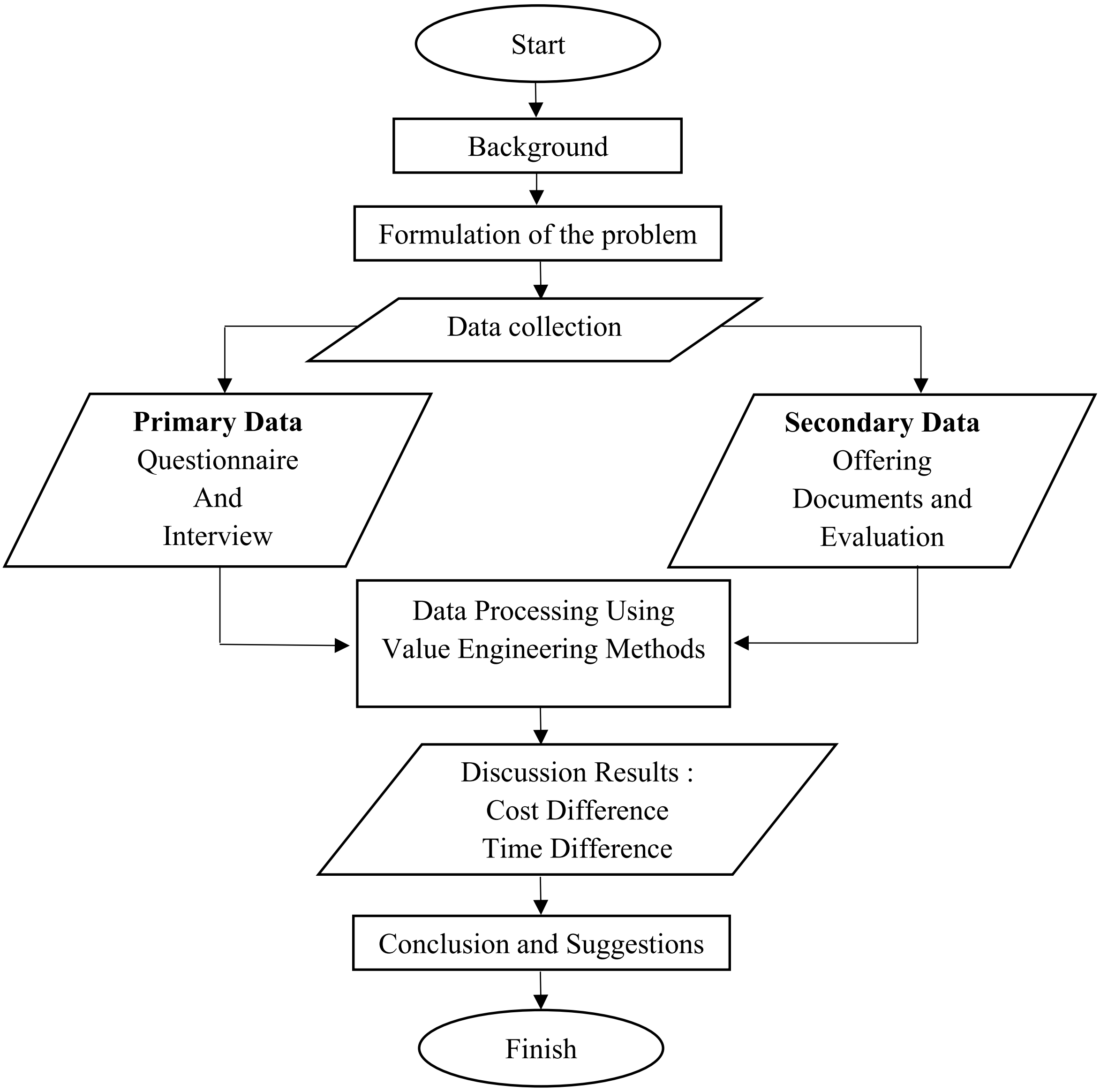

Figure 1. Research Flowchart

Results and Discussion

In this study, the data used were collected from various sources relevant to the clean water distribution network development project in the industrial area of PT. SIER Surabaya. The data collected are divided into two main categories, namely primary data and secondary data, with a scope of technical, economic, and operational information on the piping system.

Primary data were obtained directly from respondents through the distribution of questionnaires and structured interviews. Respondents consisted of professionals involved in the planning, implementation, and supervision of clean water distribution projects, including :

Implementing contractor	Field technician
Planning consultant	Project supervisor

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The primary data collection instrument is a questionnaire based on a Likert scale of 1 – 5 :

1 = Very Unimportant
2 = Not important
3 = Neutral
4 = Important
5 = Very important

1. HDPE pipe (High Density Polyethylene)

High-pressure plastic pipes called HDPE (High Density Polyethylene) are known for their flexibility and resistance to corrosion and chemicals. These pipes are very suitable for clean water distribution systems because their connections use the hot-connection method, or connection.

heat, can reduce leakage. High density polyethylene (HDPE) pipes are very suitable for use in various environments, such as uneven areas, because they are resistant to ultraviolet sunlight.

2. uPVC Pipe (Unplasticized Polyvinyl Chloride)

uPVC pipes, made of rigid plastic without plasticizers, are stronger and more durable. Because they are cheap and easy to install, they are widely used in clean water piping systems. Solvent cement systems, such as PVC glue, or rubber sockets, are used to connect them. However, uPVC pipes are not recommended for use deep underground or in high-pressure areas that do not have additional protection.

3. GI Pipe (Galvanized Iron)

Galvanized iron pipe, or GI, is coated with zinc to prevent rust. It is often used for clean water installations and household water pipes, but is now rarely used because the inner layer is susceptible to corrosion, which can contaminate the water. In addition, GI pipes are rarely used in new projects because they are heavy and difficult to install.

To assess the three types of pipes that are the focus of the research, namely HDPE pipes, uPVC pipes, and GI pipes, based on the following criteria :

a. Resistance to pressure and corrosion .
b. Ease of connection.
c. Installation efficiency .

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d. Technical age of the pipe .
e. Suitability to soil conditions at the location .
f. Material costs and work costs.

The results of this questionnaire are used to assess the technical performance and ease of implementation of each type of pipe, as well as being used as consideration in the evaluation stage of the Relative Importance Index (RII) method.

1. Calculate RII Function and Average Cost of Each Pipe

Calculating the RII Function and RII Cost on average based on each aspect of each pipe:

a) For HDPE Pipes

Table 1. Summary of Functional Aspects

Functional Aspect	RII
Corrosion resistance	0,713
Technical Age	0,860
Suitability of Unstable Land	0,947
RII Average Function	**0,84**

Table 2. Summary of Cost Aspects

Cost Aspect	RII
Material Cost	0,653
Connection Fee	0,640
Ease of Installation	0,507
RII Average Cost	**0,60**

b) For uPVC Pipes

Table 3. Summary of Functional Aspects

Functional Aspect	RII
Corrosion resistance	0,513
Technical Age	0,520
Suitability of Unstable Land	0,440
RII Average Function	**0,491**

Table 4. Summary of Cost Aspects

Cost Aspect	RII
Material Cost	0,487
Connection Fee	0,460
Ease of Installation	0,487
RII Average Cost	**0,478**

c) For GI Pipes

Table 5. Summary of Functional Aspects

Functional Aspect	RII
Corrosion resistance	0,287
Technical Age	0,593

Suitability of Unstable Land	0,380
RII Average Function	**0,42**

Table 6. Summary of Cost Aspects

Cost Aspect	RII
Material Cost	0,847
Connection Fee	0,807
Ease of Installation	0,707
RII Average Cost	**0,787**

2. Calculating Value Engineering

Value engineering calculates value by comparing the function and cost of each component. The goal is to find the best value that maximizes cost efficiency and effectiveness.

a. HDPE pipe

$$Value = \frac{F}{C} = \frac{0,84}{0,60} = 1,4$$

b. uPVC pipe

$$Value = \frac{F}{C} = \frac{0,491}{0,478} = 1,027$$

c. GI pipe

$$Value = \frac{F}{C} = \frac{0,42}{0,787} = 0,534$$

3. Calculating Cost Differences

To find out how much savings can be achieved, the cost difference calculation is done by subtracting the total alternative costs from the total existing costs.

a. HDPE Pipes and uPVC Pipes

With HDPE cost = Rp 1,918,800, and HDPE RII = 1.4, you can use the RII comparison ratio to estimate the cost of uPVC pipes based on their RII.

$$uPVC\ Pipe\ Cost\ Estimate \quad = Rp. 1.918.800\ x\ \frac{1,027}{1,4}$$
$$= Rp. 1.407.577$$

According to respondents (based on RII), the use of uPVC pipes will save Rp 1,407,577 compared to HDPE.

b. HDPE Pipes and GI Pipes

With HDPE cost = Rp 1,918,800, and HDPE RII = 1.4, you can use the RII comparison ratio to estimate the cost of GI pipes based on their RII.

$$GI\ Pipe\ Cost\ Estimation = Rp. 1.918.800\ x\ \frac{0,534}{1,4}$$
$$= Rp. 731.885$$

According to respondents (based on RII), the use of GI pipes will save Rp 731,885 compared to HDPE.

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Based on the results of calculating the cost difference between the alternative uPVC and GI pipes against the baseline pipe (HDPE), the following conclusions can be drawn:

1) The use of uPVC pipes results in cost efficiency of Rp 1,407,577 compared to HDPE pipes. This shows that the selection of uPVC pipes can significantly save project costs, while maintaining the main function of clean water distribution.
2) The use of GI pipes provides cost efficiency of Rp 731,885, compared to HDPE pipes. This shows that in terms of cost, GI pipes are the most economical alternative.

4. Calculating the Time Difference between HDPE, uPVC, and GI Pipes

The calculation of the time difference is carried out by comparing the installation duration of each type of HDPE, uPVC, and GI pipe to determine the alternative with the most efficient implementation time.

a) Time Difference between HDPE and uPVC Pipes

$$uPVC\ Pipe\ Duration = 180\ x\ \frac{0{,}633}{0{,}52} = 141\ day$$

b) Time Difference between HDPE Pipes and GI Pipes

$$GI\ Pipe\ Duration = 180\ x\ \frac{0{,}633}{0{,}713} = 171\ day$$

5. Calculating Time Difference

The calculation of the time difference is done by subtracting the alternative implementation time from the implementation time to determine the efficiency of the work duration that can be achieved.

a) uPVC Pipe Time Difference

$$Time\ Difference = 180 - 141 = 39 \text{ Day}$$

$$Time\ Efficiency = \left(\frac{39}{180}\right) x\ 100\% = 22\%$$

b) Selisih Waktu Pipa GI

$$Time\ Difference = 180 - 171 = 9 \text{ Day}$$

$$Time\ Efficiency = \left(\frac{9}{180}\right) x\ 100\% = 5\%$$

Conclusion

The analysis results reveal that HDPE pipes offer superior cost and time efficiency compared to alternatives in the value engineering evaluation for clean water distribution pipes at Rungkut Industri Estate Surabaya: the cost difference favors HDPE over uPVC by Rp. 1,407,577 and over GI by Rp. 731,885, while implementation time differences show HDPE outperforming uPVC by 39 days and GI by 9 days. These findings underscore HDPE's optimal balance of lifecycle costs and rapid deployment, making it the recommended material for similar industrial projects. For future research, a longitudinal study could track the real-world performance of HDPE installations over 5-

10 years under varying Indonesian coastal conditions, incorporating predictive modeling for maintenance costs and NRW reductions to validate long-term value engineering outcomes.

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