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Value Engineering of the Cipinang Gading Water Treatment System in Bogor City to Improve Project Cost Efficiency

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Abstract: The Cipinang Gading SPAM project was built to improve access to clean water in the city of Bogor, as well as to support the achievement of national clean water access with a target of 100% by 2030, to achieve these targets it is hoped that the available investment can be optimized. Using value engineering has proven to be able to reduce costs without sacrificing quality. This research method combines qualitative and quantitative approaches, with cost analysis, Multi Criteria Analysis (MCA), Life Cycle Cost Analysis (LCCA), and Risk Analysis methods. The results showed that PVC pipe is the best alternative to improve cost efficiency without sacrificing function, quality and risk. The application of Value Engineering in clean water management projects is the best solution to support the achievement of national targets for universal access to clean water.

Keywords: *Water Supply System, Value Engineering, Multi-Criteria Analysis, Life Cycle Cost Analysis, Project Cost, Pareto Diagram.*

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I. LITERATURE REVIEW

A. *The Water Supply System (SPAM)*

The purpose of the Water Supply System (SPAM) is to supply the community with water that satisfies quality criteria. This system consists of multiple primary parts, specifically:

- Water Intake: Devices like pumps or water pipelines that draw water from a water source.
- Water treatment includes filtration, coagulation, disinfection (e.g., chlorination), and screening, among other physical, chemical, and biological methods.
- Water Storage (Reservoir): Before clean water is supplied, it is stored in tanks or water towers Water.
- Distribution: A system of pipes that supplies water to public buildings, businesses, and homes.

B. *Value Engineering (VE)*

The goal of Value Engineering (VE), a methodical and structured team-based decision-making process, is to maximize project value while preserving function and performance quality. The full project life cycle, including planning, designing, executing, maintaining, and decommissioning, can benefit from the use of VE. By using Life Cycle Cost Analysis (LCCA), VE seeks to reduce expenses without sacrificing quality. In the construction business, this approach has been conventional since the 1950s. VE uses a multidisciplinary team approach including owners, planners, and experts to remove excessive costs through cost and function analysis.

- *The Stages of VE include:*

- Information Stage: Project data collection, including design, constraints, and high-cost work items.
- Function Analysis Stage: Function analysis of work items using the Cost/Worth (C/W) ratio to identify primary and supporting functions.
- Creativity Stage: Brainstorming alternative new designs considering materials, methods, time, and technology.
- Evaluation Stage: Alternative analysis using Life Cycle Cost (LCC) to select the best idea based on long-term costs and benefits.
- Development Stage. Including the development of the selected alternative
- Recommendation Stage: Presentation of the analysis report to management for decision-making.

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C. Cost Model

Using techniques like the Cost significant Model (CSM), which forecasts overall costs based on major cost items (80% of project expenses), cost models are used to anticipate project costs. Project managers can lower risks and minimize expenses with the aid of CSM. Its dependence on historical data and accuracy, which is dependent on data quality, are its weaknesses, though.

D. The Pareto

The 80/20 rule, which states that 80% of the effects result from 20% of the causes, is applied in the Pareto diagram. Priority concerns for improvement are identified with the aid of this diagram. This idea is applied in construction projects to concentrate on tasks that will have the biggest financial impact.

E. Multi Criteria Analysis (MCA)

Multi Criteria Analysis (MCA) is a hierarchical decision-making method that compares criteria and alternatives in pairs. MCA reduces bias by validating the consistency of evaluations and generating scores based on the priority of criteria.

F. Unit Price Analysis

Unit Price Analysis calculates the build of quantity (BoQ) by multiplying the volume of work with the unit price. Unit price includes material costs, wages, tools, and profit. Factors affecting this analysis include material, labor, and equipment coefficients, as well as direct and indirect costs such as overhead and taxes.

G. Life Cycle Cost Analysis (LCCA)

Life Cycle Cost Analysis (LCCA) compares the costs and savings of alternative designs over the life cycle of a building. LCCA helps select the most cost-effective option by considering initial costs, operational costs, maintenance, and environmental impact. This method is also used to evaluate the long-term costs of decisions not made, such as replacing building components.By applying VE, Cost Model, Pareto Diagram, MCA, Unit Price Analysis, and LCCA, construction projects can be optimized to achieve the best value with minimal cost and maintained quality.

II. RESEARCH METHOD

Structure The research's conceptual framework is centered on cutting wasteful expenses in the project design stage. These expenses frequently result from a lack of knowledge, concepts, time, or conceptualization errors. Value Engineering (VE) is one cost-cutting strategy that seeks to lower physical expenses without compromising the project's functionality. Maximum savings can be obtained while preserving the required level of quality, appearance, and functionality by implementing VE throughout the design phase. The Pareto Distribution Law, which asserts that a small percentage of project components account for the majority of expenses, supports this approach. An effective and efficient project design with reduced overall expenses is the end outcome.

A. Type and Source of Data

This research uses a qualitative and quantitative approach:

- *Qualitative:*

Descriptive analysis to understand the drinking water supply system of SPAM Cipinang Gading.

- *Quantitative:*

Numerical analysis to calculate investment costs, operation/maintenance (O/M) costs, and questionnaire results.

B. The Research Flow

The research flow can be seen in the flow chart in the image below:

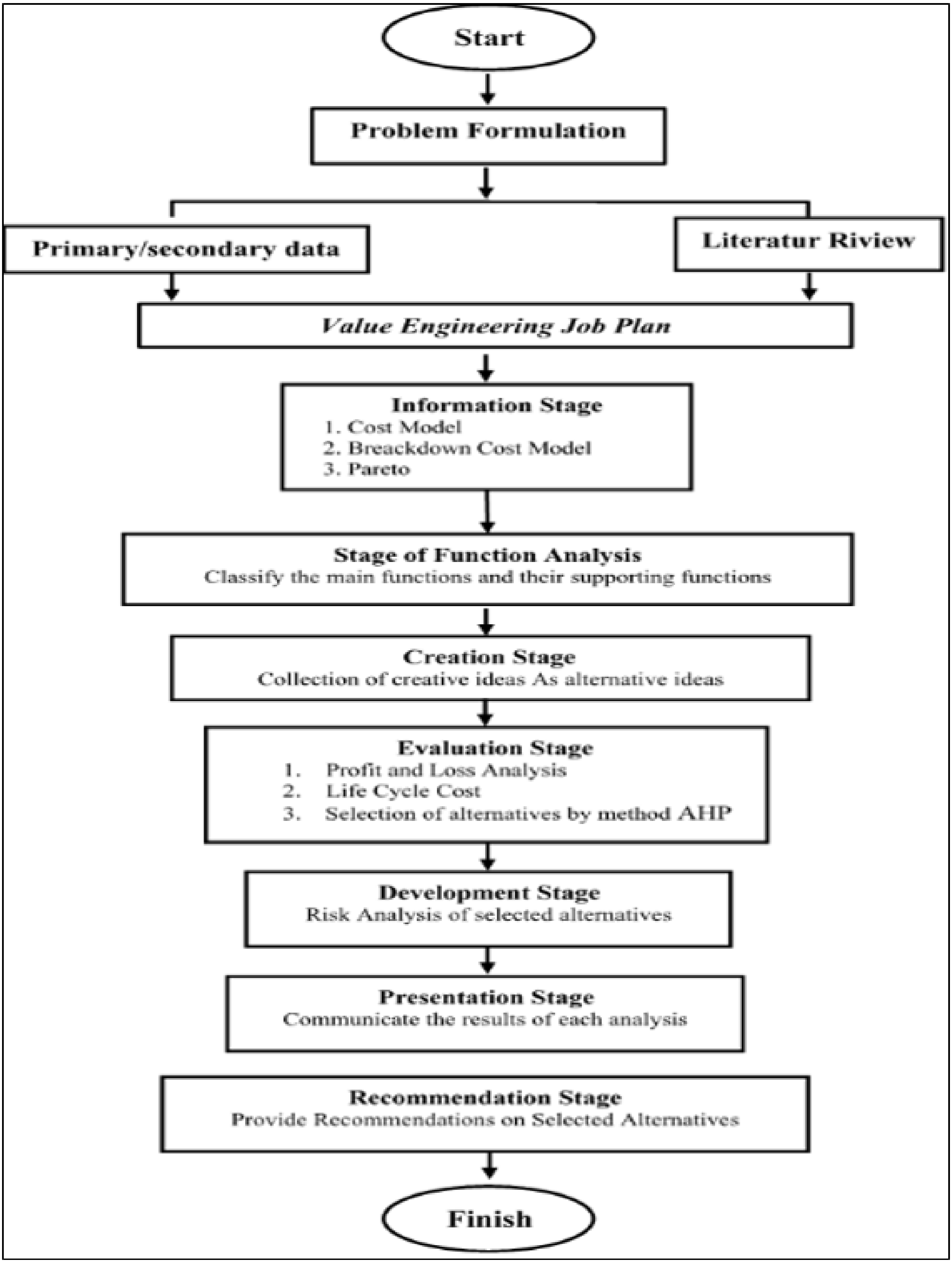

Fig 1 Flow chart

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C. Data Analysis

Data is analyzed quantitatively through three stages: classification, interpretation, and descriptive analysis. This analysis produces architectural work options that will be applied in Value Engineering. Several analysis methods used include:

- Cost Model: Calculating project costs.
- Pareto Diagram: Identifying the components that contribute the most to the costs.
- Function Analysis: Determining the main function of the project.
- Fast Diagram: Encouraging creative thinking and limiting perspectives to positive functions.

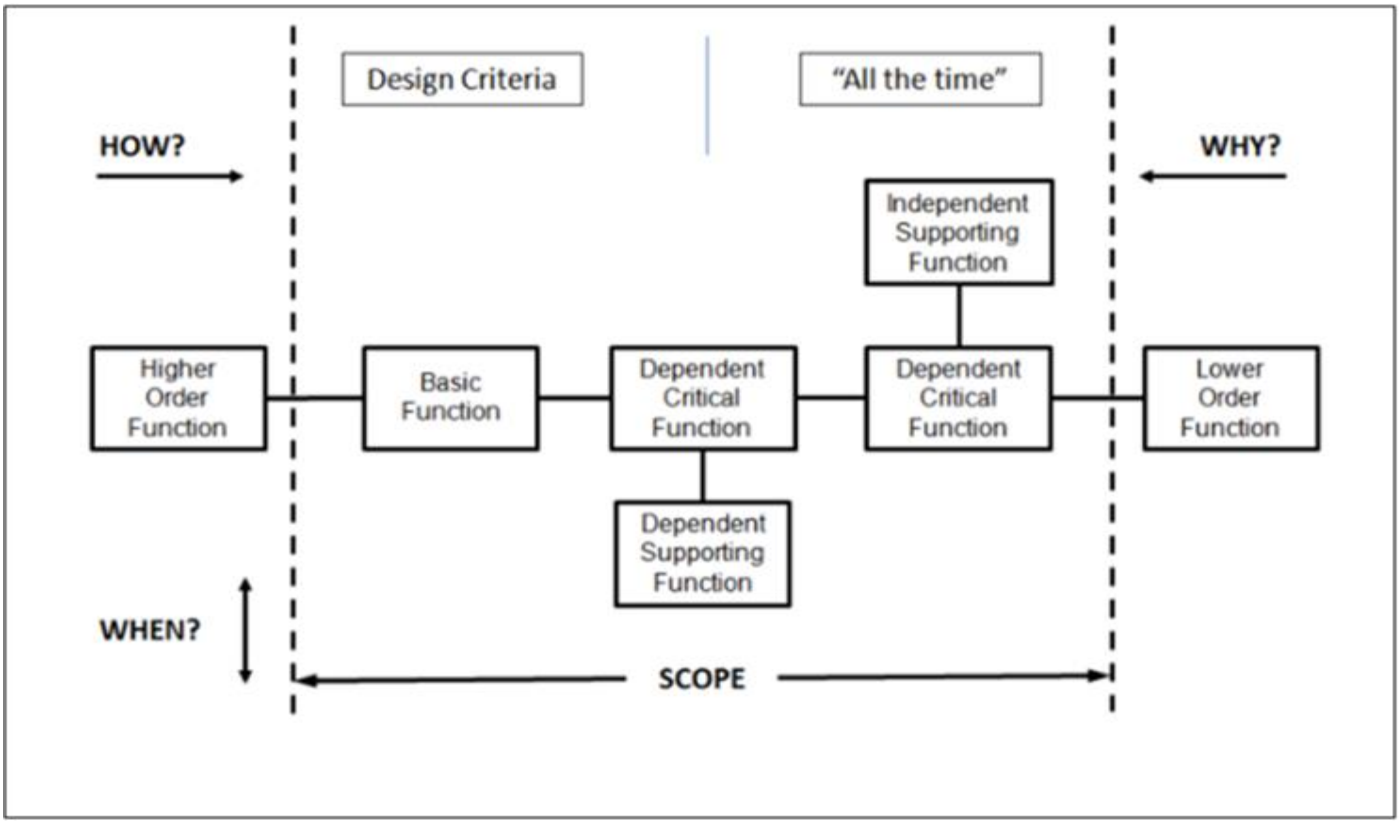

Fig 2 Fast Diagram

- Unit Price Analysis: Calculating the cost of each alternative work method.
- Multi Criteria Analysis (MCA): Assessment based on criteria, indicators, weights, scoring, and ranking.
- Life Cycle Cost Analysis (LCCA): Analysis of the project life cycle costs, including initial costs, operation/maintenance, replacement, and salvage value.

III. RESULTS AND DISCUSSION

A. Stage of General Project Data Information:

SPAM Name: Cipinang Gading Water Treatment City Bogor

- Ownership Status: Bogor City Government
- Raw Water Source: Cipinang Gading River
- Intake Capacity: 100 L/s
- Production Capacity: 2 x 50 L/s
- Service Area: Cikaret, Gunung Batu, Loji, Mulya Harja, Pasir Jaya, Pasir Mulya
- Target New Customers: 5000 New Connections (SR)
- Planner: PDAM Tirta Pakuan and PT. Priayang Raya Utama
- Scope of Activities: Construction of WTP, concrete foundations, indoor buildings, guard posts, site roads, reservoirs, transmission pipes, distribution, and equipment such as water meters and pressure reducing valves.

- *Data Hidrolis:*

The simulation results show a pressure at the taping point of 52.16 m and at the farthest point of 35.78 m.

- *Total Overall Cost:*

Build of quantity (BoQ) for the construction of the Cipinang Gading SPAM is IDR 77,843,000,000, covering intake, water treatment plant (IPA), reservoir, and distribution.

- *Cost Model:*

Identification of high-cost work items is carried out with the aim of determining which items require high costs in their execution. The step used to identify high-cost work items is to create a Cost model chart of the project as explained in the chart included in the Appendix. From the chart, the next step is to develop the Level I Cost model as follows:

Table 1 Cost Model

NO	ACTIVITY ITEMS	COST (RP)	CUMULATIVE COST (RP)	COST (%)	CUMULATIVE COST (%)
I	Main Distibustion Network Pipeline and services	23.534.899.278	23.534.899.278	30,23	30,23
II	Transmission Pipe	21.199.402.000	44.734.301.278	27,23	57,47
III	Water Treatment Plant	15.008.759.016	59.743.060.293	19,28	76,75
IV	Reservoar	7.799.999.999	67.543.060.292	10,02	86,77
V	ACP Pipe Replacement	7.300.000.000	74.843.060.292	9,38	96,15
VI	Pressure Reducing Valve (PRV)	3.000.000.002	77.843.060.294	3,85	100,00
	TOTAL RESULTS	77.843.059.017		100	

Source: Processed Data, 2024

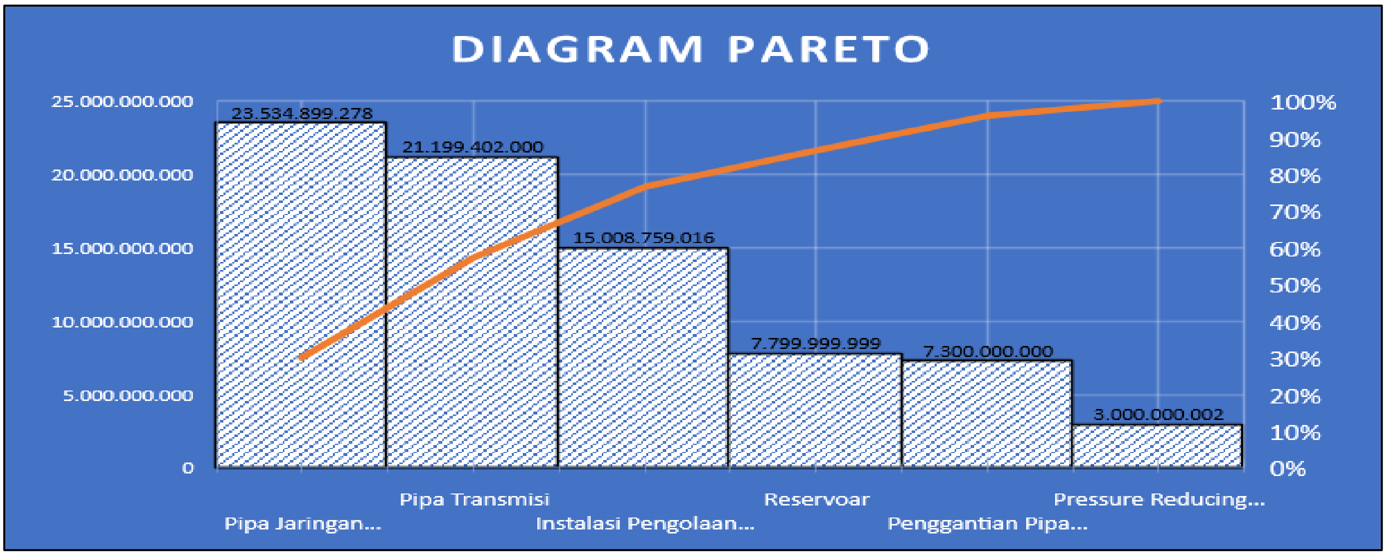

Fig 3 Diagram Pareto

Activities with high costs from the Cost model results in the Table include Main Distribution Network Pipe Work Activities and Main Distribution Network and services with a cost value of 30.23%, and Transmission Pipe Activities with a cost value of 27.23%.

Then a level 2 cost model was conducted with the results of the Procurement and Installation of HDPE Pipe Ø 2" with a cost value of 33.75%, HDPE Pipe Ø 8" with a cost value of 20.04%, HDPE Pipe Ø 12" with a cost value of 19.04%, and the Installation of Transmission Pipe Ø 20".

➤ *Function Analysis Stage*

At this stage, function identification will be carried out, consisting of active verbs and measurable nouns. Function identification is carried out randomly and then grouped and identified by their respective types.

Table 2 Cost Model

Function: Channeling water			
Work	Function		Function Types
	Verb	Noun	
HDPE (High-Density Polyethylene) Transmission Pipe PN 10 (SDR 17) ø 20"	Distributing	water	Basic
	Turning	Flow	Secondary
	Share	Flow	Secondary
	Arrange	Flow rate	Secondary
	Guard	clarity	Secondary
	Emit	Air	Secondary
	neutralize	result	Secondary
	Economical	Energy	Secondary
	Throw away	solid deposits	Secondary

Source: Processed Data, 2024 Next, the functions are included in the Fast Diagram.

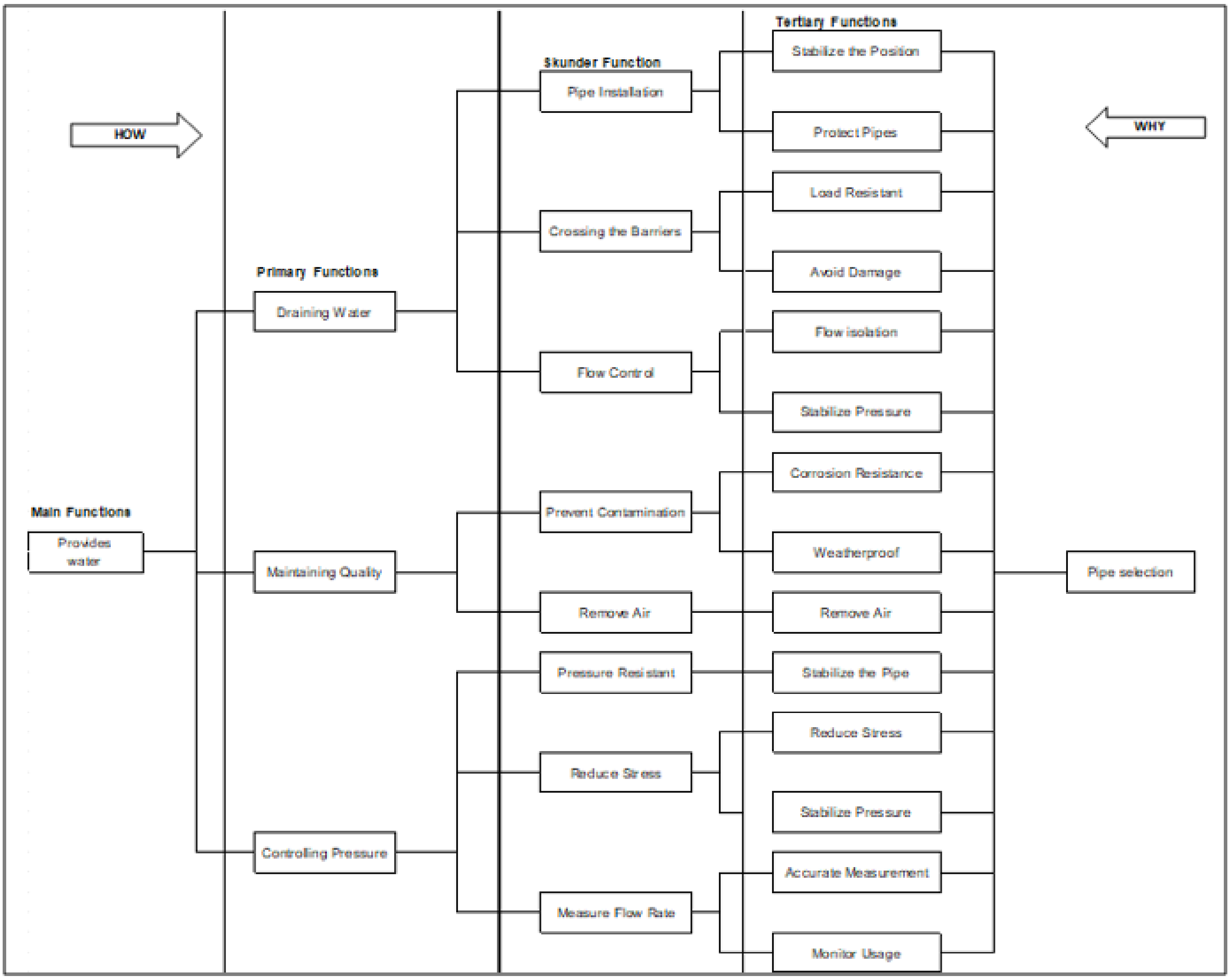

Fig 3 Fast Diagram

➢ *Creative Stage*

Obtaining as many design alternatives or ideas as possible is a goal of this stage, which can be achieved through the technique of brainstorming. In this stage, there is no need for limitations on the ideas that emerge.

Table 3 Alternative Pipe Work Items

No	Alternatif
A0	Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)
A1	Pipe PVC (Polyvinyl Chloride)
A2	Pipe uPVC (Unplasticized Polyvinyl Chloride)
A3	Pipe HDPE (High-Density Polyethylene) PN 8 (SDR 21)
A4	Pipe Galvanis
A5	Pipe PEX (Cross-linked Polyethylene)
A6	Spiral Welded Pipe
A7	Pipe PPR (Polypropylene Random) PN 10

Source: Processed Data, 2024

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➢ *Multi Criteria Analysis*

At this stage, the aim is to analyze the alternatives that have been determined at the creative stage to then select the best alternative as a proposed design at the recommendation stage. The techniques and methods used in the assessment and selection of alternatives that emerged at the previous stage.

Table 4 Assessment Criteria

Criterion	Sub Criteria	Criteria assessed
Investment Cost	Investment costs to be incurred in financing pipeline work	- The amount of expenditure to be incurred in the financing of the work - Additional costs required to support pipeline work - have a selling value after the economic expiration
Durability	Impact on water and the environment, material life	- Pipe material life - Broken vulnerability level
Implementation	Factors influencing the implementation of pipe installation	- availability of materials on the market - Work methods to support the installation of pipes - Flexible in working with specialized work areas, such as narrow work areas
Maintenance	Influencing factors in virginity during the life of the building	- Availability of materials on the market to perform small-scale changeovers - Ease of implementation of repairs - Ease in pipe cleaning
Strength	Technical specifications of pipe materials to project needs	- Quality conformity with maximum pressure requirements of 52.16 m/6 bar - strength against force
Uptime	Technical specifications of pipe materials to project work time	- Ease of mobilization of pipe materials to the work site

Source: Processed Data, 2024

The next step is to score each alternative based on the technical specification information for each assessment indicator for the work in the VE as follows:

Table 5 ø 2" Pipe Work Assessment Results

No	Alternatif	Assessment Results	Rank
1	**Desain Awal:** Pipe HDPE (*High-Density Polyethylene*) PN 10 (SDR 17)	6,76	4
2	**Alternatif 1:** Pipe PVC (*Polyvinyl Chloride*)	7,59	1
3	**Alternatif 2:** Pipe uPVC (*Unplasticized Polyvinyl Chloride*)	6,86	3
4	**Alternatif 3:** Pipe HDPE (*High-Density Polyethylene*) PN 8 (SDR 21)	6,76	4
5	**Alternatif 4:** Pipe Galvanis	5,59	6
6	**Alternatif 5:** Pipe PPR (*Polypropylene Random*) PN 10	7,27	2

Source: Processed Data, 2024

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➢ *Unit Price Analysis (AHSP) for each alternative*

At this stage, the cost of each alternative work is identified to facilitate the analysis. Then the AHSP is prepared for pipe work with a diameter of 2", diameter 8, diameter 12", and diameter 20".

➢ *Life Cycle Cost Analysis (LCCA) basic dataInterest*

The interest value (i) used is according to the official statistical news No. 02/01/Th.XXVII, January 2, 2024 of the Central Statistics Agency for buildings, electricity, gas, drinking water and communication installations of 0.39% and the last 10-year inflation rate published by BI from 2013 to 2022.

Table 6 Inflation Rate Published by BI

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average
Actual Inflation	8.38	8.36	3.35	3.02	3.61	3.13	2.72	1.68	1.87	5.51	4.16

Source: Bank Indonesia, 2022

➢ *Initial Cost*

Initial Cost= Unit Price x Alternative Volume Interest Value: 0.39% + 4.16% = 4.54%

Table 7 Initial Cost

Alternatif	Unit Price		Volume (m')	Total Cost	
Pipe ø 2"					
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	Rp	430.389,57	18456	Rp	7.943.269.848,74
Pipe PVC (Polyvinyl Chloride)	Rp	232.932,50	18456	Rp	4.299.002.220,00
Pipe ø 8"					
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	Rp	997.637,31	4727	Rp	4.715.831.584,22
Pipe PVC (Polyvinyl Chloride)	Rp	550.131,25	4727	Rp	2.600.470.418,75
Pipe ø 12"					
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	Rp	2.321.658,85	1930	Rp	4.480.801.584,03
Pipe PVC (Polyvinyl Chloride)	Rp	969.162,50	1930	Rp	1.870.483.625,00
Pipe ø 20"					
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	Rp	8.003.461,46	2610	Rp	20.889.034.397,55
Pipe HDPE (High-Density Polyethylene) PN 8 (SDR 21)	Rp	7.433.237,75	2610	Rp	19.400.750.527,50

Source: Processed Data, 2024

➢ *Operational and Maintenance Costs*

Table 8 Operational and Maintenance Costs

Alternatif	Construction Costs		Interest	O/M Cost		O/M (P/A,4,55%,50)	
Pipe ø 2"							
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	Rp	7.943.269.848,74	4,55%	Rp	158.865.396,97	Rp	3.114.134.879,22
Pipe PVC (Polyvinyl Chloride)	Rp	4.299.002.220,00	4,55%	Rp	85.980.044,40	Rp	1.685.410.796,07
Pipe ø 8"							
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	Rp	4.715.831.584,22	4,55%	Rp	94.316.631,68	Rp	1.848.827.485,48
Pipe PVC (Polyvinyl Chloride)	Rp	2.600.470.418,75	4,55%	Rp	52.009.408,38	Rp	1.019.506.549,27
Pipe ø 12"	Rp	-					
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	Rp	4.480.801.584,03	4,55%	Rp	89.616.031,68	Rp	1.756.684.685,95
Pipe PVC (Polyvinyl Chloride)	Rp	1.870.483.625,00	4,55%	Rp	37.409.672,50	Rp	733.317.438,35
Pipe ø 20"	Rp	-					
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	Rp	20.889.034.397,55	0,39%	Rp	417.780.687,95	Rp	8.189.482.650,01
Pipe HDPE (High-Density Polyethylene) PN 8 (SDR 21)	Rp	19.400.750.527,50	4,55%	Rp	388.015.010,55	Rp	7.606.005.467,67

Source: Processed Data, 2024

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➢ *Replacement Cost*

Table 10 Replacement Cost

Alternatif	Year of Replacement	Replacement Cost	Replacement Fee in the Replacement Year (P/F.4,55%.n)			Total Replacement Cost
			Year 15	Year 30	Year 45	
1	6	7	8	11	13	14
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	50	Rp 1.588.653.969,75	N/A	N/A	N/A	N/A
Pipe PVC (Polyvinyl Chloride)	15	Rp 859.800.444,00	Rp 441.100.050,75	Rp 226.295.829,61	Rp 145.022.764,26	Rp 667.395.880,36
Pipe ø 8"						
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	50	Rp 943.166.316,84	N/A	N/A	N/A	N/A
Pipe PVC (Polyvinyl Chloride)	15	Rp 520.094.083,75	Rp 266.821.828,64	Rp 136.886.556,62	Rp 87.724.404,22	Rp 403.708.385,26
Pipe ø 12"						
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	50	Rp 896.160.316,81	N/A	N/A	N/A	N/A
Pipe PVC (Polyvinyl Chloride)	15	Rp 374.096.725,00	Rp 191.921.376,10	Rp 98.460.671,11	Rp 63.098.991,79	Rp 290.382.047,21
Pipe ø 20"						
Pipe HDPE (High-Density Polyethylene) PN 10 (SDR 17)	50	Rp 4.177.806.879,51	N/A	N/A	N/A	N/A
Pipe HDPE (High-Density Polyethylene) PN 8 (SDR 21)	50	Rp 3.880.150.105,50	N/A	N/A	N/A	N/A

Source: Processed Data, 2024

➢ *LCCA*

- LCCA results are made for each work item in VE.
- *Initial Salvage Value (SV)* = *20%from Initial Cost*
- *Final Salvage Value (Sva)* = *SV (P/Fin)*

Table 9 Life Cycle Cost Analysis

Life Cycle Cost Analisys (LCCA) Pipe ø 2"			
No	**Indikator**	**Initial design**	**Alternatif**
1	Initial Cost	Rp 7.943.269.848,74	Rp 4.299.002.220,00
2	Operating Costs	Rp 3.114.134.879,22	Rp 1.685.410.796,07
3	Periodic replacement fee	Rp -	Rp 667.395.880,36
4	Salvage Value	Rp 171.722.599,70	Rp 92.938.531,79
	Total Cost	Rp 10.885.682.128,25	Rp 6.558.870.364,63

Source: Processed Data, 2024

After the LCCA is carried out, the next step is to make a recapitulation of the RAB according to the selected alternative unit price. The cost efficiency was obtained from the initial design of Rp 77,843,000,000 to Rp. 67,985,000,000. Able to increase cost efficiency by 12.6%.

➢ *Development*

Replacing pipe work items can increase the efficiency of the project value, but using other alternatives may not necessarily be possible with the same method, and it is necessary to pay attention to the risks according to the specifications and the advantages and disadvantages of the material.

IV. RECOMMENDATION

The results of the cost model function analysis and the Pareto diagram were obtained. At the creation stage, 7 alternatives were created. At the Evaluation Stage using the MCA and LCCA methods, it showed that PVC Pipe was selected as an alternative for the ø 2" pipe work, ø 8" pipe and ø 12" pipe. While for the ø 20" pipe in the MCA method, the HDPE PN 8 (SDR 21) type. Cost efficiency was obtained from the initial design of Rp. 77,843,000,000 to Rp. 67,985,000,000. Able to increase cost efficiency by 12.6%. With the salvage value of ø 2" pipe of Rp 6,558,870,365, ø 8" pipe of Rp 3,967,466,749 and ø 12" pipe of Rp 2,853,745,820, and ø 20" pipe of Rp 2,658,733,837.

V. CONCLUSION

The evaluation results using the MCA method with the assessment parameters of Cost Aspects, Implementation, Durability, Maintenance, strength, and workmanship. The results show that PVC Pipe is selected as an alternative for ø 2" pipe work, ø 8" pipe and ø 12" pipe. While for ø 20" pipe in the MCA method, the type is HDPE PN 8 (SDR 21) and the LCCA method is the PVC Pipe type. The MCA results show that the ø 20" HDPE PN 8 (SDR 21) type pipe has a value of 7.71 out of a maximum value of 10, the highest value parameters in terms of cost, durability, maintenance, and

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processing time. After LCCA was carried out, the cost efficiency was obtained from the initial design of Rp. 77,843,000,000 to Rp. 67,985,000,000. Able to achieve cost efficiency of 12.6%. With a salvage value of ø 2" pipe of Rp. 6,558,870,365, ø 8" pipe of Rp. 3,967,466,749 and ø 12" pipe of Rp. 2,853,745,820, and ø 20" pipe of Rp. 2,658,733,837.

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