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Strategic Decision-Making in The Development Scenario Selection for The *Kayu Merah* Structure at Jatibarang Field, PT Pertamina Ep

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Abstract

This research aims to support strategic decision-making in determining the most optimal development scenario for the KYM gas structure through an integrated analytical approach. The research identifies internal and external factors influencing development feasibility, translates stakeholder values into decision criteria, and systematically evaluates alternative scenarios. The method combined qualitative and quantitative approaches through PESTEL analysis, SWOT analysis, Value-Focused Thinking (VFT), and the Analytic Hierarchy Process (AHP). Primary data were obtained through surveys, semi-structured interviews, focus group discussions, and stakeholder mapping, while secondary data were derived from internal company documents, regulations, technical studies, and academic literature. The results of the environmental analysis were used to formulate fundamental objectives, means objectives, criteria, and sub-criteria for evaluation that align with strategic priorities and stakeholder expectations. The alternative development scenarios were then evaluated using AHP pairwise comparisons, accompanied by consistency ratio testing and sensitivity analysis. The findings indicate that Alternative 1, namely the production flow from KYM-B and KYM-C wells through the construction of a new flowline integrated with existing production toward the Randegan Gathering Station with facility upgrades, is the most optimal scenario. This alternative is superior because it provides a balanced performance across economic, technical-operational, regulatory-environmental, implementation risk, and stakeholder alignment aspects. The sensitivity analysis shows that the selected alternative remains robust against changes in criteria weights, with the project approval target in the second quarter of 2026 and onstream target in the fourth quarter of 2028.

INTRODUCTION

The global energy landscape is undergoing a significant transformation as countries seek to balance energy security, economic growth, and the transition toward lower-carbon energy systems (International Energy Agency [IEA], 2023; Energy Institute, 2024). In this context, natural gas has gained strategic importance as a transition fuel because it offers relatively lower carbon emissions compared with other fossil fuels while still providing reliable energy supply for industrial and power generation needs (Intergovernmental Panel on Climate Change [IPCC], 2022; International Energy Agency, 2023). According to the International Energy Agency (IEA, 2023), natural gas accounts for approximately 23 percent of the global energy mix. At the same time, oil and gas companies are increasingly required to make investment decisions under conditions of market volatility, geopolitical uncertainty, regulatory pressure, and growing demand for operational efficiency (International Energy Forum, 2023; World Bank, 2023).

In Indonesia, the role of natural gas is becoming increasingly important in supporting national energy security and industrial development (Ministry of Energy and Mineral Resources

[MEMR], 2017; National Energy Council, 2022). The National Energy General Plan (RUEN) projects a significant increase in national energy demand by 2050 (National Energy Council, 2022). To respond to this growing demand, the Government of Indonesia, through the Special Task Force for Upstream Oil and Gas Business Activities (SKK Migas), has set a national target of producing 12 BSCFD of gas by 2030 (SKK Migas, 2024). Achieving this target requires optimization of existing assets, accelerated development of new gas resources, and investment decisions that are technically feasible and economically sustainable (Ministry of Energy and Mineral Resources, 2024; International Energy Agency, 2023).

Pertamina EP, as part of Pertamina's Subholding Upstream, plays a strategic role in supporting Indonesia's upstream oil and gas production targets (PT Pertamina Hulu Energi, 2024). Within Pertamina EP, Regional 2 Zona 7 is particularly important because it includes several producing fields such as Subang, Tambun, and Jatibarang (PT Pertamina EP, 2024). These fields are located close to major industrial demand centers in West Java, making the region highly relevant for gas supply reliability (SKK Migas, 2024). However, many producing fields have entered a mature phase, resulting in declining productivity and increasing operational challenges (SPE, 2023; Economides et al., 2013). Consequently, the development of new gas resources has become increasingly important to sustain production and strengthen regional gas supply (PT Pertamina Hulu Energi, 2024). This condition highlights the urgency of developing new resources to maintain production sustainability and strengthen the regional gas supply portfolio.

One prospective resource that can contribute to this objective is the Kayu Merah (KYM) gas structure, located in the Jatibarang Field, Zona 7. Preliminary studies have identified KYM as a viable gas resource with potential contribution to future gas production. Nevertheless, despite its resource potential, a strategic decision has not yet been made regarding the most suitable development scenario for KYM’s surface production facilities. Several development alternatives are available, including utilizing existing facilities, upgrading current facilities, constructing new facilities, or adopting a hybrid approach (Sharif & Hammad, 2019; Strong et al., 2018). Each option has different implications for capital expenditure, operating cost, technical complexity, project execution timeline, regulatory compliance, environmental obligations, and gas monetization strategy (Agbede et al., 2023; Amini-Philips et al., 2022; Talipova & Parsegov, 2018).

The decision becomes more complex because the KYM development project involves not only technical and economic considerations, but also commercial and stakeholder-related factors. Existing gas buyers such as PGN, PLN, Pertagas, and other regulated buyers generally purchase gas at regulated prices, while potential premium industrial buyers may offer higher negotiated prices. Although the premium market may improve project economics, it may also require additional infrastructure investment and expose the project to higher commercial risk. Therefore, selecting the most appropriate development scenario requires a comprehensive evaluation that can balance economic attractiveness, technical feasibility, implementation risk, market opportunity, and stakeholder expectations.

Previous decision-making practices in upstream project development often emphasize economic indicators and technical feasibility as the main basis for selecting project alternatives. However, in complex development projects such as KYM, relying only on financial and technical indicators may not be sufficient. The decision must also incorporate strategic priorities, stakeholder values, implementation risks, regulatory requirements, and market uncertainties. This creates a need for an integrated decision-making framework that can translate stakeholder values into explicit evaluation criteria and compare development alternatives systematically. Value-Focused Thinking (VFT) is used to identify stakeholder values and formulate decision criteria, while the Analytic Hierarchy Process (AHP) is applied to evaluate and rank the available development alternatives. PESTEL and SWOT analyses are also used to map external and internal factors that may influence the feasibility of KYM development.

This research aims to determine the most optimal development scenario for KYM's surface production facilities by applying an integrated multi-criteria decision-making approach. Specifically, the research seeks to identify the key technical, economic, risk, market, regulatory, and stakeholder-related criteria that influence the selection of development alternatives; develop a structured evaluation framework using PESTEL, SWOT, VFT, and AHP; and determine the development scenario that provides the best balance between technical feasibility, economic viability, risk profile, market opportunity, and strategic alignment. The expected benefits include improved decision transparency, reduced project execution risk through systematic criteria evaluation, and optimized capital allocation by selecting the most balanced development scenario. The scope of this research is limited to surface production facilities, including gathering stations, gas processing facilities, flowlines, and pipeline networks required to deliver gas from wells to buyers. Subsurface activities such as reservoir characterization, drilling design, and well intervention programs are beyond the scope of this research.

METHOD

This research employed a mixed-method research design by integrating qualitative and quantitative approaches to determine the most appropriate development scenario for the KYM gas structure. The use of a mixed-method approach was considered relevant because the decision problem involved not only technical and economic considerations, but also regulatory, environmental, commercial, operational, and stakeholder-related factors. Therefore, the research design combined contextual analysis, stakeholder value identification, and multi-criteria decision-making to produce a systematic and defensible scenario recommendation.

The research process began with the identification of the main business issue, namely the absence of a structured decision-making framework for selecting the optimal surface production facility development scenario for KYM. At this stage, stakeholder mapping and rich picture analysis were used to understand the relationship among key actors, operational constraints, regulatory requirements, infrastructure limitations, market opportunities, and potential areas of misalignment. The result of this stage provided the foundation for defining the decision context and determining the boundaries of the analysis.

Primary data were collected through semi-structured interviews, focus group discussions, and questionnaire-based surveys. The interviews were conducted with key internal stakeholders from Pertamina EP Zona 7, Regional 2, and Sub holding Upstream who were directly involved in subsurface development, production operations, project planning, engineering, commercial planning, Health, Safety, Security, and Environment (HSSE), legal, land formalities, and regulatory coordination. External stakeholders, including SKK Migas and gas buyers such as Pertagas, were also involved in capturing regulatory and commercial perspectives. Focus group discussions were carried out with multidisciplinary teams to validate assumptions, refine criteria, and formulate alternative development scenarios. Meanwhile, structured questionnaires were distributed to selected experts and decision-makers to obtain pairwise comparison judgments required for the AHP.

Secondary data were obtained from internal company documents, regulatory documents, industry publications, academic literature, market data, and benchmarking studies. Internal documents included technical studies, minutes of meetings, planning documents, production forecasts, facility configuration data, cost assumptions, and project risk information. Regulatory data were collected from relevant national and regional policies, including environmental and land-use requirements such as AMDAL, UKL/UPL, LP2B, PPKH, SKK Migas guidelines, and Ministry of Energy and Mineral Resources regulations. Academic and industry literature were used to strengthen the theoretical foundation of the research, particularly related to upstream gas development, project economics, VFT, and multi-criteria decision analysis. Market and commercial data were used to assess gas price assumptions, buyer segmentation, demand trends, and competitive supply conditions.

Third, the research applied the VFT approach to translate stakeholder values into explicit decision objectives. Through this process, fundamental objectives and means objectives were identified and structured into evaluation criteria and sub-criteria. This step ensured that the decision framework was not merely based on available alternatives, but was aligned with strategic priorities, stakeholder expectations, and project objectives. The criteria developed from this stage covered technical feasibility, economic viability, implementation risk, regulatory and environmental compliance, market opportunity, and stakeholder alignment.

Fourth, alternative development scenarios for the KYM structure were formulated based on internal planning documents, technical assessments, stakeholder inputs, and benchmarking from comparable gas development projects. The alternatives represented different possible configurations of surface production facilities, including the use of existing facilities, facility upgrades, new infrastructure development, and hybrid development approaches. Each alternative was evaluated against the criteria and sub-criteria established in the previous stage.

The AHP method was then used as the main quantitative decision-support tool. Pairwise comparisons were conducted to determine the relative importance of each criterion, sub-criterion, and alternative. Respondents assessed the comparisons using Saaty's fundamental scale, ranging from 1 for equal importance to 9 for extreme importance. The results were processed into pairwise comparison matrices to calculate priority weights. To ensure the reliability of the judgments, a consistency test was performed using the Consistency Index (CI) and Consistency Ratio (CR). A comparison matrix was considered acceptable when the CR value was less than or equal to 0.10, indicating a satisfactory level of logical consistency.

Finally, validation and sensitivity analysis were conducted to assess the robustness of the ranking results. Validation was performed through discussion with relevant decision-makers to ensure that the model output was realistic and aligned with the project context. Sensitivity analysis was conducted using Microsoft Excel 2016 by adjusting the weights of key criteria to observe whether changes in assumptions affected the final ranking of alternatives. This stage was important to determine whether the recommended scenario remained stable under different decision perspectives.

RESULTS AND DISCUSSION

Analysis

This analysis incorporates macro-environmental assessment (PESTEL), internal and external strategic synthesis (SWOT), identification of key decision-makers, and formulation of decision objectives through the VFT framework. The results from this section serve as structured and traceable inputs for the subsequent multi-criteria evaluation using the AHP.

PESTEL Analysis

The PESTEL analysis is applied to examine the macro-environmental factors that may affect whether the KYM gas development project proceeds, when it should begin, and how its strategic direction is determined. The analysis is guided by a structured question list and informed by expert judgment, internal reports, and regulatory references relevant to upstream gas development in Indonesia. The complete responses obtained from the interview survey presents the complete set of stakeholder inputs supporting the PESTEL analysis. The key findings are summarized in Table 1.

Table 1. PESTEL Analysis for KYM Gas Development Project

Factor	Key External Issues	Implications for KYM Project
Political	National and regional energy policies; coordination between central and local governments; institutional alignment and policy prioritization	Potential delays and uncertainty in project execution due to governance complexity and policy alignment issues
Economic	Project investment requirements; gas pricing and contractual assumptions; internal economic thresholds; market demand uncertainty	Strong influence on capital allocation decisions and feasibility of alternative development scenarios
Social	Community acceptance; labor expectations; potential social resistance or disturbances	Risk to project schedule and operational continuity if stakeholder engagement is not effectively managed
Technological	Availability of proven technologies; compatibility with existing facilities; cost-efficiency considerations	Lower technical risk but higher importance of optimization and integration decisions
Environmental	Environmental sensitivity; land-use impacts; environmental mitigation during construction and operation	Potential impacts on construction methods, costs, and implementation schedule
Legal	Regulatory and permitting requirements (AMDAL, UKL/UPL, LP2B, PPKH); legal compliance sequencing	Critical determinant of project readiness, approval timeline, and development risk

Source: Author's compilation based on expert interviews and internal document analysis (2026)

SWOT Analysis

The SWOT analysis is conducted to synthesize both internal and external factors that influence the development of the KYM gas project. This analysis integrates qualitative strategic assessment with quantitative inputs obtained from expert judgment through a structured SWOT rating questionnaire. In this research, SWOT factors were initially identified based on internal project documentation, preliminary technical studies, stakeholder mapping, and the preceding PESTEL analysis. These factors were then validated and rated by selected respondents representing internal Pertamina entities, regulators, and related stakeholders, ensuring that the analysis reflects both organizational perspectives and external environmental considerations relevant to the KYM development context.

Identification of SWOT Factors

Based on the preliminary strategic assessment, a total of 12 (twelve) SWOT factors were identified and structured into Strengths, Weaknesses, Opportunities, and Threats. These factors represent the most relevant internal capabilities and constraints, as well as external drivers and risks influencing the KYM gas development project. The complete results of the interview-based SWOT survey are presented, providing detailed stakeholder inputs that support the identification of these factors. A qualitative summary of the identified SWOT factors prior to quantitative assessment is presented in Table 2.

Table 2. Summary of SWOT Analysis for KYM Gas Development

Aspect	Key Analytical Findings
Strengths	1. Availability of newly discovered gas reserves with commercial potential 2. Extensive experience of Pertamina EP in onshore gas development 3. Proximity to existing production facilities enabling infrastructure integration 4. Established relationships with existing gas buyers and upstream stakeholders
Weaknesses	5. Technical and capacity limitations of existing facilities 6. Complexity of internal coordination across multiple functions 7. Uncertainty in reservoir performance and facility optimization affecting supply stability

Opportunities	8. Increasing domestic gas demand driven by industrial growth and power generation needs 9. Government policies supporting gas utilization for energy security and energy transition 10. Potential cost optimization through infrastructure integration and use of proven technologies 11. Availability of potential new buyers offering more attractive commercial terms
Threats	12. Regulatory and permitting risks related to land use and environmental approvals 13. Overlapping authorities between central and local governments 14. Gas price volatility and competition from alternative supply sources 15. Market-driven requirements for strict gas quality specifications 16. Social risks including community resistance and land acquisition issues

Source: Author's compilation based on expert interviews and internal document analysis (2026)

The qualitative identification above provides the foundation for subsequent quantitative evaluation using expert judgment.

SWOT Rating Results from Expert Survey

To strengthen objectivity and reduce subjective bias, the identified SWOT factors were evaluated through a structured questionnaire distributed to selected respondents. Each factor was rated using a five-point Likert scale ranging from Very Low (1) to Very High (5), reflecting its relative significance, severity, or impact on the KYM development project. Survey responses were aggregated to calculate the mean score and dominant rating for each SWOT factor. The categorization follows an equal-width interval approach, as summarized below:

Table 3. Mean Score Range for each Category

Mean Score Range	Category
1.00 – 1.80	Very Low
1.81 – 2.60	Low
2.61 – 3.40	Moderate
3.41 – 4.20	High
4.21 – 5.00	Very High

Source: Author's elaboration based on Likert scale categorization (2026)

The summarized results of the SWOT rating survey are presented in Table 4.

Table 4. SWOT Rating Summary

Code	SWOT Factor	Mean Score	Dominant Rating	Interpretation
S1	Organizational experience & capability	4.33	Very High	Strong internal readiness
S2	Tangible assets & infrastructure availability	3.89	High	Key enabler for integration and cost efficiency
S3	Technical expertise & operational reliability	4.22	Very High	Core technical strength
W1	Internal technical/operational/ financial constraints	3.11	Moderate	Material internal constraint with varied views
W2	Infrastructure/workforce/ coordination limitations	3.22	Moderate	Execution friction & coordination burden
W3	Asset maturity & subsurface uncertainty affecting specs/continuity	3.44	High	Critical internal risk to deliverability
O1	External demand growth & supportive market dynamics	4.22	Very High	Strong demand-side pull

O2	Energy transition & pro-gas utilization policy	4.22	Very High	Strong policy-driven opportunity
O3	Industrial/regional growth increasing market attractiveness	4.22	Very High	Most attractive external upside
T1	Regulatory complexity & permitting uncertainty	3.94	High	Major external risk to schedule & readiness
T2	Increasing gas quality specs & supply reliability requirements	3.06	Moderate	Manageable but requires early design alignment
T3	Social & environmental issues (community/land/etc.)	4.11	High	Most critical external threat to project continuity

Source: Author's compilation based on expert survey results (2026)

SWOT Synthesis and Strategic Implications

The SWOT analysis shows that the success of the KYM development project depends on PT Pertamina EP's ability to use its organizational experience, technical expertise, and infrastructure, while managing internal risks and external regulatory and social uncertainties. The alignment between internal strengths and external opportunities, such as rising gas demand, supportive energy transition policies, and growing industrial markets, indicates that KYM has strong potential as a commercially viable gas project. However, significant threats from permitting complexity, social acceptance, and regulatory uncertainty require a strategy that reduces approval delays, land-use risks, and operational disruptions. Internal challenges, including asset maturity and subsurface uncertainty, further emphasize the need for technical robustness, gas specification compliance, and reliable long-term supply. These findings provide clear, traceable inputs for defining stakeholder values, objectives, and evaluation criteria in the upcoming VFT analysis. Basing the VFT framework on SWOT results ensures that scenario evaluations align with strategic priorities and practical constraints.

Value-Focused Thinking (VFT)

The application of VFT in this research is based on a synthesis of internal organizational capabilities, external constraints, and stakeholder expectations identified in the preceding analyses. Key stakeholder values relevant to the KYM development include economic viability, technical and operational feasibility, regulatory and environmental compliance, risk minimization, and long-term stakeholder acceptance. These values represent the strategic interests of Pertamina EP, Sub holding Upstream, regulators, and potential gas buyers, and thus form the basis for structuring the project's decision objectives. In accordance with the VFT framework, identified objectives are systematically classified into fundamental objectives and means objectives. Based on this classification, the fundamental objective of the KYM gas development project is formulated as follows:

"To determine the most appropriate production facility integration and pipeline connectivity scenario that optimizes natural gas deliverability from the KYM structure while supporting Pertamina EP's long-term business sustainability."

This objective captures the core strategic intent of the project by integrating economic value creation, technical feasibility, regulatory compliance, and stakeholder alignment. To operationalize this fundamental objective, a set of means objectives is identified, including optimizing capital and operating expenditures, ensuring technical and operational feasibility, accelerating gas onstream timelines, maintaining regulatory and environmental compliance, and minimizing implementation and execution risks. These means objectives translate stakeholder values into actionable dimensions that can later be evaluated across alternative development scenarios. In the KYM project context, regulatory approvals and land acquisition risks represent a dominant constraint shaping feasible development pathways and therefore constitute a central consideration in structuring the means objectives.

Table 7 summarizes the relationship between the fundamental objective and the corresponding means objectives, illustrating how strategic values are systematically translated into decision-relevant objectives.

Table 7. Fundamental and Means Objectives for KYM Development Project

Fundamental Objectives (What decision-makers ultimately value)	**Means Objectives (How the objectives can be achieved)**
Maximize Project Economic Value	- Optimize capital expenditure (CAPEX) through facility integration - Improve operating cost efficiency (OPEX) - Enhance project economic indicators (NPV, IRR, payback period)
Ensure Technical and Operational Feasibility	- Select appropriate and proven production facility configurations - Utilize existing infrastructure where technically feasible - Ensure operational reliability and production sustainability
Ensure Regulatory and Environmental Compliance	- Comply with environmental requirements (AMDAL, UKL/UPL) - Manage land-use constraints (LP2B, LSD, PPKH) - Anticipate regulatory approvals and permitting timelines
Reduce Project Implementation Risks	- Simplify development scope and execution complexity - Shorten gas onstream timeline - Reduce exposure to schedule delays and cost overruns
Maintain Stakeholder Alignment and Acceptance	- Address expectations of regulators, local communities, and gas buyers - Minimize social disruption and community resistance - Ensure alignment with corporate and national energy objectives

Source: Author's elaboration based on VFT-AHP framework (Keeney, 1992; Saaty, 2008) and expert validation (2026)

Table 7 summarizes the relationship between the fundamental objective and the corresponding means objectives, illustrating how stakeholder values and strategic priorities are systematically translated into actionable decision objectives. By structuring objectives into fundamental and means categories, this framework ensures that subsequent analyses remain anchored in value-based reasoning rather than isolated technical preferences.

Development Alternatives Formulation

Rather than selecting among predefined technical solutions, this stage emphasizes the structured creation of decision-relevant alternatives that reflect distinct strategic trade-offs among cost, schedule, risk, and commercial positioning. At the early stage of evaluation, two broad development paths were initially considered:

a. development of the KYM structure under the Low CO_2 reservoir condition, and;
b. development under a combined Low CO_2 and High CO_2 condition.

A combined Low CO_2 and High CO_2 development path was screened out in the initial assessment because it would require more advanced gas treatment facilities to reduce CO_2

impurities in sales gas. This requirement is expected to significantly increase capital intensity, technical complexity, and project execution risk. In addition, the relatively limited gas reserves with High CO_2 in the KYM structure further weaken the justification for pursuing a capital-intensive High CO_2 development scenario, as the potential incremental revenue from higher-priced low-CO_2 sales gas is unlikely to sufficiently offset the increased investment and operational costs. Thereby reducing overall economic attractiveness relative to the Low CO_2 option, given comparable resource potential. Consequently, the subsequent alternative formulation focuses exclusively on the Low CO_2 case as the primary decision context.

In the Low CO_2 scenario, alternative development configurations were developed through internal technical reviews and structured consultations with subject-matter experts, taking into account key practical constraints such as facility readiness, pipeline connectivity, buyer access and pricing structures, as well as permitting and land-use considerations. Several alternatives demonstrate significantly different levels of exposure to land acquisition and permitting complexity, establishing regulatory feasibility as a critical differentiator among scenarios. The purpose of this stage is to define a set of strategically distinct and feasible development alternatives for consistent evaluation in the subsequent multi-criteria decision analysis, rather than to finalize engineering design. KYM-01 is an existing producing well connected to Stasiun Pengumpul (SP) Randegan by an established flowline. Its production configuration remains unchanged in all alternatives and is treated as a constant baseline, not a decision variable, in development planning.

A structured summary of the development alternatives is presented in Table 8 below, highlighting key differentiating features such as pipeline routing, facility integration, buyer alignment, and strategic positioning.

Table 8. Development Alternatives for KYM Gas Development Project

Alt.	New Production Flowline	Production Facility Integration	Existing Buyer	Potential Buyer	Key Strategic
1	18 km -KYM-B, 13 km - KYM-C to SP Randegan	SP Randegan Upgrading	DGAS	PGN/ SMU	Optimize use of SP Randegan, potential higher gas sales
2	18 km -KYM-B, 13 km - KYM-C to SP Randegan	SP Randegan Upgrading with Gas Compression	DGAS	PGN/ SMU	Improved deliverability, higher CAPEX, potential higher gas sales
3	21 km -KYM-B, 22 km - KYM-C to SPUA	SPUA Upgrading	Pertagas	-	Optimize use of SPUA, existing PJBG (lower price)
4	21 km -KYM-B, 22 km - KYM-C to SPUA	SPUA Upgrading with Gas Compression	Pertagas	-	Improved deliverability, higher CAPEX, existing PJBG (lower price)
5	21 km -KYM-B to SPUA, 13 km - KYM-C to SP Randegan	SPUA & SP Randegan Upgrading	Pertagas DGAS	PGN/ SMU	Optimize use of SPUA & SP Randegan, Optimize CAPEX

Note: KYM-01 existing well produced to SP Randegan for all alternatives

Source: Author's elaboration (2026)

Based on the alternative comparison framework, five feasible alternatives were identified for evaluation:

1. Alternative 1 : New production flowlines from KYM-B and KYM-C wells are routed together with existing production from the KYM-01 well, to the upgraded existing production facilities at SP Randegan.
2. Alternative 2 : Alternative 1 with the addition of gas compression facilities at SP Randegan to improve deliverability.
3. Alternative 3 : New production flowlines from KYM-B and KYM-C wells will be routed to the upgraded existing production facilities at SPU A, while the existing KYM-01 well continues to be routed to SP Radegan.
4. Alternative 4 : Alternative 3 with the addition of gas compression at SPU A to improve deliverability.
5. Alternative 5 : New production flowline from KYM-B will be routed to SPU A with facility upgrading, KYM-C will be routed to SP Randegan with facility upgrading, while KYM-01 continues to be routed to SP Randegan.

These alternatives represent different infrastructure utilization strategies, such as reliance on existing production facilities (SP Randegan and SPU A), implementation of gas compression to address deliverability constraints and various commercialization pathways involving both current and prospective gas buyers with differing pricing structures and gas specification requirements. Although these alternatives vary in technical configuration and operational complexity, each is designed to achieve the same fundamental objective as defined in the VFT framework.

Each alternative is structured to address specific means objectives identified within the VFT framework. For example, alternatives that incorporate compression are intended to enhance gas deliverability and production reliability. In contrast, alternatives that utilize existing infrastructure are designed to optimize CAPEX and expedite the onstream schedule. This explicit alignment ensures that the alternatives function as strategic responses to stakeholder-driven objectives rather than as isolated technical configurations.

An internal weighted scoring exercise was conducted as a preliminary feasibility check to assess constructability, operability, safety, reliability, and execution considerations. These results served only as an initial reference and do not substitute for the formal multi-criteria prioritization performed using the AHP. The structured set of development alternatives established in this section offers a consistent and defensible foundation for subsequent evaluation. The following subsection specifies the criteria and sub-criteria for assessing these alternatives in accordance with stakeholder values and strategic objectives.

Criteria and Sub-Criteria Definition

To enable a structured and defensible evaluation of the KYM gas development alternatives, the means objectives derived from the VFT framework are translated into a set of measurable evaluation criteria and sub-criteria. This step functions as the analytical bridge between the qualitative value-based reasoning in the preceding section and the quantitative multi-criteria assessment conducted using the AHP.

By defining the criteria prior to numerical weighting, the evaluation framework minimizes solution-driven bias and ensures that subsequent judgments remain anchored to strategic objectives rather than isolated technical preferences. Based on this synthesis, five main evaluation criteria are established to reflect the key dimensions that determine the overall desirability and feasibility of KYM development alternatives:

In the KYM project context, regulatory approvals and land-related constraints constitute a critical driver of strategic decision-making, rather than a secondary operational consideration. Experience from comparable oil and gas projects in Indonesia indicates that delays in land acquisition, environmental permitting (AMDAL, UKL-UPL), forestry and spatial permits (PPKH, LP2B, LSD), and multi-level government approvals are frequently the primary drivers of schedule slippage and project risk. Consequently, regulatory and land feasibility are explicitly embedded in the criteria structure as core determinants of scenario attractiveness, alongside traditional economic and technical metrics.

Each main criterion is further divided into sub-criteria that translate stakeholder values into measurable and comparable performance dimensions. These sub-criteria encompass capital and operating expenditures, economic value indicators, facility integration readiness, production reliability, gas quality compliance, permitting and land feasibility, execution complexity, buyer and commercial alignment, and social acceptance. The complete structure of evaluation criteria and sub-criteria used in this research is summarized in Table 9, which presents a transparent mapping between stakeholder-driven objectives and the measurable decision elements incorporated in the AHP model.

Table 9. Evaluation Criteria and Sub-Criteria for KYM Development Alternatives

Main Criterion	Sub-Criterion	Sub-Criteria
Economic Performance	Capital Expenditure (CAPEX)	Total investment required for pipeline construction, facility upgrading, compression installation, and supporting infrastructure
	Operating Expenditure (OPEX)	Expected operating and maintenance costs associated with production facilities, compression, utilities, and logistics
	Economic Value Indicators	Financial attractiveness measured through NPV, IRR, PI, payback period, and related economic metrics
Technical and Operational Feasibility	Facility Configuration & Integration	Compatibility and readiness of proposed facilities with existing infrastructure (SP Randegan and SPU A)
	Production Reliability & Deliverability	Ability of the system to maintain stable gas production, flow assurance, and delivery capacity
	Gas Quality Compliance	Capability to meet buyer gas specifications, including CO_2 content, water content, pressure, and moisture requirements
Stakeholder Alignment	Institutional Approval (internal & external)	Degree of alignment with internal corporate approvals (technical, financial, and governance) and external regulatory endorsements required for project execution
	Environmental Permits, Land Feasibility & Regulatory Approvals	Feasibility of securing land access and regulatory approvals (AMDAL, UKL-UPL, PPKH, LP2B, LSD), including risk of permitting delays
	Buyer & Commercial Alignment	Compatibility with existing and potential gas buyers, including pricing structure, contract readiness, and sales gas specifications
	Social Acceptance & Local Stakeholder Impact	Potential social risks, community acceptance, and local stakeholder engagement challenges
Project Implementation & Execution Risk	Schedule & Onstream Risk	Risk of delays affecting early gas production and commercial delivery timelines
	Execution Complexity	Degree of technical, logistical, contractual, and operational complexity associated with implementing each development alternative

Source: Author's elaboration based on VFT-AHP framework (Saaty, 2008; Keeney, 1992) (2026)

By translating VFT-derived objectives into a structured criteria hierarchy, the decision framework ensures that the subsequent AHP assessment reflects what decision-makers value, rather than what is merely technically feasible. This criteria structure serves as the foundation for constructing the AHP hierarchical model in the next sub-section, where stakeholder judgments are elicited through pairwise comparisons to derive priority weights and rank the KYM development alternatives in a consistent and analytically rigorous manner.

Table 10. VFT Means Objective to AHP Criteria

VFT Means Objective	AHP Criteria
Optimize CAPEX	Economic Performance
Optimize OPEX	
Improve Deliverability	Technical and Operational Feasibility
Ensure Regulatory & Land Feasibility	Regulatory and Environmental Compliance
Reduce Execution Risk	Project Implementation Risk
Align Buyers & Stakeholders	Stakeholder Alignment

Source: Author's elaboration based on VFT-AHP framework (Saaty, 2008; Keeney, 1992) (2026)

The transition from VFT to the AHP requires converting value-based objectives into measurable evaluation criteria. Each means objective identified within the VFT hierarchy is systematically translated into one or more criteria and sub-criteria that can be quantitatively assessed across alternatives. This process ensures that the AHP model accurately represents stakeholder values in a structured and measurable format, thereby maintaining consistency between qualitative value elicitation and quantitative decision analysis.

Analytic Hierarchy Process (AHP)

AHP provides a structured and transparent framework to translate value-based objectives derived from the VFT analysis into quantitative priority weights. This method enables consistent comparison of development alternatives across economic, technical, regulatory, execution, and stakeholder-related dimensions.

AHP decision hierarchy

The AHP assessment begins by constructing a hierarchical decision model that reflects the KYM decision logic from objectives to measurable criteria and finally to alternatives. The hierarchy comprises:

1. the overall goal of selecting the most appropriate KYM development scenario;
2. the main evaluation criteria derived from the VFT objectives;
3. the corresponding sub-criteria that operationalize those objectives into assessable dimensions; and
4. the KYM development alternatives formulated in the Low CO_2 decision context.

The complete hierarchy used in this research is summarized in Table 11.

Table 11. AHP Hierarchical Structure for KYM Development Scenarios Selection

Level	Element	Description
Level 1	Goal	Selection of the most appropriate development scenario for the KYM gas structure
Level 2	Criteria	Economic Performance
		Technical and Operational Feasibility
		Regulatory and Environmental Compliance
		Project Implementation Risk
		Stakeholder Alignment
Level 3	Sub-criteria	Capital Expenditure (CAPEX)
		Operating Expenditure (OPEX)
		Project Economic Indicators (NPV, IRR, PI, Payback Period)
		Facility Configuration and Integration Feasibility
		Operational Reliability and Sustainability

		Compliance with Environmental Requirements (AMDAL, UKL/UPL)
		Land Use and Permitting Constraints (LP2B, LSD, PPKH)
		Gas Onstream Timeline
		Execution Complexity and Schedule Risk
		Alignment with Buyer Requirements
		Community and Regulatory Acceptance
Level 4	Alternatives	Alternative 1 - KYM-B & KYM-C to SP RDG (Upgrade)
		Alternative 2 - Alt. 1 + Compression at SP RDG
		Alternative 3 - KYM-B & KYM-C to SPU A (Upgrade)
		Alternative 4 - Alt. 3 + Compression at SPU A
		Alternative 5 - Split Flow to SPU A & SP RDG

Source: Author's calculation based on AHP survey results (2026)

Pairwise comparisons and priority derivation

Once the hierarchy is established, AHP applies pairwise comparisons to elicit stakeholder judgments regarding the relative importance of:

a. The main criteria,
b. Sub-criteria under each main criterion, and
c. The relative preference of alternatives with respect to each sub-criterion.

Judgments are collected from relevant decision-makers and subject-matter experts using Saaty’s fundamental scale, ensuring that qualitative preferences can be expressed consistently in numerical form from 1 to 9 scale. The comparison scale adopted in this research is presented in Table 7. The resulting pairwise comparison matrices are then synthesized to compute local priority weights (e.g., criteria weights and sub-criteria weights) using the eigenvector-based priority estimation commonly adopted in AHP applications. The main-criteria pairwise comparison matrix used in this research is presented in Table 12.

Table 12. Pairwise Comparison Matrix of Main Criteria

Criteria	Economic	Technical	Regulatory & Environmental	Project Risk	Stakeholder
Economic	1	3	2	2	1/2
Technical	1/3	1	1/2	2	1/3
Regulatory & Environmental	1/2	2	1	2	2
Project Risk	1/2	1/2	1/2	1	1/4
Stakeholder	2	3	1/2	4	1

Source: Author's calculation based on AHP survey results (2026)

Note:

- The pairwise comparison values were obtained from an AHP survey conducted with expert respondents
- The matrix reciprocal, where aij = 1/aji
- The values aij are derived from Saaty’s fundamental scale based on expert judgment.

Consistency check

To ensure the credibility of judgments and to reduce arbitrary weighting, consistency is evaluated for each pairwise comparison matrix using the Consistency Ratio (CR). A CR within the acceptable threshold indicates that the judgments are sufficiently coherent for decision synthesis; if not, the relevant comparisons are reviewed and refined. The criteria weights and the associated consistency test results are summarized in Table 13.

Table 13. Criteria Weights and Consistency Test Results

Code	Criteria	Local Weight (w)	λmax	CI	CR
C1	Economic Performance	0,259	**5.4348**	**0.1087**	**0.0970**
C2	Technical and Operational Feasibility	0,111			
C3	Regulatory and Environmental Compliance	0,244			
C4	Project Implementation Risk	0,086			
C5	Stakeholder Alignment	0,299			

Source: Author's calculation based on AHP synthesis (2026)

Consistency Metrics:

- Consistency Index (CI)=(λmax-n) / (n-1)
- Consistency Ratio (CR)=CI÷RI
- The judgment is considered if CR≤0.1

Synthesis and scenario ranking

After establishing the priority weights, the overall priority score for each alternative is obtained through hierarchical synthesis. Local weights of sub-criteria are combined with their parent-criterion weights to produce global weights, which are then used to aggregate alternative priorities into a final ranking. In this research, the distinction between local and global weights is explicitly reported to preserve traceability and to clarify how strategic drivers, such as permitting/land constraints and schedule risk, propagate into the final decision outcome.

The local and global weights of sub-criteria are summarized in Table 14.

Table 14. Local and Global Weights of Sub-Criteria

Parent Criterion	Sub-criterion	Local Weight	Global Weight
Economic Performance	Capital Expenditure (CAPEX)	0,272	0,070
	Operating Expenditure (OPEX)	0,120	0,031
	Economic Indicators (NPV, IRR, PI, Payback Period)	0,608	0,157
Technical & Operational Feasibility	Facility Configuration and Integration	0,167	0,019
	Operational Reliability	0,833	0,093
Regulatory & Environmental Compliance	Environmental Approval (AMDAL, UKL/UPL)	0,143	0,035
	Land Use and Permitting (LP2B, LSD, PPKH)	0,857	0,209
Project Implementation Risk	Gas Onstream Timeline	0,800	0,069
	Execution Complexity and Schedule Risk	0,200	0,017
Stakeholder Alignment	Buyer Requirements Alignment	0,250	0,075
	Community and Regulatory Acceptance	0,750	0,225

Source: Author's calculation based on AHP survey results (2026)

Note: Global weights are calculated by multiplying the local weight of each sub-criterion by the weight of its corresponding parent criterion.

The outcome of the AHP analysis provides a structured and defensible basis for selecting the most suitable KYM development scenario by integrating:

a. stakeholder priorities,
b. value-based criteria derived from VFT, and
c. consistency-checked quantitative synthesis.

Building on the derived global weights of sub-criteria, the next stage of analysis integrates these priority values with the performance of five alternative KYM gas development scenarios through pairwise comparison.

Table 15. Final Scoring Global Weight and all Alternatives

Parent Criterion	Sub-criterion	Global Weight	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5
Economic Performance	Capital Expenditure (CAPEX)	0,070	0,063	0,268	0,144	0,396	0,129
	Operating Expenditure (OPEX)	0,031	0,091	0,227	0,106	0,215	0,360
	Economic Indicators (NPV, IRR, Payback Period)	0,157	0,478	0,075	0,203	0,110	0,135
Technical & Operational Feasibility	Facility Configuration and Integration	0,019	0,286	0,343	0,133	0,165	0,073
	Operational Reliability	0,093	0,370	0,301	0,096	0,170	0,063
Regulatory & Environmental Compliance	Environmental Approval (AMDAL, UKL/UPL)	0,035	0,379	0,361	0,074	0,113	0,073
	Land Use and Permitting (LP2B, LSD, PPKH)	0,209	0,366	0,362	0,115	0,092	0,065
Project Implementation Risk	Gas Onstream Timeline	0,069	0,447	0,220	0,108	0,150	0,074
	Execution Complexity and Schedule Risk	0,017	0,457	0,207	0,098	0,178	0,060
Stakeholder Alignment	Buyer Requirements Alignment	0,075	0,078	0,078	0,266	0,374	0,205
	Community and Regulatory Acceptance	0,225	0,450	0,319	0,100	0,074	0,058
		Scoring:	**0,357**	**0,256**	**0,135**	**0,152**	**0,099**

Source: Author's calculation based on AHP survey results (2026)

These local priorities are then aggregated (sum product) using the corresponding global weights to produce an overall composite score for each alternative. The results of the AHP synthesis indicate that Alternative 1 achieves the highest score, followed by Alternative 2, while Alternatives 3, 4, and 5 show relatively lower performance. This outcome suggests that routing gas to SP Randegan without additional compression provides the most balanced solution across economic, technical, regulatory, project risk, and stakeholder considerations, thereby serving as the preferred development scenario for the KYM gas project.

Sensitivity Analysis

Sensitivity analysis enables decision makers to assess how the prioritization of alternatives shifts in response to changes in the weighting of criteria. This process determines whether a more significant criterion influences the selection of the optimal alternative, identifies any resulting changes in the preferred alternative, and quantifies their magnitude. In this research, a sensitivity analysis is conducted by systematically adjusting the weight assigned to each criterion. The weight of the selected criterion is set to zero, while the remaining criteria are adjusted proportionally. The resulting changes in the priorities of the alternatives are then observed as the criterion's weight varies. This approach is applied to the criteria of economic, technical, regulatory & environmental, project risk, and stakeholder. The resulting prioritization of alternatives is visualized in Figure 3 below.

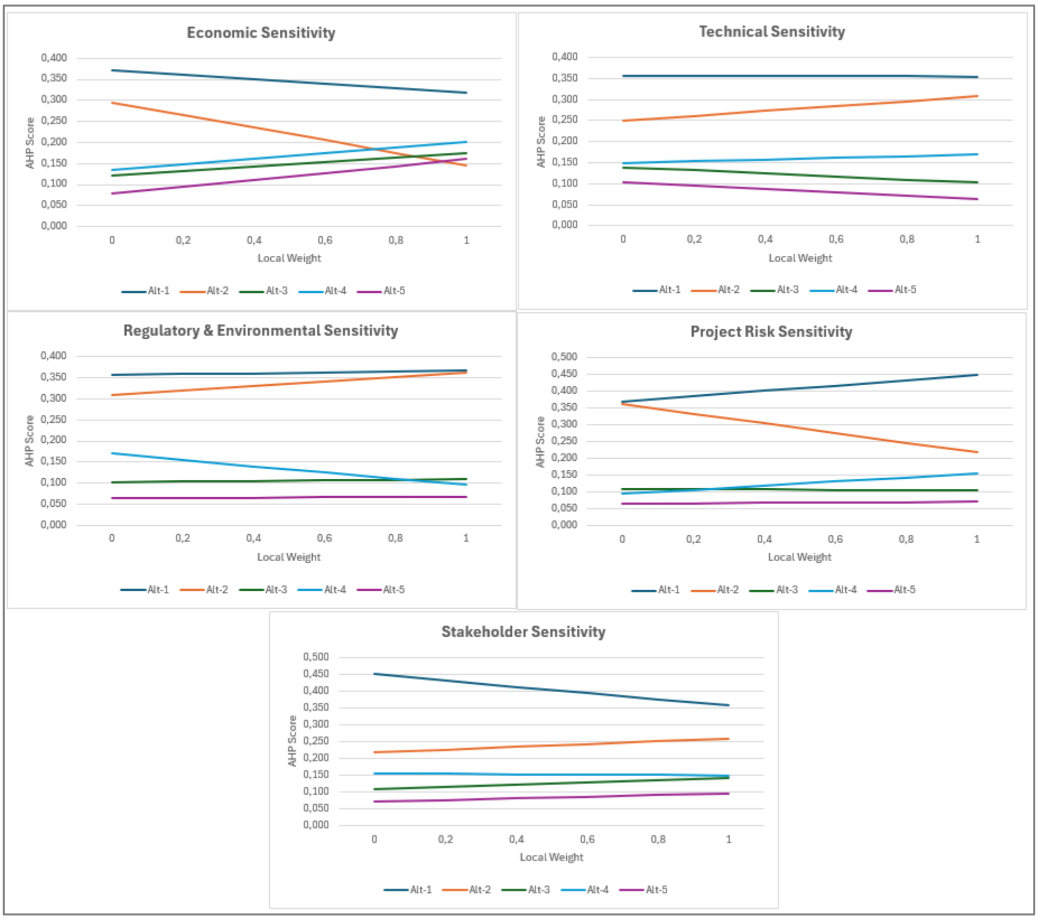

Figure 1. Sensitivity Analysis on variable economic, technical, regulatory & environmental, project risk, and stakeholder criterion
Source: Author calculation, (2026)

The sensitivity analysis results presented in Figure 3 demonstrate the robustness of the decision model by assessing how variations in the weight assigned to each main criterion influence the ranking of alternatives. The analysis involved varying the weight of a single criterion from 0 to 1, with proportional adjustments to the remaining criteria. Subsequent changes in alternative priorities were observed for the Economic, Technical, Regulatory, Environmental, Project Risk, and Stakeholder criteria.

Overall, Alternative 1 consistently ranks highest across most weighting scenarios, indicating it is the most robust and balanced alternative. This outcome suggests that Alternative 1 performs well across multiple criteria and does not rely heavily on any single decision factor. The Economic Sensitivity graph exhibits the greatest variation among alternatives. As the weight of the Economic criterion increases, the scores of Alternatives 3, 4, and 5 rise, whereas Alternative 2 declines significantly. Multiple line intersections indicate that the ranking of lower-priority alternatives is sensitive to changes in economic preferences. Despite these shifts, Alternative 1 remains the top-ranked option throughout the analysis. In the Technical Sensitivity graph, Alternative 2 improves as the importance of the technical criterion increases, while Alternatives 3 and 5 decline gradually. However, no significant rank reversal occurs for the highest-ranked alternative, indicating stable decision outcomes in scenarios that emphasize technical considerations. The Regulatory and Environmental Sensitivity graph displays stable trends with minimal changes in ranking. Alternatives 1 and 2 remain dominant, while Alternative 4 decreases slightly as the importance of regulatory considerations increases. These results indicate that the decision model is relatively insensitive to changes in regulatory and environmental priorities. The Project Risk Sensitivity graph demonstrates that Alternative 1 becomes increasingly favorable as the importance of project risk increases, while Alternative 2 declines significantly. This finding suggests that Alternative 1 performs more strongly with respect to schedule and complexity risk considerations. The Stakeholder Sensitivity graph indicates that Alternatives 2, 3, and 5 improve slightly as the importance of stakeholder considerations increases, while Alternative 1 decreases moderately. Despite this trend, Alternative 1 maintains the highest overall score.

Business Solution

The business issue highlights the absence of an integrated, objective, and accountable decision-making framework for selecting the most appropriate development scenario for the KYM gas structure. Addressing this gap, this research proposes a structured business solution that combines both qualitative and quantitative decision-support approaches. The proposed framework integrates technical, economic, risk, and stakeholder considerations into a unified evaluation model by synthesizing external and internal analyses through PESTEL and SWOT, structuring stakeholder values using VFT, and applying quantitative prioritization through the AHP. Through this integrated approach, a complex and multi-dimensional decision problem is transformed into a transparent, consistent, and defensible decision-support framework.

The results of the AHP analysis indicate that Alternative 1, which routes gas from KYM-B and KYM-C to SP Randegan with facility upgrading, achieves the highest overall score among the evaluated development scenarios. This outcome reflects its consistent performance across key decision criteria. From an economic perspective, Alternative 1 benefits from relatively lower CAPEX due to the utilization of existing infrastructure, while maintaining competitive project economics. From a technical standpoint, integration with existing facilities reduces system complexity and enhances operational feasibility. Furthermore, this alternative exhibit lower exposure to regulatory, environmental, and land-related constraints, as identified in the preceding SWOT and PESTEL analyses, thereby improving its overall implementation readiness. To illustrate the technical configuration of the selected alternative, the process flow arrangement of Alternative 1 is presented in Figure 2.

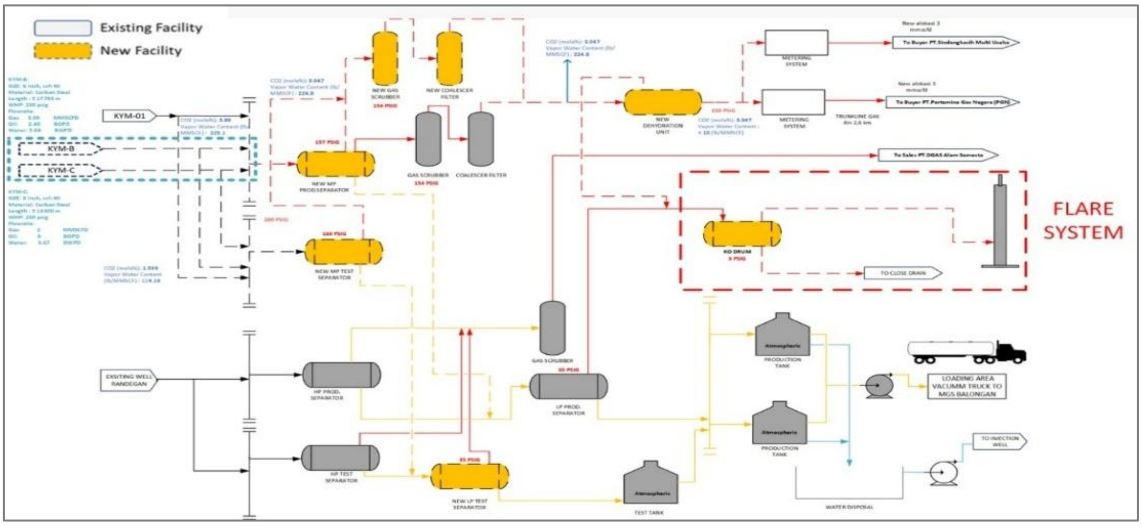

Figure 2. Process Flow Diagram Alternative-1
Source: Adapted from Pertamina EP internal technical document (2023)

From a strategic perspective, the preference for Alternative 1 reflects a pragmatic decision-making approach that emphasizes value optimization through the effective use of existing assets, rather than pursuing more capital-intensive and complex expansion options.

This result is consistent with internal strengths identified in the SWOT analysis, particularly Pertamina EP's established infrastructure, technical capabilities, and operational experience. It also demonstrates a risk-aware strategy in addressing external uncertainties, including permitting complexity, land-use constraints, and stakeholder-related challenges. The findings suggest that considerations such as faster monetization, lower execution risk, and higher implementation readiness are prioritized over alternatives that may offer higher potential returns but involve greater uncertainty and execution complexity.

From a managerial perspective, the selection of Alternative 1 provides clear and actionable direction for project implementation. The company should prioritize optimizing and integrating existing facilities at SP Randegan as the primary development pathway for the KYM structure. This approach requires ensuring that facility configurations comply with gas quality specifications and maintain operational reliability to support continuous gas delivery to buyers. At the same time, proactive management of regulatory compliance, environmental requirements, and stakeholder engagement is essential to mitigate potential delays and ensure smooth project execution. In addition, the structured decision-making framework developed in this research can be institutionalized within Pertamina EP as a standardized tool for evaluating future upstream development projects, thereby enhancing decision transparency, consistency, and alignment across technical, commercial, and regulatory functions.

Overall, the integration of environmental analysis, value-based decision structuring, and multi-criteria evaluation demonstrates that a systematic and structured approach can significantly improve the quality and robustness of strategic decision-making in upstream oil and gas projects, particularly in complex development contexts such as the KYM project.

CONCLUSION

The conclusions are formulated to directly address the research objectives and provide a clear synthesis of the research findings. First, regarding the identification and classification of critical decision-making criteria, five key criteria guide the evaluation of development scenarios for the KYM gas structure: economic performance, technical and operational feasibility, regulatory and environmental compliance, project implementation risk, and stakeholder alignment. These criteria, identified using the VFT analysis, are detailed as measurable sub-criteria. The AHP results demonstrate that stakeholder alignment, technical reliability, and economic indicators are the most influential factors in the decision-making process, suggesting that optimal decision-making in upstream gas development depends not only on financial performance but also on execution feasibility and the capacity to address external constraints, such as regulatory and land issues common in Indonesia. Second, a structured multi-criteria evaluation framework is developed by integrating VFT and AHP. The VFT approach systematically translates stakeholder values into fundamental and means objectives organized into a hierarchy of evaluation criteria and sub-criteria, grounding the decision framework in strategic priorities rather than predefined technical alternatives. The AHP method then quantifies stakeholder judgments through pairwise comparisons, deriving priority weights for each criterion and sub-criterion, enabling systematic comparison of alternatives by integrating quantitative indicators with qualitative considerations. The hierarchical structure, supported by consistency ratio testing and sensitivity analysis, ensures consistent, transparent, and replicable evaluation of complex, multidimensional decision factors while maintaining stable rankings across varying assumptions. Third, the analysis identifies Alternative 1 as the most optimal development scenario, involving routing production from KYM-B and KYM-C through new flowlines integrated with existing production from KYM-01 to SP Randegan, supported by facility upgrading. This alternative achieves the highest overall priority score, offering a balanced trade-off across all evaluation criteria by leveraging existing infrastructure to reduce capital requirements and system complexity while enhancing implementation readiness, with lower exposure to permitting and land-use constraints. From an implementation perspective, the proposed development timeline targeting project approval by Q2 2026 and full onstream delivery by Q4 2028 is considered feasible, with phased execution ensuring alignment between drilling activities, facility upgrading, and production readiness. Overall, the selection of Alternative 1 reflects a pragmatic and risk-aware strategic decision prioritizing timely monetization, controlled capital expenditure, and execution feasibility, highlighting that optimal development decisions in upstream gas projects must balance economic value with technical feasibility and external constraints. Furthermore, the research demonstrates that combining value-based decision structuring with multi-criteria evaluation provides a robust, transparent, and actionable framework for supporting decision-making in complex upstream development environments.

REFERENCES

Agbede, O. O., Akhigbe, E. E., Ajayi, A. J., & Egbuhuzor, N. S. (2023). Structuring financing mechanisms for LNG plants and renewable energy infrastructure projects globally. *IRE Journals, 7*(5), 379–392.

Amini-Philips, A., Ibrahim, A. K., & Eyinade, W. (2022). *Financing the energy transition: Models for linking decarbonization strategies with corporate performance.*

Economides, M. J., Hill, A. D., Ehlig-Economides, C., & Zhu, D. (2013). *Petroleum production systems* (2nd ed.). Pearson.

Energy Institute. (2024). *Statistical review of world energy 2024*. https://www.energyinst.org/statistical-review

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Mitigation of climate change*. Cambridge University Press. https://doi.org/10.1017/9781009157926

International Energy Agency. (2023). *Southeast Asia energy outlook 2023*. IEA.

International Energy Agency. (2023). *World energy outlook 2023*. IEA.

International Energy Forum. (2023). *IEF energy outlook 2023*. International Energy Forum.

Keeney, R. L. (1992). *Value-focused thinking: A path to creative decision making*. Harvard University Press.

Keeney, R. L. (1996). Value-focused thinking: Identifying decision opportunities and creating alternatives. *European Journal of Operational Research, 92*(3), 537–549.

Ministry of Energy and Mineral Resources. (2017). *Presidential Regulation No. 22 of 2017 concerning the National Energy General Plan (RUEN).* Government of Indonesia.

Ministry of Energy and Mineral Resources. (2024). *Handbook of energy and economic statistics of Indonesia 2024*. Ministry of Energy and Mineral Resources.

National Energy Council. (2022). *Indonesia energy outlook 2022*. National Energy Council.

PT Pertamina EP. (2024). *Annual report 2024*. PT Pertamina EP.

PT Pertamina Hulu Energi. (2024). *Sustainability report 2024*. PT Pertamina Hulu Energi.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International Journal of Services Sciences, 1*(1), 83–98.

Sharif, S. A., & Hammad, A. (2019). Simulation-based multi-objective optimization of institutional building renovation considering energy consumption, life-cycle cost and life-cycle assessment. *Journal of Building Engineering, 21*, 429–445.

SKK Migas. (2024). *Annual report 2024*. Special Task Force for Upstream Oil and Gas Business Activities.

Society of Petroleum Engineers. (2023). *Managing mature oil and gas fields: Best practices for production optimization*. Society of Petroleum Engineers.

Strong, D., Kay, M., Conner, B., Wakefield, T., & Manogharan, G. (2018). Hybrid manufacturing—Integrating traditional manufacturers with additive manufacturing (AM) supply chain. *Additive Manufacturing, 21*, 159–173.

Talipova, A., & Parsegov, S. (2018). Evolution of natural gas business model with deregulation, financial instruments, technology solutions, and rising LNG export: Comparative study of projects inside the US and abroad. *SPE Annual Technical Conference and Exhibition*, D021S019R005.

World Bank. (2023). *Commodity markets outlook: Lower prices, little relief*. World Bank.