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Analysis of Financial Feasibility Study in the Development of Katulampa SPAM Using Fuzzy Method

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ABSTRACT

Water is a natural resource that is very important for all living things. For humans, water is used for bathing, washing and drinking, so it is necessary to pay attention to its quality. Water quality is the main factor to determine the suitability of water for use. The purpose of this study was to analyze the financial feasibility of a clean water distribution network development project for SPAM Katulampa Bogor City. Fuzzy financial analysis uses fuzzy numbers that can calculate the sensitivity level of changes in a variable because it uses a range of values that makes the sensitivity value more sensitive and this is not found in non-fuzzy financial analysis (conventional). The NPV, IRR, and B/C R values obtained in the fuzzy method have the same impact as the conventional method, where the NPV and IRR values indicate that the Katulampa SPAM project is feasible to continue.

Keywords: *Financial Analysis, Fuzzy Method, NPV, IRR, B/C/R.*

INTRODUCTION

The utilization of water resources for various purposes has been increasing over the years. This trend is an implication of population growth and the expanding activities of society in water usage, resulting in an escalating demand for clean water availability. However, numerous regions are currently experiencing challenges in ensuring the availability of clean water. One alternative solution to address these issues is the development of infrastructure for raw water supply to meet community needs. The development of clean water infrastructure, which serves as a vital sector supporting public welfare, must be systematically and sustainably planned. Furthermore, raw water management requires comprehensive and well-thought-out planning that involves community participation. This involvement ensures that once the infrastructure is built, the community contributes to maintaining its sustainability, enabling it to last as per its planned lifespan. Such infrastructure development is expected to alleviate water scarcity for various needs, including drinking water, irrigation, livestock, fisheries, electricity generation, and others.

One of the current water supply challenges in Bogor City is the imbalance between supply and demand for water in existing service areas, leading to a shortage in supply capacity. Additionally, the existing pipeline network has limited capability. The installed capacity managed by the regional water utility company (PDAM) to supply clean water to newly developed areas and residential zones still falls short of supporting the government’s program targeting 10 million household water connections under the 2020–2024 National Medium-Term Development Plan (RPJMN).

Considering the development program and field conditions, an alternative water treatment system is required to divide service zones, ensuring equitable distribution and maintaining quality, quantity, and continuity of service. PDAM Bogor City is currently increasing its production capacity by approximately 50% of the existing capacity or about 500 liters per second.

Based on the Bogor City Water Supply System (SPAM) master plan for meeting the long-term water supply needs of Bogor City residents through 2029, the existing water supply system, relying on raw water from the Cisadane River, is projected to be insufficient. One of the feasible solutions is to increase production capacity by utilizing water from the Ciliwung River as an alternative surface water source in Bogor City.

The initial step in this project involves conducting a feasibility study on the clean water system and the construction of the Katulampa water treatment plant in Bogor City. A financial feasibility study is crucial before initiating the development of the SPAM Katulampa distribution network project. This study aims to determine whether the investment in the project will yield profits or result in losses for the company.

Financial feasibility studies typically cover an extended period, where the time factor is closely related to the value of money. Projects cannot proceed without first meeting the criteria that serve as the basis for investment decisions involving substantial funds.

Numerous studies have been conducted on the financial feasibility of infrastructure projects and corporate establishments, including those by Rahadi (2018), Farida (2015), Ahmad (2015), and Primasari (2017). These studies evaluate the financial aspects of project development and company establishment to determine whether they yield financial benefits or incur losses.

The financial analysis approach commonly employs economic indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP). These metrics take into account cash flow and benefits, constrained by the inherent limitations in estimating costs and benefits. However, these conventional measurements often fall short when analyzing projects with uncertain or indefinite cash flows and benefits.

Estimating costs and benefits is inherently complex for several reasons. First, each project is unique, often lacking sufficient historical data for reliable estimation. Second, cash flows and benefits may be intangible or extend over long durations, making precise quantification challenging. Third, conventional techniques struggle to address delayed benefits, high capital costs, and difficulties in predicting long-term advantages. Additionally, the estimation process is frequently influenced by subjective human judgments and incomplete knowledge, leading to potential inaccuracies in forecasting costs and benefits. Consequently, relying solely on conventional techniques may result in suboptimal investment decisions or misaligned estimations of project feasibility (Omitaomu & Badiru, 2007).

Investment feasibility assessments are further complicated by uncertainties stemming from unavoidable simplifications in modeling, incomplete understanding of functionalities, external factors beyond stakeholder control, operational biases, and minor errors in execution. These uncertainties are inherently multidimensional, with one factor often influencing others. Techniques such as random number generation, probability theory, and fuzzy systems have demonstrated potential for addressing these challenges.

According to Lindley, probability is the only reasonable approach to addressing uncertainty and is sufficient for all problems involving uncertainty. However, when dealing with multiple sources of imprecise information, such as those found in investment scenarios, the multidimensional complexity often exceeds the capacity of probabilistic models. Therefore, the concept of fuzzy systems becomes essential in addressing such challenges (RH, 1987).

Investment feasibility analysis using the fuzzy method provides a better representation of field conditions and serves as a more precise tool for assessing feasibility. For example, estimating cash flow and discount rates over a multi-year period is highly complex and often impossible to determine with complete accuracy. This difficulty is often due to challenges in statistically calculating correlation coefficients. The fuzzy approach addresses this issue by expressing estimated cash flow and discount rates as a range of values, effectively capturing inherent uncertainties.

The fuzzy investment model for analyzing the financial feasibility of SPAM Katulampa offers a novel approach by integrating uncertainty into the evaluation process. This allows for a more comprehensive understanding of available alternatives, thereby facilitating better decision-making. In this study, two analytical approaches are employed: the conventional financial perspective, which utilizes traditional financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP), and the fuzzy approach, which incorporates uncertainties to provide a more realistic assessment. The combination of these two approaches ensures a more objective and accurate evaluation of the financial feasibility of the SPAM Katulampa development project.

Given this background, conducting a financial feasibility analysis of the SPAM Katulampa clean water distribution network development project using the fuzzy method is crucial. Such an analysis plays a pivotal role in enhancing and expanding clean water distribution networks, ultimately improving service quality. Therefore, the primary objective of this study is to analyze the financial feasibility of the SPAM Katulampa clean water distribution network development project using the fuzzy method, providing valuable insights to support informed and effective decision-making.

LITERATURE REVIEW

An activity that utilizes resources to obtain benefits, or an activity involving expenditures with the expectation of future returns that can be planned, financed, and executed as a single unit, constitutes a project investment activity.

Project investment refers to the effort of allocating scarce production factors to a specific project (whether new development or expansion) at a specific location over a predetermined period (Gray C, Simanjuntak P, Sabur LK, Maspaitella PFL, 2002). These scarce production factors include:

Capital: Financial resources necessary for funding the project.

Natural resources: Assets derived from the environment that are critical for project execution.

Skilled labor and expertise: The human capital required to implement and manage the project effectively.

Feasibility Study of Investment

According to Suratman, investment within a company pertains to the utilization of resources with the expectation of generating beneficial returns in the future. It can also be defined as the allocation of a certain amount of capital (either small or large) to initiate a business or project at present, with the hope of recovering the invested capital along with profits in the future (Suratman, 2001).

Investment types, as categorized by Kasmir, are divided into two categories (Kasmir and Jakfar, 2003):

a. Real Investment
   Real investment involves investments in fixed assets, such as land, buildings, equipment, or machinery.
b. Financial Investment
   Financial investment refers to investments in contractual agreements, such as the purchase of stocks, bonds, or other securities like certificates of deposit.

According to Suratman, a project feasibility study is defined as research or an evaluation conducted to assess whether a project is feasible or not (Suratman, 2001). Therefore, conducting a feasibility study before initiating any project is essential to ensure that the project will not be futile in the future. The objectives of a feasibility study, as outlined by Kasmir, include the following (Kasmir and Jakfar, 2003):

a) Risk Mitigation
The feasibility study functions to minimize undesired risks, both those that are controllable and those that are uncontrollable.
b) Facilitating Planning
By forecasting future events, the feasibility study aids in identifying and planning for necessary actions, streamlining the planning process.
c) Easing Project Implementation
With a pre-established plan, the execution of the project becomes more straightforward, ensuring that the project stays on target and aligns with the planned objectives.
d) Enhancing Supervision
Supervision is crucial to ensure that the project implementation does not deviate from the established plan, helping maintain consistency and effectiveness.
e) Streamlining Control
Control mechanisms are employed to correct any deviations in project implementation, ensuring that the project adheres to its original objectives and ultimately achieves the intended results.

The aspects assessed in the investment feasibility study of a business or project, as defined by Kasmir, include the following (Kasmir and Jakfar, 2003):

a) Legal Aspect
The legal aspect addresses the completeness and validity of company documents, ranging from the business entity structure to the necessary permits and licenses.
b) Market and Marketing Aspect
This aspect evaluates whether the company has access to the desired market opportunities, considering both market conditions and marketing strategies.
c) Financial Aspect
The financial aspect assesses the costs involved in the project, including an evaluation of the scale and scope of these expenses.
d) Technical or Operational Aspect
This aspect focuses on the technicalities or operational procedures required for running the business or project.
e) Management or Organizational Aspect
This aspect evaluates the management of the project, focusing on the organizational structure and the competence of the personnel involved.
f) Socio-Economic Aspect
The socio-economic aspect considers the broader impact the business or project will have on the surrounding community and economy.
g) Environmental Impact Aspect
This aspect examines the environmental consequences of the project, including its effects on land, water, and air quality, which will ultimately impact living organisms and ecosystems.

Development of Fuzzy Systems

Fuzzy sets were first introduced by Prof. L.A. Zadeh from Berkeley in 1965. For the first decade, the emergence of fuzzy sets did not attract significant attention. However, in recent years, there has been a substantial increase in the number of researchers and papers concerning fuzzy sets and their applications, leading to the formation of the International Fuzzy Systems Association (IFSA) (Martini et al., 2010).

It is essential for computers to understand human language; however, the challenge lies in the many ambiguities present in everyday language that cannot be addressed using conventional logical processing. As an example, if we say that a person is tall, we cannot precisely define the exact height in centimeters that would qualify someone as tall. Fuzzy sets provide the right tool to express such ambiguities. They serve as a medium for communication that reflects natural logic and complexity between humans and social knowledge (Martini et al., 2010).

Initially, fuzzy set theory was considered merely a technique to mathematically express ambiguity in language. However, the theory has now evolved into a means of quantitatively measuring various types of ambiguity, encompassing concepts of probability.

A fuzzy system is a structured and dynamic numerical predictor. It has the capability to develop intelligent systems within uncertain and imprecise environments. The system predicts a function using fuzzy logic. Fuzzy logic is a subset of Boolean logic that is used to handle the concept of truth degrees, where the truth value ranges between true and false. Fuzzy logic frequently utilizes linguistic and verbal information. In fuzzy logic, several processes are involved, including the determination of fuzzy sets, the application of if-then rules, and the process of fuzzy inference. The problem-solving flow using the fuzzy method is presented in Figure 1.

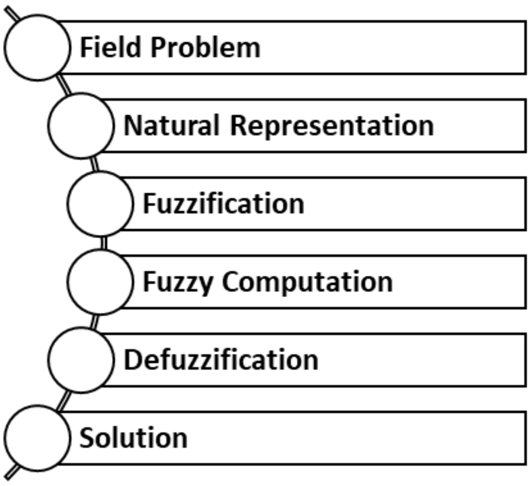

Figure 1 Problem-solving process using the Fuzzy Method.

Financial Feasibility Analysis

Papulele states that when making capital investments in a project, an analysis is needed to determine the level of profit gained from the investment, avoid wastage, assess the available investment opportunities, and select the most profitable project alternative while determining investment priorities (Papulele, 2011).

Fuzzy theory is a method for representing uncertainty, which is a common factor in technical analysis. Fuzzy financial analysis uses fuzzy numbers that can compute the sensitivity of changes in a variable by utilizing a range of values, making sensitivity values more responsive. This feature is not present in non-fuzzy (conventional) financial analysis. Buckley was one of the pioneers of this approach (Buckley, 1987). This approach has also been presented by several authors, including research titled Fuzzy Cash Flow Analysis Using Present Worth Criterion (Chiu, CY. Park, 1994), Dynamical Analysis and Adaptive Fuzzy Control for The Fractional-Order Financial Risk Chaotic System (Sukono et al., 2020), and Company Financial Path Analysis Using Fuzzy C-Means and Its Application in Financial Failure Prediction (Liu and Wu, 2018).

Cash Flow

There are three key considerations in investment activities:

a) The presence of uncertainty in business operations
b) Limited available funds
c) Future income and expenses must be converted into present value for comparison.

Since future income and expenses contain uncertainty, their future value must be converted into present value (PV). The amount of money one year from now converted to its present value is expressed as:

$$PV = F / (1 + r) \quad (1)$$

For the second, third, and subsequent years, the conversion factor for the value of money (the denominator) is raised to the power of the respective time period.

$$PV = \frac{F}{(1+r)^t} = F\frac{1}{(1+r)^t} = F.DF \quad .... (2)$$

Where:

PV = Present value of future money (at year t)
F = Future value of money (at year t)
r = Discount rate (as a percentage)
t = Time period (in years)
$\frac{1}{(1+r)^t}$ DF = Discount factor

Fuzzy Net Present Value **(NPV)**

Determining investment feasibility using the fuzzy method provides an illustration of real-world values, making it a more precise tool for feasibility analysis. The application of fuzzy methods to cash flow calculations was initiated by Dhillon et al. (2016), who described fuzzy concepts using trapezoidal membership functions to address contemporary issues. Meanwhile, Buckley employed Triangular Fuzzy Numbers (TFN) to calculate fuzzy net present value (Fuzzy NPV) and fuzzy net future value (Fuzzy NFV) with fuzzy interest rates over a period of n years (Buckley, 1987). Buckley's approach involved deriving fuzzy equations for calculating interest payments and effective interest rates accurately. Fuzzy calculations over specific time periods result in nonlinearity, making the computations increasingly complex.

Based on NPV analysis, investment opportunities can be evaluated to determine whether they should proceed or be abandoned. The deterministic (certainty) value of the project can be estimated based on projections, enabling decision-making on whether the project is beneficial if implemented. The required data includes the expected annual cash flow Vi for each year of the project, the investment cost X, and the required rate of return (denoted as project beta) over the investment period n. The annual cash flow reflects the annual profit, which is essentially the difference between operational revenue and operational costs for a specific year of the project. The aggregated quantity is derived using the discounting parameter beta with the following formula:

$$X = (x_1, x_2, \alpha', \beta'), \text{.................... ... (3)}$$

In this context, L represents the duration of the investment activity. The discounting parameter r implicitly reflects the degree of risk tolerance of the investor or decision-maker. Increasing r implies that the investment carries a higher risk, as higher future cash flows are required to achieve the same aggregate return. The investment cost X is a one-time expense incurred at the project's inception to enable participation. The value of the investment can be calculated as follows:

$$NPV = S_0 - X = \sum_{i=0}^{L} \frac{V_i}{(1+r)^i} - X, \text{........ (4)}$$

The decision rule for investment feasibility is straightforward: if NPV > 0, the investment is deemed acceptable (feasible). Conversely, if NPV<0, the investment is considered not feasible.

According to Majlender (2003), the expected cash flow for each year should be estimated using trapezoidal fuzzy numbers, represented as:

$$V_i = (a_i, b_i, \alpha_i, \beta_i) \text{ .... (5)}$$

For i = 0, 1, L, let the most probable value of the expected cash flow in year i of the project lie within the interval [ai, bi], which serves as the core of the trapezoidal fuzzy number Vi. The lower potential decrease is represented as ($ai-\alpha i$), and the upper potential increase as ($bi+\beta i$). This defines the bounds of the fuzzy cash flow for year i.

Similarly, the expected investment cost can be estimated using a trapezoidal fuzzy distribution of the form:

$$X = (x_1, x_2, \alpha', \beta'), \text{ .... (6)}$$

Let the most probable value of the expected investment cost lie within the interval [X_1, X_2], which serves as the core of the trapezoidal fuzzy number X. The lower potential decrease is represented as ($X_1-\alpha'$), and the upper potential increase as ($X_2+\beta'$).

Thus, the trapezoidal fuzzy number X representing the expected investment cost can be defined as:

Where:

- X_1: The lower bound of the most likely investment cost (core value).
- X_2: The upper bound of the most likely investment cost (core value).
- α': The potential decrease from X_1.
- β': The potential increase from X_2.

This representation incorporates the potential uncertainties into the investment cost by considering both reductions and increases, reflecting the dynamic nature of real-world investment scenarios. Such an approach provides a more flexible and realistic framework for evaluating financial feasibility under fuzzy conditions.

***Internal Rate of Return* (IRR)**

The Internal Rate of Return (IRR) is the discount rate at which the Net Present Value (NPV) equals zero, expressed as a percentage (Gray et al., 2002). According to Sutojo, IRR is the interest rate that, when used to discount all cash inflows over the operational years of a project, will yield a total cash amount equal to the project's investment cost (Sutojo, 1993). The IRR of an investment is defined as the discount rate that makes the NPV of the cash flows equal to zero.

One of the challenges in interpreting this concept is that IRR requires a definite value (Buckley, 1987). The purpose of calculating the IRR is to determine the annual rate of return on a project. IRR represents the rate of return on an investment and reflects the percentage gain a project is expected to generate each year.

The calculation of IRR is essential for evaluating the feasibility and profitability of an investment, providing a clear metric for decision-making in project appraisal and financial planning.

$$IRR = i_1 + \left[\frac{NPV_1}{NPV_1 - NPV_2}\right](i_2 - i_1) \quad \text{... (7)}$$

Where:
i_1: the interest rate that results in a positive NPV
i_2: the interest rate that results in a negative NPV
NPV1: the positive NPV value
NPV2: the negative NPV value

From the conventional approach, the Internal Rate of Return (IRR) of an investment is defined as the interest rate (r) that results in a net cash flow of zero. An investment is considered feasible when IRR > r. Similar to NPV, IRR is also uncertain (fuzzy) due to the variability of the interest rate. The equation used in this study is as follows:

$$\sum_{t=0}^{n} \frac{Ft}{(1+IRR)^t} - Io = 0 \quad \text{.... (8)}$$

Where:
IRR = *Internal Rate of Return*
An investment is considered feasible if IRR > r

Benefit *Cost (B/C) Ratio Fuzzy*

The Net Benefit-Cost Ratio (Net B/C) is a comparison between the total positive Present Value and the total negative Present Value. The calculation of Net B/C is conducted to assess how many times the benefits obtained exceed the costs incurred.

According to Gray et al., the mathematical formulation is expressed as follows (Gray C, Simanjuntak P, Sabur LK, Maspaitella PFL, 2002):

$$netB/C = \frac{\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}}$$

, for Bt-Ct > 0
, for Bt-Ct < 0

.... (9)

Where:
Bt: project revenue in a specific year
Ct: project cost in a specific year
n: project lifespan
i: interest rate

A project is considered feasible if the Net B/C value is greater than or equal to one, and not feasible if the Net B/C value is less than one.

***Payback Period* (PBP)**

The Payback Period (PBP) calculates the year in which the investment will break even. The equation for PBP used in this study is as follows:

$$\mathrm{PBP} = \frac{\mathrm{I}}{\mathrm{Ab}} \quad \text{....... (10)}$$

Where:
I: Total investment required
Ab: Net benefits obtained annually.

***Break Event Point* (BEP)**

Determining capacity planning often involves significant financial investments. Therefore, the analysis of investment value requires careful consideration. Capacity/quantity planning to achieve the minimum production level without incurring losses in agro-industries can employ the "break-even analysis" (Break-Even Point/BEP) (Tampubolon, 2005). The break-even planning model determines the output quantity (in monetary or physical terms) required for the company to avoid losses. Capacity/quantity product planning analysis can utilize the following formulas:

Formula for BEP in Producing a Single Product

P x Q = Fc + (Vc + Q) .. .. (11)

Where:
P: Selling price per unit
Q: Quantity of units produced
Fc: Fixed costs
Vc: Variable cost per unit

b. Formula for BEP in Producing Multiple Products

$$BEP\,(Rp) = \frac{Fc}{\sum\left[(1-\frac{Vc}{Pi})(Wi)\right]} \quad \text{.......(12)}$$

Where:
P: Price per unit of the product
Q: Quantity produced
Fc: Total fixed costs
Vc: Variable cost per unit
W: Percentage of the product in the total sales mix
i: Unit of the product.

MATERIALS & METHODS

Object, Location, and Duration of Study

This study was conducted at SPAM Katulampa PERUMDA Tirta Pakuan, located at Jalan Siliwangi No. 121, RT.07/RW.02, Sukasari, Bogor Timur District, Bogor City, West Java, 16142. The research took place from February 2021 to October 2021.

Research Approach

The research employed a descriptive method with a qualitative approach, aiming to address the company's challenges in the form of a case study. This approach allowed the researcher to gain a broad and in-depth understanding over a specific period during the research timeline. Berg (2001) asserts that the goal of descriptive research is to answer particular questions through the application of systematic procedures.

Data Sources and Collection Techniques

This study utilized both primary and secondary data.

- Primary Data: Collected through interviews, discussions, and observations by respondents.
- Secondary Data: Sourced from various data releases, the company's annual reports, related information, and other supporting materials.

Respondent Selection Method

The study employed a non-probability sampling method, specifically judgment sampling. According to Sumarwan et al. (2018), judgment sampling involves selecting samples based on the expertise of the subjects under study. The evaluation of the sample was carried out by assessing and determining respondents based on specific criteria. Respondents were selected for their expertise and competence, with a minimum requirement of five years of experience in the feed additive industry, qualifying them as expert sources.

Data Analysis Method

The data was processed and analyzed using a descriptive method. This analysis aimed to resolve the company's issues through a case study approach. Data processing and analysis were conducted using the Competitive Analysis framework as outlined in Strategic Marketing Plus 2000 (Kertajaya, 2005). This approach provided a conceptual marketing analysis framework for addressing the company's challenges systematically and strategically.

Development and Implementation of Fuzzy Financial Models and Analysis

a. Selected Feasibility Indicators

The assessment and selection of feasibility indicators were carried out through literature review to determine the criteria used to decide whether a proposed project is feasible or not. The feasibility indicators include:

a) Net Present Value (NPV): The difference between the present value of benefits and the present value of costs at a specific discount rate.
b) Internal Rate of Return (IRR): The discount rate at which the net present value of the cash flow of a project equals zero.
c) Net Benefit-Cost Ratio (Net B/C): The absolute value of the ratio between positive NPV and negative NPV.

These three indicators were selected because they are based on cash flow analysis, which is a crucial component in financial evaluation.

b. Determining Variables to Be Fuzzified

The determination of feasibility variables was conducted through literature review. Variables influencing the feasibility of the bioethanol industry that were fuzzified include general assumptions affecting sensitivity, namely raw material costs, product selling prices, and discount rates.

c. Fuzzification of Selected Variables

The fuzzy membership function used for fuzzification was the Triangular Fuzzy Number (TFN). Fuzzification involved the following steps: Establishing the membership function, Defining levels for each factor, Setting lower bounds for the lowest levels and upper bounds for the highest levels, and Determining lower bound differences between levels for each factor.

***d.* Development of Fuzzy Calculation Model**

The fuzzy model was developed using the MATLAB 6.5 application.

e. Defuzzification of Calculation Results

Defuzzification is the process of converting fuzzy output into a single-valued output. Several defuzzification methods exist, but the Centroid Method is commonly used. This method calculates a single output value by finding the center of gravity (CoG) of the membership function for fuzzy values.

f. Implementation

The model design was implemented in the form of computer programs using MATLAB for calculations and Delphi as the user interface software.

g. Model Verification and Validation

The verification process was conducted using actual data to determine whether the model is feasible for use and meets the established criteria. According to Sargent (1998), the type of programming language employed significantly influences the correctness of the resulting program. Verification was carried out by inputting secondary data obtained from the bioethanol industry located at PG Jatitujuh, Majalengka. Model validation is the process of testing the substance of the model to ensure that the computer-generated model falls within an acceptable range of accuracy and is consistent with the objectives of its application. As Sargent (1998) noted, the attributes used in the validation process are heavily influenced by the conditions of the system being modeled—whether it is an observable system or a non-observable system. Observable systems allow the collection of real-world operational behavior data for analysis, while non-observable systems do not.

The validation of the fuzzy investment model's accuracy was conducted using the Comparison to Other Models technique. This method compares the outputs of the model being validated with the outputs of other validated models, ensuring the reliability and validity of the fuzzy financial investment model.

RESULT

Fuzzy Financial Model Calculation

The fuzzy criteria for feasibility assessment are presented in Table 1 (Martini et al., 2010).

Table 1. Fuzzy criteria for feasibility assessment.

Criteria	Not Feasible	Moderately Feasible	Feasible	Highly Feasible
NPV	< 0	0 < NPV ≤ 10% x investasi	8% x investasi < NPV ≤ 17% x investasi	NPV > 15% x investasi
IRR	< r	r ≤ IRR ≤ 6% + r	4% + r < IRR ≤ 15% + r	IRR ≥ r + 12
B/C R	< 1	1 < B/C ≤ 1,3	1,25 < B/C ≤ 1,75	B/C > 1,6

Fuzzy NPV Calculation

The calculation in the financial feasibility model is based on cash flow, which is derived from the difference between total cash inflows and total cash outflows. The cash flow is then fuzzified using the Triangular Fuzzy Number (TFN) membership function. The fuzzification of cash flow is done using low, medium, and high ranges. The fuzzified cash flow results are presented in Table 2, while the interest rate used for the NPV calculation is classified into low, medium, and high ranges, which are also presented in Table 3.

Table 2. ***Fuzzified Cash Flow (in billion IDR)***

Period	Low	Medium	High
0	-83,46	-79,46	-75,46
1	1,41	5,41	9,41
2	4,49	8,49	12,49
3	7,6	11,6	15,6
4	31,57	35,57	39,57
5	70,93	74,93	78,93
6	101,9	105,9	109,9
7	97,78	101,78	105,78
8	153,42	157,42	161,42
9	102,91	106,91	110,91
10	61,21	65,21	69,21
11	57,36	61,36	65,36
12	57,36	61,36	65,36

Table 3. Interest Rate with Low, Medium, & High Ranges

Period	Low	Medium	High
1	0,02	0,05	0,08
2	0,02	0,06	0,10
3	0,02	0,07	0,11
4	0,02	0,08	0,12
5	0,02	0,07	0,12
6	0,02	0,06	0,11
7	0,02	0,08	0,13
8	0,02	0,09	0,14
9	0,02	0,05	0,10
10	0,02	0,09	0,13
11	0,02	0,08	0,13
12	0,02	0,06	0,12

To calculate the fuzzy Net Present Value (NPV) using the provided data, we use the following formula:

$$PV_i = \begin{bmatrix} \sum_{t=0}^{ni}\left(\frac{max\{f_{t0},0\}}{\coprod_{x=0}^{t}(1+r_{x2})} + \frac{min\{f_{t0},0\}}{\prod_{x=0}^{t}(1+r_{x0})}\right), \\ \sum_{t=0}^{ni}\left(\frac{f_{t1}}{\prod_{x=0}^{t}(1+r_{x1})}\right), \\ \sum_{t=0}^{ni}\left(\frac{max\{f_{t2},0\}}{\coprod_{x=0}^{t}(1+r_{x0})} + \frac{min\{f_{t2},0\}}{\prod_{x=0}^{t}(1+r_{x2})}\right) \end{bmatrix}$$

To classify the *Present Value* (*PV*) in fuzzy form, each *PV* value is represented as a triangular fuzzy number (TFN). For each period *t*, the fuzzy present value *PVt* can be defined in terms of three parameters: a_t, b_t, and c_t, where:

- a_t is the lower bound of the triangular fuzzy number (the minimum possible value),
- b_t is the most likely or central value of the fuzzy number,
- c_t is the upper bound of the triangular fuzzy number (the maximum possible value).

Thus, for each fuzzy present value PVi, where i=1,2,3, we have:

$$PV_1 = (a1, b1, c1)$$
$$PV_2 = (a2, b2, c2)$$
$$PV_3 = (a3, b3, c3)$$

Where:

- PV_1 represents the fuzzy present value calculated using the lowest estimates of cash flow and the discount rate,
- PV_2 represents the fuzzy present value calculated using medium estimates of cash flow and the discount rate,
- PV_3 represents the fuzzy present value calculated using the highest estimates of cash flow and the discount rate.

In this classification, each PVi reflects a different scenario based on varying assumptions about the cash flow and the discount rate. After calculating the fuzzy PV for each scenario, the next step would involve defuzzification to obtain a crisp value for decision-making purposes.

$$PV_1 = \begin{bmatrix} \left(-83{,}46 + \frac{1{,}41}{1{,}08} + \frac{4{,}49}{(1{,}08)(1{,}10)} + \frac{7{,}6}{(1{,}08)(1{,}10)(1{,}11)} + \frac{31{,}57}{(1{,}08)(1{,}10)(1{,}11)(1{,}12)} \right), \\ \left(-79{,}46 + \frac{5{,}41}{1{,}05} + \frac{8{,}49}{(1{,}05)(1{,}06)} + \frac{11{,}6}{(1{,}05)(1{,}06)(1{,}07)} + \frac{35{,}57}{(1{,}05)(1{,}06)(1{,}07)(1{,}08)} \right), \\ \left(-75{,}46 + \frac{9{,}41}{1{,}02} + \frac{12{,}49}{(1{,}02)(1{,}02)} + \frac{15{,}6}{(1{,}02)(1{,}02)(1{,}02)} + \frac{39{,}57}{(1{,}02)(1{,}02)(1{,}02)(1{,}02)} \right) \end{bmatrix}$$

$$PV_1 = \begin{bmatrix} (-83{,}46 + 1{,}3 + 3{,}78 + 5{,}76 + 21{,}37), \\ (-79{,}46 + 5{,}15 + 7{,}63 + 9{,}74 + 27{,}65), \\ (-75{,}46 + 9{,}22 + 12 + 14{,}7 + 36{,}56) \end{bmatrix}$$

$$PV_1 = \begin{bmatrix} (-51{,}25), \\ (-29{,}29), \\ (-2{,}98) \end{bmatrix}$$

With the cash flow and interest rate data above, the values obtained for n=4 are:
a1 = -51,25 billion
b1 = -29,29 billion
c1 = -2,98 billion
These represent the fuzzy present value PV_1 for the fourth period, where the values correspond to the lower, most likely, and upper bounds of the fuzzy number, respectively.

$$PV_2 = \begin{bmatrix} \left(\begin{array}{c} -83{,}46 + \frac{1{,}41}{1{,}08} + \frac{4{,}49}{(1{,}08)(1{,}10)} + \frac{7{,}6}{(1{,}08)(1{,}10)(1{,}11)} \\ + \frac{31{,}57}{(1{,}08)(1{,}10)(1{,}11)(1{,}12)} + \frac{70{,}93}{(1{,}08)(1{,}10)(1{,}11)(1{,}12)(1{,}12)} \end{array} \right), \\ \left(\begin{array}{c} -79{,}46 + \frac{5{,}41}{1{,}05} + \frac{8{,}49}{(1{,}05)(1{,}06)} + \frac{11{,}6}{(1{,}05)(1{,}06)(1{,}07)} \\ + \frac{35{,}57}{(1{,}05)(1{,}06)(1{,}07)(1{,}08)} + \frac{74{,}93}{(1{,}05)(1{,}06)(1{,}07)(1{,}08)(1{,}07)} \end{array} \right), \\ \left(\begin{array}{c} -75{,}46 + \frac{9{,}41}{1{,}02} + \frac{12{,}49}{(1{,}02)(1{,}02)} + \frac{15{,}6}{(1{,}02)(1{,}02)(1{,}02)} \\ + \frac{39{,}57}{(1{,}02)(1{,}02)(1{,}02)(1{,}02)} + \frac{78{,}93}{(1{,}02)(1{,}02)(1{,}02)(1{,}02)(1{,}02)} \end{array} \right) \end{bmatrix}$$

$$PV_2 = \begin{bmatrix} \left(-51{,}25 + \frac{70{,}93}{(1{,}08)(1{,}10)(1{,}11)(1{,}12)(1{,}12)} \right), \\ \left(-29{,}29 + \frac{74{,}93}{(1{,}05)(1{,}06)(1{,}07)(1{,}08)(1{,}07)} \right), \\ \left(-2{,}98 + \frac{78{,}93}{(1{,}02)(1{,}02)(1{,}02)(1{,}02)(1{,}02)} \right) \end{bmatrix}$$

$$PV_2 = \begin{bmatrix} (-51{,}25 + 42{,}88), \\ (-29{,}29 + 54{,}45), \\ (-2{,}98 + 71{,}49) \end{bmatrix}$$

$$PV_2 = \begin{bmatrix} (-8{,}37), \\ (25{,}16), \\ (68{,}51) \end{bmatrix}$$

For n = 5, the values obtained are:
a2 = -8,37 billion
b2 = 25,16 billion
c2 = 68,51 billion
These represent the fuzzy present value PV_2 for the fifth period, where the values correspond to the lower, most likely, and upper bounds of the fuzzy number, respectively.

$$PV_3 = \begin{bmatrix} \left(-8{,}37 + \frac{101{,}9}{(1{,}08)(1{,}10)(1{,}11)(1{,}12)(1{,}12)(1{,}11)} \right), \\ \left(25{,}16 + \frac{105{,}9}{(1{,}05)(1{,}06)(1{,}07)(1{,}08)(1{,}07)(1{,}06)} \right), \\ \left(68{,}51 + \frac{109{,}9}{(1{,}02)(1{,}02)(1{,}02)(1{,}02)(1{,}02)(1{,}02)} \right) \end{bmatrix}$$

$$PV_3 = \begin{bmatrix} (-8{,}37 + 55{,}5), \\ (-25{,}16 + 72{,}59), \\ (-68{,}51 + 97{,}6) \end{bmatrix}$$

$$PV_3 = \begin{bmatrix} (47{,}13), \\ (47{,}43), \\ (29{,}09) \end{bmatrix}$$

For n = 6, the values obtained are:
a3 = 47,13 billion
b3 = 47,43 billion
c3 = 29,09 billion
These values represent the fuzzy present value PV_3 for the sixth period, with the lower, most likely, and upper bounds of the fuzzy number, respectively.
From the values of a, b, and c obtained for each n, the Net Present Value (NPV) can be determined using the following equation (Omitaomu and Badiru, 2007):

$$NPV = \frac{a + 4b + c}{6}$$

NPV for n = 4

$$NPV = \frac{-51{,}25 + 4(-29{,}29) - 2{,}98}{6}$$

$$NPV = \frac{-54{,}23 - 117{,}16}{6}$$

$$NPV = -28{,}565\ milyar$$

NPV for n = 5

$$NPV = \frac{-8{,}37 + 4(25{,}16) + 68{,}51}{6}$$

$$NPV = \frac{60{,}14 + 100{,}64}{6}$$

$$NPV = 26{,}8\ milyar$$

NPV for n = 6

$$NPV = \frac{47{,}13 + 4(47{,}43) + 29{,}09}{6}$$

$$NPV = \frac{76{,}22 + 100{,}64}{6}$$

$$NPV = 44{,}32\ milyar$$

The resulting NPV is then summed up, yielding a fuzzy NPV of 42.55 billion. Since the obtained fuzzy NPV is positive (NPV>0), the SPAM Katulampa project is deemed feasible to proceed.

B/C Ratio Fuzzy

Another investment criterion is the Benefit/Cost (B/C) Ratio. This criterion compares the benefits obtained from the project to the costs of the project. It represents the difference between the present value of revenues and the present value of costs. In this study, the fuzzy B/C Ratio calculation is performed using the model developed by Kahraman (2001), which has been applied to the manufacturing industry.
The B/C ratio is calculated using low, medium, and high interest rates, resulting in three B/C ratios (low, medium, and high).
If t = 1, the B/C Ratio is calculated as follows:

$$B\ /\ C = \frac{\sum_{t=0}^{n} B_t (1 + r)^{-t}}{\sum_{t=0}^{n} C_t (1 + r)^{-t}}$$

$$B\ /\ C = \frac{19{,}75(1 + 0{,}02)}{79{,}46(1 + 0{,}08)}, \frac{19{,}75(1 + 0{,}02)}{79{,}46(1 + 0{,}02)}, \frac{19{,}75(1 + 0{,}08)}{79{,}46(1 + 0{,}02)}$$

$$B\ /\ C = 0{,}23; 0{,}25; 0{,}26$$

From the above calculations, the resulting B/C ratios are 0.26 (high), 0.25 (medium), and 0.23 (low). Next, to obtain the single value, the following calculation is performed:

$$\frac{0{,}23 + 2(0{,}25) + 0{,}26}{4} = 0{,}25$$

The B/C Ratio obtained using the fuzzy method for the SPAM Katulampa project is 0.25. This criterion indicates that the SPAM Katulampa project is not feasible to proceed with because the B/C Ratio is less than 1.

IRR Fuzzy

Internal Rate of Return (IRR) is the rate of return that makes the NPV of the cash inflows equal to the NPV of the cash outflows. A project is considered feasible for implementation if the IRR is greater than the required rate of return, typically based on the bank's interest rate.
The fuzzy IRR is calculated from the net cash flow. The net cash flows are classified into low, medium, and high ranges, as shown in

Table 11. Based on these cash flows, the IRR is calculated as follows:

$$IRR = i_{(+)} + \frac{NPV_{(+)}}{NPV_{(+)} - NPV_{(-)}}\left(i_{(-)} - i_{(+)}\right)$$

$$IRR = 0{,}07 + \frac{26{,}8}{26{,}8 - (-28{,}565)}(0{,}08 - 0{,}07)$$

$$IRR = 0{,}07 + \frac{26{,}8}{55{,}365}(0{,}08 - 0{,}07)$$

$$IRR = 0{,}118$$

$$IRR = 11{,}8\%$$

The fuzzy IRR calculated from the above formula is 11.8% (IRR > r). This result indicates that the SPAM Katulampa project is feasible to continue.

DISCUSSION

The findings of this study demonstrate that the fuzzy financial analysis method effectively evaluates the feasibility of the SPAM Katulampa project. Based on the NPV, IRR, and B/C ratio calculated using the fuzzy methodology, the project is deemed viable for continuation. For instance, the NPV value of 42.55 billion (NPV > 0) supports the financial feasibility of the project, corroborating previous findings by Martini et al. (2010) on the applicability of fuzzy investment models in similar contexts. The B/C ratio obtained through fuzzy calculations was 0.25, indicating that the project is not feasible based on this specific criterion, as it is less than 1. This finding aligns with Kahraman (2001), who emphasizes that B/C ratios in manufacturing and infrastructure projects should exceed the unity threshold to be deemed acceptable. It reflects that while cash inflows are positive, they are not sufficient to offset the costs at a satisfactory level.

The fuzzy IRR calculated at 11.8% (IRR > r) provides further support for the project's feasibility. This result suggests that the expected return exceeds the required discount rate, consistent with Chiu and Park's (1994) findings that fuzzy cash flow analysis often yields accurate insights into project viability. It emphasizes the significance of incorporating variability and uncertainty in financial modeling.

This study also highlights the value of using fuzzy set theory to address uncertainties in cash flow and discount rate projections. As Buckley (1987) noted, the incorporation of triangular fuzzy numbers (TFN) enables more realistic modeling by considering the ranges of variables rather than fixed values, thus improving decision-making reliability. This is particularly relevant for infrastructure projects with significant financial risks.

Finally, the validation and verification process using actual data from the PG Jatitujuh bioethanol industry reinforce the credibility of the fuzzy financial analysis model. The approach aligns with Sargent's (1998) validation principles, which stress the importance of comparing outputs with established models and real-world data to ensure accuracy. Future applications of this method could further enhance its robustness in diverse project types.

CONCLUSION

The analysis using fuzzy NPV, IRR, and B/C Ratio confirms that the SPAM Katulampa project is financially feasible and suitable for implementation. This demonstrates the effectiveness of fuzzy methodologies in handling uncertainty in financial decision-making.

SUGGESTION

Further studies should focus on optimizing financial strategies to enhance the SPAM Katulampa project's economic viability.

The fuzzy approach utilized in this research should be expanded to evaluate other projects, offering a practical framework for managing uncertainty.

Declaration by Authors

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