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Article

Evaluation Of Decision-Making Strategy For The Relocation Of National Strategic Energy Infrastructure Using The Analytic Hierarchy Process (AHP) And Technique For Order Preference By Similarity To Ideal Solution (TOPSIS).

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Abstract

The JKRT Fuel Terminal (TBBM) is the main supply point for fuel (BBM) and LPG in western Java and the Greater Jakarta (Jabodetabek) area, which makes it a strategic piece of national energy infrastructure. Operating it on the current site is becoming difficult: there is little room left to expand, the lack of an adequate buffer zone raises safety risks, and demand is expected to keep growing. Left unaddressed, these constraints could translate into lost revenue and missed opportunity, so the terminal's development options deserve a structured evaluation. This study examines three of them: keeping the existing site with only a minimal re-layout, combining it with a facility in Northwest Cikarang (CBL), or combining it with one at Muara Cisadane. The evaluation pairs two well-established decision methods. AHP (Analytic Hierarchy Process) sets the relative importance of each criterion, and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) ranks the alternatives against those weights. Four criteria frame the assessment: Safety and Asset Integrity, Operational Supply, Operational Distribution, and Investment Efficiency and Economics. Judgments came from six experts inside and outside the organization, collected through questionnaires and combined using the geometric mean. Under AHP, Safety and Asset Integrity dominated at 54.9%, well ahead of Investment Efficiency and Economics (23.8%), Operational Supply (12.7%), and Operational Distribution (8.5%). Carrying these weights into TOPSIS, the JKRT + CBL combination ranked first with a closeness coefficient (CCi) of 0.750, ahead of JKRT + Muara Cisadane (0.681) and the existing terminal (0.115). Varying the weight of the dominant criterion by ±20% in a sensitivity test left the ranking intact, which points to a robust result. Taken together, the combined AHP–TOPSIS approach offers a systematic and traceable basis for comparing development options for national strategic energy infrastructure.

Keywords: Analytic Hierarchy Process; Energy Infrastructure; Relocation, Fuel Terminal, TOPSIS.

1. Introduction

National energy security rests heavily on how reliable the logistics chain for fuel (BBM) and LPG is: the storage terminals, jetties, pipeline networks, and distribution facilities that feed demand centers in metropolitan areas (IEA, 2023). This is why optimizing energy infrastructure sits squarely within the 2025–2029 National Medium-Term Development Plan (RPJMN) and Asta Cita 2, both of which treat energy self-sufficiency as a pillar of national independence.

Across western Java and the supporting areas around Greater Jakarta, TBBM JKRT is the main hub for moving BBM and LPG out to consumers.

It takes supply from the Balongan refinery by pipeline and tanker, then sends the products onward to depots and fuel stations through pipelines and road transport. The difficulty lies in its location. Sitting in a densely populated area, the terminal carries high safety risk and runs into problems with spatial-planning suitability and undersized buffer zones, none of which meets the requirements of Director General of Mineral and Coal Decree No. 309.K/30/DJB/2018 (Ministry of Energy and Mineral Resources, 2018).

The large-scale incident in 2023 made the case for action hard to ignore: high-risk facilities near residential areas, fuel terminals included, need to be made safer through HSSE measures or moved altogether under a deliberate relocation plan. At the same time, demand is climbing. Energy use in western Java is projected to rise about 2.8% a year through 2040 (BPPT, 2022), and at Tanjung Priok the tank and jetty capacity is already stretched, with an average Berth Occupancy Ratio (BOR) of 58% closing in on the Ministry of Transportation's 65% threshold.

Taken together, these constraints suggest that without upgrades and fresh investment the existing terminals in western Java will struggle to keep up with BBM/LPG demand, leaving potential revenue on the table. Deciding whether to relocate or to keep and optimize the current infrastructure therefore calls for an evaluation method that can weigh four dimensions at once, transparently and accountably: Safety & Asset Integrity, Operational Supply, Operational Distribution, and Investment Efficiency & Economics (Fairuz et al., 2023; Sun et al., 2025). Multi-criteria decision-making is not new to energy infrastructure planning.

Although multi-criteria decision-making (MCDM) approaches have been broadly applied in energy infrastructure planning, previous research has mainly concentrated on geological storage, upstream logistics facilities, hydrogen and CO_2 storage, as well as LNG terminal location selection. These studies offer valuable methodological foundations for dealing with complex decision-making problems, but they differ from the present study in terms of research focus, evaluation criteria, and operational setting. In particular, limited studies have specifically examined the relocation and development of fuel terminals located in densely populated urban areas. To address this gap, the present study reviews relevant prior research and positions its contribution, as summarized in Table 1.

Table 1. Comparison of Previous Studies and Research Gap

Study	Research Object	Method	Main Focus	Identified Gap
Fairuz et al. (2023)	Shore base location in upstream oil and gas	AHP	Selection of logistics facility location with HSE as the dominant criterion	Focused on upstream oil and gas logistics, not strategic fuel terminal relocation in a dense urban area
Harati et al. (2024)	Hydrogen storage sites in depleted gas fields	AHP–PROMETHEE	Geological storage site selection	Focused on hydrogen storage, not BBM/LPG terminal infrastructure
Xu et al. (2025)	CO_2 storage sites from Direct Air Capture technology	AHP–GIS	Spatial screening for CO_2 storage location	Focused on CO_2 storage and GIS-based screening, not operational fuel distribution infrastructure
Zhang et al. (2024)	Salt cavern oil storage	AHP	Suitability evaluation for oil storage in salt caverns	Focused on geological storage, not relocation of existing urban fuel terminal facilities
Sun et al. (2025)	CO_2 geological storage	Risk-based assessment framework	Long-term storage potential and site security	Did not address fuel terminal relocation, distribution continuity, and

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				investment efficiency
This study	TBBM JKRT development and relocation alternatives	Integrated AHP–TOPSIS	Multi-criteria evaluation of safety, supply, distribution, and investment efficiency	Integrates AHP weighting and TOPSIS ranking for strategic fuel terminal development in a densely populated area

As indicated in Table 1, AHP and other multi-criteria decision-making (MCDM) methods have been widely applied in energy-related site selection studies. Nevertheless, research focusing on the relocation or strategic development of existing fuel terminals located in densely populated areas remains limited. In addition, previous studies have not sufficiently combined safety aspects, asset integrity, supply reliability, distribution performance, and economic efficiency within an integrated AHP–TOPSIS framework designed specifically for BBM/LPG terminal infrastructure. In the context of TBBM JKRT, this issue is particularly important because the decision-making process must consider not only technical and economic factors, but also spatial planning restrictions, operational continuity, and national energy security.

This study addresses this gap by applying an integrated AHP–TOPSIS framework to assess strategic development alternatives for TBBM JKRT as a vital national energy infrastructure asset. Unlike earlier studies that mostly emphasize greenfield site selection, this research examines an existing infrastructure case with complex safety, operational, spatial, and investment constraints. The main contribution of this study is the formulation of a transparent and traceable decision-making framework that integrates expert-based criteria weighting through AHP with alternative ranking using TOPSIS. Accordingly, this study aims to: (1) evaluate three development alternatives for TBBM JKRT; (2) determine the most appropriate strategy based on safety, operational, and economic considerations; and (3) examine the robustness of the selected strategy through sensitivity analysis.

2. Material and Method

2.1. Study Location

Location Options

a. The existing TBBM JKRT, kept as the current terminal but with its layout reconfigured.
b. TBBM JKRT paired with Cikarang Barat Laut (CBL), which sits in the designated industrial area of Bekasi Regency.
c. TBBM JKRT paired with Muara Cisadane, in the designated industrial area of Tangerang Regency.

2.2. Evaluation Criteria and Subcriteria

The alternatives were judged against four main criteria, broken down into eight subcriteria. Safety & Asset Integrity covers compliance with regulations and spatial planning (buffer zones included) together with the reliability and integrity of the assets. Operational Supply looks at access to refinery and import supply and at the receiving capacity of the tanks and jetties. Operational Distribution concerns the distance to demand centers and, again, jetty and tank capacity. Investment Efficiency & Economics weighs economic feasibility against the goal of the lowest CAPEX.

2.3. Expert Judgment Data Collection

Data for the AHP analysis were obtained through expert-based assessment. The study involved six experts who were selected using purposive sampling, considering their relevant expertise and professional experience in fuel terminal operations, infrastructure investment, safety management, asset integrity, financial feasibility, and spatial planning. In the context of AHP, the reliability of judgment is more strongly influenced by the expertise and relevance of the respondents than by the number of participants. This is especially applicable to strategic and technical decision problems that require informed professional judgment. Therefore, the expert panel was arranged to reflect the main aspects of the evaluation framework, rather than to represent a general population.

The experts consisted of both internal and external professionals from various disciplines related to the assessment criteria. Their backgrounds included engineering and supply distribution, investment project supervision, oil and gas safety and asset integrity, business development and investment in the refinery and petrochemical sector, financial investment approval within an oil and gas holding company, and land control as well as spatial planning under the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN). The involvement of experts with these different areas of expertise was considered appropriate, as each participant contributed a specific perspective needed to evaluate the strategic alternatives for the relocation and development of TBBM JKRT.

The assessment process was carried out through pairwise comparisons based on Saaty's fundamental scale, ranging from 1 to 9. The individual responses were then integrated using the Aggregation of Individual Judgments (AIJ) technique with the geometric mean approach. This method allows the study to generate a consolidated expert preference while maintaining consistency with the AHP framework. As a result, the criteria weights produced in this study are supported by informed judgments from professionals representing technical, operational, safety, financial, and regulatory dimensions, thereby strengthening the credibility of the strategic decision-making process for the development of TBBM JKRT.

2.4. Analytic Hierarchy Process (AHP)

Method AHP gives the decision a clear structure by breaking the problem into a hierarchy of goal, criteria, and alternatives (Saaty, 2008). The procedure runs in four steps: build the pairwise comparison matrix, normalize it, derive the priority weights with the eigenvector method, and then check consistency through the Consistency Index (CI) and Consistency Ratio (CR). The CI follows:

$$CI = (\lambda max - n) / (n - 1) \quad (1)$$

A matrix is treated as consistent when CR ≤ 0.10; if it exceeds that, the judgments are revised and re-entered.

2.5. TOPSIS Method

Once AHP produced the criteria weights, the alternatives were ranked with TOPSIS. Before the TOPSIS calculation was carried out, each development alternative was assessed against the eight subcriteria using a five-point Likert scale, where 1 represents a highly unsuitable condition and 5 represents a highly suitable condition. The evaluation considered both qualitative and quantitative aspects, including regulatory and spatial planning compliance, asset reliability, supply access, receiving capacity, distance to demand centers, terminal infrastructure such as jetty and storage tanks, economic feasibility, and CAPEX requirements. Through this scoring approach, various types of assessment data were transformed into standardized numerical inputs, allowing them to be consistently compared in the subsequent TOPSIS analysis.

2.6. Sensitivity Analysis

A sensitivity analysis was run to see how much the ranking shifts when the weight of the dominant criterion changes. The weight of Safety & Asset Integrity was lowered by 20% and raised by 20% from its original value, and the remaining criteria were adjusted proportionally so that the weights still summed to 1.000.

The flowchart below sets out this procedure:

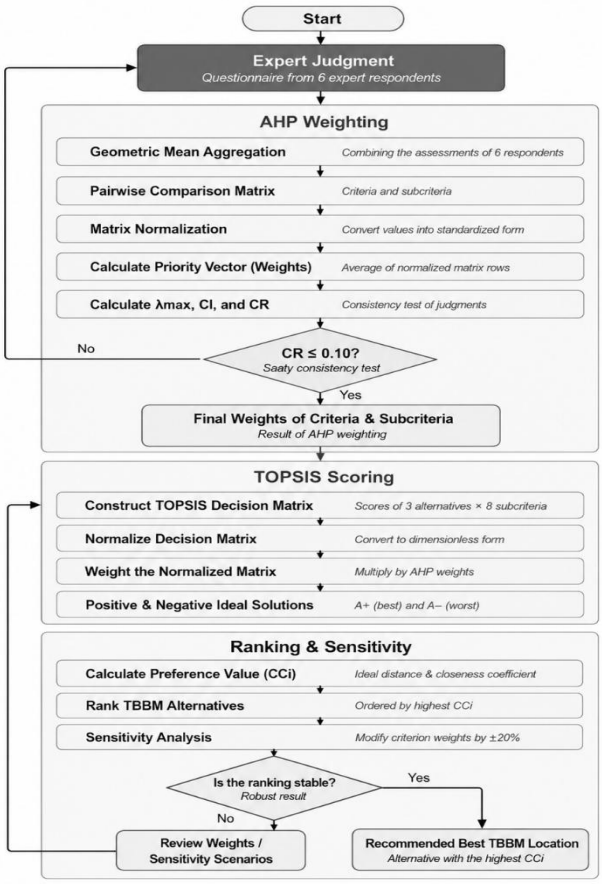

Fig. 1. AHP & Topsis Method Flow

3. Results and Discussion

3.1. Analysis of the Characteristics of Evaluation Aspects

On Safety & Asset Integrity, the existing TBBM JKRT carries the highest risk: its buffer zones are tight and the surrounding area is densely populated, a concern the 2023 incident only sharpened by raising the terminal's social risk exposure. JKRT + CBL looks better on spatial planning, since it sits in a designated industrial area in Bekasi Regency where more land is available. JKRT + Muara Cisadane brings spatial flexibility of its own along the coast, though it comes with technical hurdles, hydrodynamics and sedimentation among them, that would call for regular dredging.

On Operational Supply, the existing TBBM JKRT holds the clearest edge. It draws directly from the Balongan refinery through a pipeline of roughly 209 km and can also be supplied via Tanjung Priok Port. JKRT + CBL adds redundancy to the system by introducing a satellite node, while JKRT + Cisadane opens the door to supply diversification through its coastal access.

On Investment Efficiency & Economics, JKRT + CBL performs best financially. Its jetty facilities, covering the mooring dolphin, breasting dolphin, trestle, and jetty head, come to a total CAPEX of IDR 31.78 billion, plus IDR 4.75 billion a year for maintenance dredging. JKRT + Cisadane, by comparison, needs IDR 138.33 billion in CAPEX, largely because building on the coast is more complex.

3.2. AHP Results — Criteria Weighting

The responses provided by the six experts were combined using the geometric mean method to generate an aggregated pairwise comparison matrix for the main criteria. This procedure was adopted to consolidate individual expert judgments while preserving the reciprocal characteristics required in the AHP methodology. As presented in Table 1, the aggregated matrix illustrates the relative importance of the four primary criteria, namely Safety & Asset Integrity, Operational Supply, Operational Distribution, and Investment Efficiency & Economics.

Table 2. Pairwise Comparison Matrix of Main Criteria

Criteria	Safety & Asset Integrity	Operational Supply	Operational Distribution	Investment Efficiency & Economics
Safety & Asset Integrity	1	3,80	5,26	3,42
Operational Supply	0,26	1	1,38	0,54
Operational Distribution	0,19	0,72	1	0,25
Investment Efficiency & Economics	0,29	1,86	3,94	1
Total	1,75	7,39	11,59	5,21

After the pairwise comparison matrix had been developed, the normalization process was conducted by dividing each element in the matrix by the total value of its respective column. The priority weight of each criterion was subsequently obtained by averaging the normalized values in each corresponding row. The normalized matrix, together with the resulting priority vector, is presented in Table 2. The results show that Safety & Asset Integrity achieved the highest priority weight, accounting for 54.9%. This indicates that safety performance, regulatory compliance, and asset reliability serve as the most important factors in assessing the development alternatives for TBBM JKRT. The remaining criteria were ranked as follows: Investment Efficiency & Economics at 23.8%, Operational Supply at 12.7%, and Operational Distribution at 8.5%.

Table 3. Normalized Matrix and Priority Weights

Criteria	Regulatory and Spatial Planning Compliance, Including Buffer Zone Requirements	Asset Reliability & Integrity	BRK
Regulatory and Spatial Planning Compliance, Including Buffer Zone Requirements	0,436	0,436	0,44
Asset Reliability & Integrity	0,564	0,564	0,56
Total	1	1	1

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Criteria	Supply Access from Refinery/Impor	Receiving Capacity, including Storage Tanks & Jetty	BRK
Supply Access from Refinery/Impor	0,275	0,275	0,27
Receiving Capacity, including Storage Tanks & Jetty	0,725	0,725	0,73
Total	1	1	1

Criteria	Distance to Demand Centers	Jetty & Storage Tank Capacity	BRK
Distance to Demand Centers	0,783	0,783	0,78
Jetty & Storage Tank Capacity	0,217	0,217	0,22
Total	1	1	1

Criteria	Economic Feasibility	Lowest Capex / Lowest Capital Expenditure	BRK
Economic Feasibility	0,844	0,844	0,84
Lowest Capex / Lowest Capital Expenditure	0,156	0,156	0,16
Total	1	1	1

The AHP model was validated by conducting a consistency evaluation, which included the calculation of the maximum eigenvalue (λ_{max}), Consistency Index (CI), Random Index (RI), and Consistency Ratio (CR). As shown in Table 1c, the obtained CR value falls within the acceptable threshold of 0.10. This indicates that the expert assessments are consistent and reliable, thereby supporting the use of the resulting priority weights as input for the subsequent TOPSIS analysis.

Table 4. AHP Consistency Test: λmax, CI, RI, CR

Consistency Measure	Value
Number of criteria (n)	4
λmax	4.077
Consistency Index (CI)	0.026
Random Index (RI)	0.900
Consistency Ratio (CR)	0.028

The results indicate that the weighting process was conducted using a structured and rigorous AHP procedure, rather than depending solely on expert judgment. Therefore, the resulting criteria weights can be considered a strong and reliable basis for assessing and ranking the alternative development strategies through the TOPSIS method.

3.3. TOPSIS Results — Alternative Ranking

The TOPSIS analysis was initiated by translating the performance of each alternative into a standardized five-point rating scale, as presented in Table 5. This scale was adopted to ensure that both qualitative and quantitative data across the subcriteria could be assessed and compared in a consistent manner. The assigned scores were determined by considering the technical, operational, safety, spatial planning, and economic characteristics of each development alternative.

Table 5. Scoring Scale for TOPSIS Assessment

Score	Interpretation
1	Very Unsuitable
2	Unsuitable
3	Moderate
4	Suitable
5	Very Suitable

Table 6. Initial Decision Matrix of Alternatives

Loc	Reg	Intgr	Suppl	Rece	Dist	Jett	Econ	Capex
Exst	1	2	5	5	5	4	3	5
CBL	3	4	4	4	4	4	4	3
Cisa	4	3	4	4	4	4	3	2

After the scoring stage was completed, the performance values of the three development alternatives were organized into an initial decision matrix, as shown in Table 6. The matrix presents the score assigned to each alternative for every subcriterion. The Existing JKRT alternative showed strong performance in supply access, receiving capacity, distance to demand centers, and CAPEX efficiency. However, it received a low score for regulatory and spatial planning compliance, mainly due to its limited buffer zone and location near densely populated settlements. Meanwhile, the JKRT + CBL and JKRT + Cisadane alternatives demonstrated better performance in terms of safety and spatial planning, although each alternative had different

implications regarding economic feasibility and implementation complexity.

The initial decision matrix was normalized to address differences in measurement scales among the subcriteria. The normalization was carried out by dividing each value by the square root of the sum of squared values for its respective subcriterion. The normalized decision matrix obtained from this process is presented in Table 7.

Table 7. Normalized Decision Matrix

Loc	Reg	Intgr	Suppl	Rece	Dist	Jett	Econ	Capex
Exst	0,196	0,371	0,662	0,662	0,662	0,577	0,514	0,811
CBL	0,588	0,743	0,530	0,530	0,530	0,577	0,686	0,487
Cisa	0,784	0,557	0,530	0,530	0,530	0,577	0,514	0,324

The weighted normalized decision matrix was then developed by multiplying each value in the normalized matrix by the corresponding weight obtained from the AHP analysis, as presented in Table 8. This stage allows the relative importance of each criterion and subcriterion to be incorporated into the TOPSIS procedure. Accordingly, subcriteria with greater AHP-derived weights have a stronger effect on the final preference ranking.

Table 8. Weighted Normalized Decision Matrix

Loc	Reg	Intgr	Suppl	Rece	Dist	Jett	Econ	Capex
Exst	0,047	0,115	0,023	0,061	0,044	0,011	0,103	0,030
CBL	0,141	0,230	0,019	0,049	0,035	0,011	0,138	0,018
Cisa	0,188	0,173	0,019	0,049	0,035	0,011	0,103	0,012

The criteria weights from the AHP analysis fed into the TOPSIS process. Each subcriterion score for every alternative was placed on a 1–5 scale, from very unsuitable to very suitable, then normalized and weighted. From the positive and negative ideal solutions, the distances D^+ and D^- and the closeness coefficient (CCi) were calculated, as Table 9 shows.

Table 9. TOPSIS Final Calculation and Ranking

Solusi Ideal +	0,188	0,230	0,023	0,061	0,044	0,011	0,138	0,030
Solusi Ideal -	0,047	0,115	0,019	0,049	0,035	0,011	0,103	0,012

Alternatif	(Di+)	(Di-)	CCi	Ranking
Existing JKRT	0,185	0,024	0,115	3
JKRT + CBL	0,051	0,153	0,750	1
JKRT + Cisadane	0,071	0,152	0,681	2

The final ranking was determined by identifying the positive ideal solution (PIS) and negative ideal solution (NIS) from the weighted normalized decision matrix. The PIS reflects the best attainable performance value for each subcriterion, while the NIS represents the least desirable performance value. The Euclidean distance of each alternative from both ideal solutions was then calculated to obtain the closeness coefficient (CCi). In the TOPSIS approach, the alternative with the highest (CCi) value is considered the most suitable development strategy.

The results show that the JKRT + CBL combination achieved the highest closeness coefficient, with a CCi value of 0.750, placing it as the first-ranked alternative. This indicates that the CBL option offers the most balanced performance across safety, operational capability, and economic feasibility aspects. The JKRT + Muara Cisadane alternative ranked second with a CCi value of 0.681, followed by the Existing JKRT alternative in third place with a CCi value of 0.115. Although the existing JKRT terminal showed favorable performance in operational supply and CAPEX-related aspects, its major limitations in regulatory and spatial planning compliance substantially reduced its overall preference score. Therefore, the TOPSIS results confirm that JKRT + CBL is the most appropriate and robust development strategy for TBBM JKRT.

3.4 Sensitivity Analysis

To check how robust the ranking is, the weight of the dominant criterion, Safety & Asset Integrity, was varied by ±20%, with the outcomes in Table 10 :

Table 10. Sensitivity Analysis

Ranking	-20%		+20%	
	Ranking	CCi	Ranking	CCi
Existing JKRT	3	0,164	3	0,076
JKRT + CBL	1	0,738	1	0,755
JKRT + Cisadane	2	0,636	2	0,706

The results hold steady across both scenarios. Whether the weight is lowered by 20% or raised by 20%, the order does not move: JKRT + CBL stays first, JKRT + Cisadane second, and the existing TBBM JKRT third. Because the ranking is so insensitive to these changes, the model can be read as stable, and the case for choosing JKRT + CBL stands up well even when the dominant criterion's weight is shifted either way.

3.5. Strategic Implications for National Energy Security

The findings suggest that how TBBM JKRT is developed is not just an operational matter for the oil and gas company. It carries weight for national energy security as well, especially across western Java and the Greater Jakarta area, which lean heavily on the terminal as their main distribution hub.

Building a satellite node at CBL could do three things: cut the risk of a supply disruption stemming from a single point of failure at the existing JKRT terminal; make the energy logistics system more flexible by spreading out the receiving points; and help sustain operations over the long run, all while keeping the supply access JKRT already enjoys from the Balongan Refinery Unit and Tanjung Priok Port.

4. Conclusions

The integrated AHP–TOPSIS analysis of the development and relocation options for TBBM JKRT points to a few clear conclusions. Among the criteria, Safety & Asset Integrity weighs heaviest at 54.9%, with Investment Efficiency & Economics next at 23.8%, then Operational Supply at 12.7% and Operational Distribution at 8.5%.

Carrying those weights into the TOPSIS ranking, the combination of TBBM JKRT + Cikarang Barat Laut (CBL) emerges as the best alternative, with a closeness coefficient (CCi) of 0.750, ahead of TBBM JKRT + Muara Cisadane (CCi = 0.681) and the existing TBBM JKRT (CCi = 0.115). The sensitivity analysis, which reworked the weight of the dominant criterion, left this order unchanged, so the ranking holds up regardless of how the criteria weights are shifted.

On the methodological side, the study shows that a hybrid AHP–TOPSIS approach gives a systematic and traceable way to evaluate national strategic energy infrastructure. Two extensions would strengthen future work: applying Fuzzy AHP–TOPSIS to absorb the uncertainty in expert judgments, and bringing in fuller economic measures such as Net Present Value (NPV), Internal Rate of Return (IRR), and risk-adjusted return to give strategic decisions a richer financial footing.

References

[1] Bappenas. 2021. *Rencana Pembangunan Jangka Menengah Nasional (RPJMN) 2020–2024*. Jakarta: Kementerian PPN/Bappenas.

[2] BPPT. 2022. *Outlook Energi Indonesia 2022*. Jakarta: Badan Pengkajian dan Penerapan Teknologi.

[3] Fairuz, M., N. Rahman, and M. Yusoff. 2023. "AHP Application to Select Logistical Location in Upstream Oil and Gas Operation: A Case Study." *Energy Reports* 9: 1021–1033.

[4] Harati, S., M. Ghasemi, and M. Rasti-Barzoki. 2024. "Multi-Criteria Site Selection Workflow for Geological Storage of Hydrogen in Depleted Gas Fields: A Case for the UK." *International Journal of Hydrogen Energy* 49 (3): 1450–1464.

[5] Hasheminasab, S. M., B. Karimi, and M. Yazdani. 2024. "Hybrid AHP–TOPSIS Approach for Multi-Criteria Evaluation of Refinery Location Alternatives." *Journal of Environmental Management* 345: 119233.

[6] IEA. 2023. *World Energy Outlook 2023*. Paris: International Energy Agency.

[7] Juric, M., I. Kovacevic, and J. Dolic. 2021. "The Selection of an LNG Terminal Location by Evaluating Its Potential Impact on Marine Environments, Safety, and Costs." *Energy Reports* 7: 4201–4213.

[8] Kementerian ESDM. 2018. *Keputusan Direktur Jenderal Mineral dan Batubara No. 309.K/30/DJB/2018 tentang Pedoman Teknis Pengamanan Terminal BBM*. Jakarta: Kementerian Energi dan Sumber Daya Mineral.

[9] Nouri, M., A. Karimi, and H. Shahriar. 2023. "Feasibility Study of Gas Storage Areas Using Fuzzy-AHP Model: Case Study of Bushehr Province." *Energy Reports* 9: 2150–2165.

[10] Saaty, T. L. 2008. "Decision Making with the Analytic Hierarchy Process." *International Journal of Services Sciences* 1 (1): 83–98.

[11] Sun, W., X. Tang, Z. Li, and R. Guo. 2025. "CO_2 Geological Storage Site Selection and Long-Term Potential Assessment Framework Based on TOUGH2/ECO2N." *Energy* 289: 129874.

[12] UNDRR. 2015. *Sendai Framework for Disaster Risk Reduction 2015–2030*. Geneva: United Nations Office for Disaster Risk Reduction.

[13] Xu, Y., W. Zeng, H. Li, and B. Chen. 2025. "Developing a Preliminary Site Selection Method for Direct Air Capture and CO_2 Storage Technology with a Case Study in North Germany." *Journal of Cleaner Production* 412: 138422.

[14] Zhang, N., S. Liu, and J. Wang. 2024. "Overview of Salt Cavern Oil Storage Development and Site Suitability Analysis." *Journal of Loss Prevention in the Process Industries* 87: 105948.