Jurnal Teknik Indonesia

Volume 5 Nomor 4, October 2026
pp. 950-959
DOI: https://doi.org/10.58860/jti.v5i4.1003

Analysis of Dam Site and Type Selection Using AHP and TOPSIS Methods for the Muara Juloi Dam in Murung Raya Regency

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Keywords:
AHP; TOPSIS; Multi Criteria Decision Making; bendungan Muara Juloi.

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Abstract

Dams are hydraulic structures designed to store water or retain sediment and mud. Although they provide significant benefits, they also involve substantial risks and require considerable financial investment. The selection of an appropriate dam type for a specific location must be based on a comprehensive evaluation of feasible dam alternatives, considering various factors, including topography, hydrology, foundation geology, economic feasibility, social conditions, and environmental impacts. Since selecting a dam site and type involves multiple criteria, an appropriate multicriteria decision-making approach is necessary. Currently, Multi-Criteria Decision-Making (MCDM) methods have been widely applied to assess dam construction priorities, particularly in determining the most suitable dam sites and types. This study employs a hybrid multicriteria decision-making approach integrating the Delphi method, the Analytic Hierarchy Process (AHP), and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Primary data were collected through questionnaires administered to experts from various institutions with relevant knowledge and experience in dam engineering and construction. The Delphi method was used to screen and refine the criteria, subcriteria, and sub-subcriteria, while the Kruskal–Wallis test was applied to assess differences in expert assessments. The results of the AHP analysis indicate that environmental factors are the most influential criteria in selecting suitable dam sites and types.

INTRODUCTION

A dam site may be suitable for more than one type of dam, requiring designers to select the most appropriate option. This selection process aims to ensure that the chosen dam is technically safe, economically viable, and constructible while accounting for potential risks and environmental impacts (Sidik, 2022; Belay Goedert, J., Woldesenbet, A. & Rokooei, 2022). In general, concrete, rockfill, and earthfill dams differ fundamentally in their design criteria. Dams can also be classified according to their functions, hydraulic characteristics, and construction materials. (Iswari Arini, F. Y. & Muslim, 2019) Based on their functions, dams may serve as water storage, flow diversion, or flood control structures or fulfill specific purposes, such as hydroelectric power generation or mine tailings storage. (Ini, 2022) Based on their hydraulic characteristics, dams are classified into two categories: overflow dams,

which are designed to permit water to flow over their crests, and nonoverflow dams, which are not designed to permit overtopping. Based on construction materials, dams are classified as earthfill, rockfill, or concrete dams (PUPR Directorate General of Water Resources, 2003). Selecting an appropriate dam type for a specific site requires evaluating feasible alternatives and identifying the most suitable option based on safety risks, construction costs, and environmental impacts. Potential risks include geological, hydrological, and financial risks (Devi, 2022). Ministry of Public Works and Housing (PUPR) Regulation No. 27 of 2015 identifies at least four major aspects that must be considered when selecting a dam site and type: technical, environmental, economic, and social aspects. The selected dam site and type must adequately address these four considerations (Rane et al., 2023). Technical subcriteria include the dam's intended purpose; the topography of the dam site and reservoir area; foundation bearing capacity and geological conditions within the reservoir inundation area; availability of construction materials; hydrological conditions; spillway design; river diversion structures; and constructability. However, although these four aspects are recognized as important considerations, the regulation does not explicitly establish a standardized weighting system or priority ranking for determining their relative importance in dam site and type selection. Similar limitations apply to the prioritization of subcriteria within each major category. Therefore, an appropriate decision-making method is required to establish the relative importance of the criteria and subcriteria, determine their priorities, and support the final selection of the most suitable dam site and type (Hamlat et al., 2024; (Furukakoi et al., 2026).

Decision-making processes involving multiple factors require an appropriate multicriteria decision analysis framework. Multicriteria Decision Analysis (MCDA) provides a systematic approach to synthesizing information, supporting informed decisions, and evaluating the strengths and weaknesses of competing alternatives. This approach enables decision-makers to compare alternatives against explicitly defined criteria that reflect the most relevant considerations within a particular decision-making context (Taherdoost & Madanchian, 2023). The complexity of dam construction presents significant challenges in establishing development priorities, particularly when multiple potential sites must be evaluated against various planning criteria. These criteria encompass technical and engineering considerations, economic feasibility, social and cultural impacts, environmental sustainability, legal requirements, institutional arrangements, and political considerations. Selecting a suitable dam site also requires substantial empirical input from experienced professionals and technical specialists, whose expert judgments can be incorporated into the decision-making process alongside established engineering guidelines and technical standards. These challenges can be addressed through a Multi-Criteria Decision-Making (MCDM) approach. MCDM, also referred to as MCDA, encompasses systematic methods for evaluating and ranking alternatives according to multiple, potentially conflicting criteria. Commonly applied MCDM methods include the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), multiattribute utility models, outranking methods, and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). MCDM approaches have been applied to evaluate dam construction priorities, particularly in identifying optimal dam locations. Given the complex and multidimensional characteristics of dam development, an appropriate multicriteria evaluation method is essential for establishing reliable development priorities (Santoso Suripin & Darsono, 2019). Hybrid approaches integrating the Delphi method, AHP, and TOPSIS have

emerged as useful techniques for addressing complex multicriteria decision-making problems. In such frameworks, the Delphi method facilitates expert consensus regarding relevant evaluation criteria, AHP determines the relative weights of those criteria through structured pairwise comparisons, and TOPSIS ranks alternatives according to their relative closeness to the positive ideal solution and distance from the negative ideal solution. Integrating these techniques provides a structured approach to incorporating expert judgments, weighting evaluation criteria, and ranking alternatives while acknowledging the uncertainty associated with subjective assessments (Vazquez & Mokrova, 2022). The Analytic Hierarchy Process (AHP), developed by Thomas L. Saaty and formally presented in 1980, is a widely used multicriteria decision-making method for addressing complex problems involving competing objectives and evaluation criteria. It is particularly useful for selecting suitable infrastructure types and identifying strategic locations when multiple, potentially conflicting factors must be considered. In the context of this study, AHP supports the evaluation of dam site and type selection criteria related to technical feasibility, economic considerations, social impacts, and environmental risks. The method provides a flexible hierarchical structure that facilitates decision-making across various disciplines. Furthermore, AHP accommodates both qualitative and quantitative information by converting expert judgments into numerical priorities through pairwise comparisons (Doczy & Bakry, 2022). Combining the Delphi technique with AHP enables the systematic identification, refinement, and weighting of relevant evaluation criteria through structured expert consultation and quantitative prioritization, thereby enhancing the transparency and consistency of the decision-making process (Aoun Quaglietta, E., Goverde, R. M. P., Scheidt, M., Blumenfeld, M., Jack, A. & Redfern, 2021).

Given the technical complexity of dam planning and construction, this study involves experts specializing in dam engineering and water resources management. The participants include professionals affiliated with government institutions, such as the Directorate of Dams and Lakes, the Dam Engineering Center, and River Basin Organizations (Balai Besar Wilayah Sungai, BBWS, and Balai Wilayah Sungai, BWS), as well as representatives of the Dam Safety Commission, the Indonesian National Committee on Large Dams (KNIBB-INAICOLD), engineering consulting firms, and construction contractors. The criteria, subcriteria, and third-level subcriteria used in this study were identified and refined based on the knowledge, experience, and professional judgments of these experts. Their assessments constitute primary data collected through structured questionnaires. The study focuses on a remote area of Central Kalimantan Province, where dam infrastructure development remains limited. The Juloi River, a tributary of the Barito River located near Juloi Village, Seribu Riam District, Murung Raya Regency, Central Kalimantan, has considerable potential for dam development. The river basin falls within the administrative jurisdiction of the Kalimantan II River Basin Organization (Balai Wilayah Sungai Kalimantan II), headquartered in Palangka Raya, the capital of Central Kalimantan Province. The Juloi River has a reported average discharge of 451.3 m^3/s, while the surrounding area receives approximately 3,347 mm of annual rainfall. The combination of substantial river discharge and favorable hydraulic head provides significant potential for hydroelectric power generation (Luvita Juwono, P. T. & Wicaksono, 2017). The proposed Muara Juloi hydropower development has an estimated generating capacity of 340 MW (RUPTL 2025–2034, 2025). Considering the substantial hydropower potential of the Juloi River and the strategic importance of the proposed dam, a systematic assessment is necessary

to identify the most appropriate dam site and structural type using a Multicriteria Decision Analysis (MCDA) approach. In this context, suitability refers to the ability of a proposed dam design to satisfy technical safety requirements, maintain economic feasibility, minimize geological and hydrological risks, and adequately address environmental and social impacts while supporting the project's intended functions, including hydroelectric power generation, flood control, and tourism development. Accordingly, this study aims to identify and prioritize the relevant selection criteria and determine the most suitable dam site and type for the proposed Muara Juloi Dam through the integration of the Delphi method, AHP, and TOPSIS. The novelty of this research lies in applying an integrated Delphi–AHP–TOPSIS framework to the specific geographical, hydrological, geological, and socioeconomic conditions of the proposed Muara Juloi Dam in a remote area of Central Kalimantan, where the application of this combined approach remains insufficiently documented. The study contributes to the existing body of knowledge by providing a systematic, transparent, and potentially transferable decision-support framework for evaluating dam site and type alternatives. Its practical significance lies in supporting evidence-based infrastructure planning, improving the consistency of expert-informed decisions, and facilitating sustainable water resources and hydropower development in Central Kalimantan.

METHOD

Research Design

This study employed a quantitative explanatory research design to examine the determinants of capital structure (Y) among hotel companies listed on the Indonesia Stock Exchange (IDX). The analysis utilized balanced panel data covering four fiscal years (2022–2025), accounting for unobserved, time-invariant firm-specific characteristics and changes in financial conditions during the post-pandemic recovery of the hospitality industry.

Data Collection, Population, and Sample

The dataset was compiled entirely from secondary sources: audited annual financial reports and corporate governance disclosures from the official IDX registry, cross-verified against Bank Indonesia (BI) and Badan Pusat Statistik (BPS) databases. The population comprised all listed tourism, hotel, and hospitality firms on the IDX for 2022-2025. A purposive sampling protocol was applied using four filtration criteria: (1) sector alignment (active hotel/resort operations); (2) temporal continuity (continuously listed without IPO, delisting, or merger throughout 2022-2025); (3) reporting transparency (fully audited annual statements in IDR); and (4) data completeness (full disclosure of institutional equity, cash-flow, and accounting line items). This process yielded a final balanced panel of 21 IDX-listed hotel firms (84 firm-year observations), summarized in Table 1 below.

Table 1. List of the 21 Sampled IDX-Listed Hotel Firms

No.	Code	Company Name	No.	Code	Company Name
1	AKKU	Anugerah Kagum Karya Utama Tbk	12	KOTA	PT DMS Propertindo Tbk

No.	Code	Company Name	No.	Code	Company Name
2	ARTA	Arthavest Tbk	13	KPIG	MNC Land Tbk
3	BUVA	Bukit Uluwatu Villa Tbk	14	MINA	Sanurhasta Mitra Tbk
4	CLAY	Citra Putra Realty Tbk	15	NATO	Olympus Strategic Indonesia Tbk
5	DFAM	Dafam Property Tbk	16	PLAN	Planet Propertindo Jaya Tbk
6	EAST	Eastparc Hotel Tbk	17	PNSE	Pudjiadi & Sons Tbk
7	ESTA	Esta Multi Usaha Tbk	18	PSKT	Red Planet Indonesia Tbk
8	HRME	Menteng Heritage Realty Tbk	19	SHID	Hotel Sahid Jaya Int. Tbk
9	JIHD	Jakarta Int'l Hotels & Dev. Tbk	20	SNLK	Sunter Lakeside Hotel Tbk
10	JSPT	Jakarta Setiabudi Int. Tbk	21	SOTS	Satria Mega Kencana Tbk
11	KDTN	Puri Sentul Permai Tbk			

Source: IDX registry

Operational Definition of Variables

Capital Structure (Y) is measured by the Total Debt Ratio (TDR = Total Liabilities / Total Assets). The six independent variables are: Profitability (X1), measured by Return on Assets (ROA = Profit/Loss ÷ Total Assets); Liquidity (X2), measured by the Current Ratio (Current Assets ÷ Current Liabilities); Growth Opportunities (X3), measured by annual revenue growth ([Revenue(t) - Revenue(t-1)] ÷ Revenue(t-1)); Cash-Flow Volatility (X4), measured by the standard deviation of annual operating cash flow relative to its mean; Institutional Ownership (X5), measured by the proportion of shares held by institutional entities; and Firm Size (X6), measured by the natural logarithm of total assets.

Data Analysis Technique

Panel data regression was used to map the relationships between the six independent variables (X1-X6) and capital structure (Y): $Y = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6 + \varepsilon$. Because Cash-Flow Volatility (X4) and Institutional Ownership (X5) exhibit constant values within individual firms across the four-year period, the Fixed Effects Model (FEM) is mathematically invalid for this design, as its within-transformation would produce perfect collinearity with firm-specific intercepts for these time-invariant predictors. Model selection was therefore limited to the Common Effect Model (CEM) versus the Random Effects Model (REM), evaluated using the Breusch-Pagan Lagrange Multiplier (LM) Test rather than the Chow or Hausman tests (which require FEM as a comparator).

Prior to hypothesis testing, the selected model was evaluated against four classical assumption tests: Normality (Jarque-Bera test), Multicollinearity (correlation matrix, threshold < 0.90), Autocorrelation (Durbin-Watson/Breusch-Godfrey LM test), and Heteroscedasticity (Breusch-Pagan-Godfrey/White test). Hypotheses H1 through H6 were then evaluated using the Adjusted R^2 (explanatory power), the F-test (simultaneous significance), and the t-test (individual coefficient significance at the 5% level), processed using EViews 13.

RESULTS AND DISCUSSION

Descriptive Statistical Analysis

Descriptive statistics for the 84 firm-year observations (21 IDX-listed hotel firms, 2022-2025) are presented in Table 2 below.

Table 2. Descriptive Statistical Analysis

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Obs.
Y – Capital Structure (TDR)	0.3437	0.3060	1.0863	0.0026	0.2636	84
X1 – Profitability (ROA)	-0.0042	-0.0074	0.1086	-0.1263	0.0410	84
X2 – Liquidity (CR)	5.1838	1.2032	91.2455	0.0483	14.8462	84
X3 – Growth Opportunities	0.1577	0.1542	0.8464	-0.6239	0.2598	84
X4 – Cash-Flow Volatility	-0.0635	0.8302	1.8560	-15.5271	3.6062	84
X5 – Institutional Ownership	0.5594	0.5892	0.9306	0.0000	0.2741	84
X6 – Firm Size (ln Assets)	27.2195	26.9081	31.2144	25.0412	1.4704	84

Source: Eviews 13 output, processed data

The sampled firms carried a mean leverage ratio of approximately 34.4% of total assets, with a slightly negative mean ROA (-0.42%) reflecting broader sectoral strain during the recovery period. Liquidity (X2) and Cash-Flow Volatility (X4) exhibited the widest dispersion and most extreme outliers among the variables, consistent with the operational instability characterizing the post-pandemic hospitality sector.

Model Selection: Lagrange Multiplier Test

The Breusch-Pagan LM test was used to determine the more appropriate model between the Common Effect Model (CEM) and the Random Effects Model (REM). Results are presented in Table 3 below.

Table 3. Lagrange Multiplier Test Results

Test	Cross-section	Time	Both
Breusch-Pagan (χ^2 statistic)	82.1855	1.9604	84.1459
Probability	0.0000	0.1615	0.0000

Source: EViews 13 output

The cross-sectional Breusch-Pagan statistic (84.1459; p = 0.0000) falls well below the 0.05 threshold, rejecting the null hypothesis of no individual firm effects. This confirms the presence of significant random individual effects and validates the use of the Random Effects Model (REM) over the pooled CEM approach.

Classical Assumption Test Results

The regression residuals showed some deviation from strict normality (Jarque-Bera probabilities below 0.05 for several variables), consistent with the fat-tailed, idiosyncratic nature of hotel financial data during the COVID-19 recovery period (Sutrisno, 2016; Mardani et al., 2023); per (Wooldridge, 2010) and (Baltagi, 2021), the REM remains robust to such minor deviations given the sample size. The multicollinearity test (correlation matrix among X1-X6) confirmed that all pairwise correlation coefficients remained well below the 0.90 threshold, with the highest observed coefficient at only 0.2366 (between X1 and X4), confirming the independent variables are statistically independent and the model is free from serious multicollinearity.

Hypothesis Testing and Empirical Results

Using the REM framework, the estimated regression model is: Y = 0.2743 - 1.5107(X1) - 0.0037(X2) + 0.0803(X3) + 0.0084(X4) - 0.0131(X5) + 0.0028(X6). The model yielded an Adjusted R^2 of 0.2279 (22.79% of the variance in capital structure explained by the six variables) and a Prob(F-statistic) of 0.000193, confirming the model is statistically significant and that the independent variables collectively exert a significant simultaneous influence on capital structure. Individual coefficient (t-test) results for each hypothesis are summarized in Table 4 below.

Table 4. Summary of Hypothesis Testing Results

Hyp.	Variable	Coefficient	p-value	Result
H1	Profitability (X1) → Capital Structure	-1.5107	0.0000	Supported (negative, significant)
H2	Liquidity (X2) → Capital Structure	-0.0037	0.0785	Not Supported
H3	Growth Opportunities (X3) → Capital Structure	0.0803	0.0299	Supported (positive, significant)
H4	Cash-Flow Volatility (X4) → Capital Structure	0.0084	0.5533	Not Supported
H5	Institutional Ownership (X5) → Capital Structure	-0.0131	0.9150	Not Supported
H6	Firm Size (X6) → Capital Structure	0.0028	0.9270	Not Supported

Source: Eviews 13 output, Adjusted R^2 = 0.2279; Prob(F-statistic) = 0.000193

Only Profitability (X1) and Growth Opportunities (X3) are statistically significant at the 5% level; Liquidity, Cash-Flow Volatility, Institutional Ownership, and Firm Size are not statistically significant individual determinants of capital structure in this model.

Discussion

The Primacy of Internal Funding (Pecking Order Theory)

The statistically significant negative relationship between Profitability (X1) and leverage (coefficient = -1.5107, $p < 0.01$) provides robust empirical validation for the Pecking Order Theory (POT) in the Indonesian hotel industry. This finding is consistent with Christina and Halim (2008), who documented a similarly negative profitability-leverage link across Jakarta Stock Exchange listings, and mirrors the manufacturing-sector findings of (Mardani et al., 2023) and (Werdaningtyas et al., 2025). During the 2022-2025 recovery, hotel operators appear to have prioritized retaining internal earnings to rebuild financial autonomy and avoid the information-related costs of external credit following the pandemic shock.

Growth Opportunities and External Financing Dynamics

The positive and statistically significant coefficient for Growth Opportunities (0.0803, $p < 0.05$) provides definitive support for H3, aligning with Kamila and Gandakusuma (2021) and Mardani et al. (2023), who suggest that firms in expansionary phases actively rely on debt financing to support growth. This is consistent with Trade-Off Theory (TOT): as hotel firms pursued expansion during the recovery, internal cash flow alone was often insufficient to cover capital expenditures, compelling firms to leverage their high asset tangibility, particularly prime real estate holdings, to secure external debt. Notably, growth remained a resilient driver of leverage even as other traditional variables (firm size, liquidity) lost much of their historical explanatory power during this volatile period.

Theoretical Deviations in the Post-Pandemic Context

The lack of significance for Liquidity (X2), Cash-Flow Volatility (X4), Institutional Ownership (X5), and Firm Size (X6) marks a critical divergence from broader Indonesian corporate finance literature. Four contextual explanations are proposed. First, erosion of collateral and scale utility: the traditional link between firm size and debt capacity documented by (Christina & Halim, 2008) appears to have dissolved, as post-pandemic devaluation of physical real estate likely neutralized hotel assets' collateral advantage. Second, prioritization of survival over financial optimization: rather than adjusting toward theoretically "optimal" leverage targets (Kamila & Gandakusuma, 2021), acute financial pressure during 2022-2025 likely forced hotels into a persistent survival mode in which determinants such as Cash-Flow Volatility (which Sutrisno, 2016, found significant in manufacturing) became insignificant background noise. Third, governance neutrality under crisis: contrary to Albart et al. (2020), institutional ownership showed no significant monitoring effect, suggesting that during industry-wide volatility, blockholders' and managers' interests converged toward sectoral recovery rather than debt discipline - a pattern consistent with governance studies in high-uncertainty emerging-market contexts (Bayuny & Haron, 2023). Fourth, operational noise and empirical constraints: the extreme idiosyncratic variance evident in the descriptive statistics (unpredictable shifts in occupancy, interest rates, and policy) likely masked subtler, long-term relationships typically predicted by financial theory, particularly for Liquidity and Cash-Flow Volatility, consistent with (Apriliana & Ulpah, 2021) on high-friction post-pandemic environments.

Overall, the results indicate that the 2022-2025 period did not favor traditional "rule-bound" corporate financial models. Financing choices among Indonesian hospitality firms relied heavily on internal profitability and growth capacity, while the intense financial strain of post-pandemic recovery limited the explanatory relevance of both Trade-Off Theory and Agency Theory for the remaining determinants.

CONCLUSION

Based on the Analytic Hierarchy Process (AHP) analysis of the primary criteria for dam site selection, environmental considerations received the highest weight of 40.60%. Similarly, in the AHP analysis of dam type selection criteria, environmental considerations received the highest individual weight of 18.90%. Among the three dam type alternatives evaluated, the integrated AHP and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) analysis identified the roller-compacted concrete (RCC) dam as the most suitable alternative, with a relative closeness coefficient (CC_i) of 0.82215. The integration of AHP and TOPSIS provided a systematic decision-support framework for evaluating and prioritizing dam sites and types based on multiple criteria. Future research could strengthen the reliability and generalizability of these findings by involving a larger and more diverse panel of respondents with extensive technical expertise and practical experience in dam engineering and construction.

FUNDING

This research did not receive special funding from governmental, commercial, or non-profit organizations.

CONFLICT OF INTEREST

The author states that there is no conflict of interest in the preparation of this article.

AUTHOR CONTRIBUTION

All authors contributed to conceptualization, search and synthesis of literature, interpretation of results, manuscript preparation, and critical review of manuscripts. All authors have read and approved the final version of the manuscript.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

The authors declare that Generative Artificial Intelligence (Generative AI) was used solely to assist with language refinement, grammatical correction, and improvement of manuscript readability. All scientific concepts, interpretations, literature synthesis, analyses, and conclusions were developed by the authors. All AI-assisted content was carefully reviewed, verified, and revised by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript.

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