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Integration of Artificial Intelligence-Based Decision Support Systems for Business Risk Mitigation: A Case Study of PT Pertamina (Persero)

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Abstract

The volatility of global energy markets, exchange rate fluctuations, supply chain disruptions, and cybersecurity threats require oil and gas companies to possess proactive and precise risk mitigation capabilities. This study aims to analyze the role, suitability, and strategic design of integrating Artificial Intelligence (AI)-based Decision Support Systems (DSS) to support business risk mitigation at PT Pertamina (Persero). Using a qualitative method through a critical literature review of recent publications (2021–2026) and a descriptive-critical case study of the company's official publications, the findings show that the capabilities of Machine Learning, Predictive Analytics, Natural Language Processing, and Anomaly Detection can overcome the limitations of conventional, reactive DSS. Although PT Pertamina (Persero) transformed its digital infrastructure into the Pertamina Digital Hub in late 2024, the critical analysis identifies four strategic gaps: fragmented data integration across business units, limited real-time prediction updates, a distance between algorithmic outputs and managerial judgment, and the readiness of governance and legal accountability. This study recommends an integrated DSS-AI architecture hybridized with the ISO 31000:2018 framework, the development of a risk priority dashboard, the application of human-in-the-loop principles, and a phased implementation roadmap based on pilot projects.

Keywords: Artificial Intelligence, Decision Support System, Risk Management, Business Risk Mitigation, PT Pertamina (Persero)

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INTRODUCTION

Global economic uncertainty, escalating geopolitical tensions, fluctuating energy commodity prices, and supply chain vulnerabilities have fundamentally changed the landscape of modern business management. Companies are no longer expected to focus solely on expanding profitability; they must also demonstrate operational resilience through the ability to identify, predict, and control various sources of risk before they develop into crises. This urgency reaches a critical point in the oil and gas industry, which is capital-intensive, operates high-risk technologies, and has tightly coupled processes. A disruption at a single operational node—such as damage to a production facility or a pipeline leak—can trigger a domino effect that cripples processing, storage, transportation, and distribution of energy on a wide scale.

Historically, management has relied on computer-based Decision Support Systems (DSS) to structure information and evaluate policy alternatives so that decisions do not rest solely on intuition or individual experience. However, when organizations face surges in data volume (big data) and rapidly changing risk variables, conventional DSS show limitations because they tend to process historical data statically and are less responsive in predicting risks that have not yet occurred. The integration of Artificial Intelligence (AI) is a strategic breakthrough for addressing this gap. AI technology enables systems to learn hidden patterns from historical data, detect operational anomalies early, project failure probabilities, and formulate evidence-based (data-driven) mitigation recommendations (Sircar et al., 2021; Bahaloo et al., 2023; Almazrouei et al., 2023).

As a state-owned energy enterprise (BUMN) that integrates its business chain from the upstream, midstream, to downstream sectors, PT Pertamina (Persero) plays a vital role in safeguarding national energy security while facing multisectoral risk exposure covering production, processing, procurement, distribution, finance, occupational safety, and environmental sustainability. In response to the demands of digital transformation, the company developed the Pertamina Digital Hub as a transformation of the Pertamina Integrated Enterprise Data and Command Center (PIEDCC) on December 11, 2024, built on three main pillars: Remote Surveillance, Digital Factory, and the Technical Orchestration Center (PT Pertamina (Persero), 2025).

Nevertheless, the existence of digital monitoring and analytics infrastructure does not automatically prove that all corporate risk management processes have been integrated into a single, cross-functional AI-based DSS ecosystem. By distinguishing digital capabilities that have been officially published from conceptual development designs, this article aims to examine the conceptual framework of AI-based DSS, synthesize recent research findings, analyze the suitability and gaps of its application at PT Pertamina (Persero), and formulate

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strategic recommendations to improve the effectiveness of the company's business risk mitigation.

RESEARCH METHOD

Sampling and Data Collection Techniques

Literature sources were selected purposively, using inclusion criteria of accredited/reputable national and international journal articles within the last five years (2021–2026) that discuss the convergence of DSS, Artificial Intelligence, Machine Learning, and risk management in the energy industry. Empirical data on the risk profile and digital capabilities of PT Pertamina (Persero) were collected through documentation of the company's official publications, particularly the PT Pertamina (Persero) Annual Report 2024, as well as the international standard ISO 31000:2018.

Data Analysis Technique

Data analysis was carried out in three systematic stages: (1) Comparative Literature Synthesis, namely comparing the approaches, findings, and research gaps of fifteen recent studies; (2) Gap Analysis, namely matching the theoretical framework of AI-based DSS with the factual condition of risk mapping and digital infrastructure at PT Pertamina (Persero); and (3) Conceptual Design Formulation, namely drafting recommendations for the system architecture, key performance indicators, and a phased implementation roadmap.

RESULTS AND DISCUSSION

Mapping of the Digital Ecosystem and Risk Profile of PT Pertamina (Persero)

Based on the 2024 Annual Report, PT Pertamina (Persero) has built a progressive digitalization foundation by realizing 16 of the 17 strategic initiatives in the ICT Masterplan 2020–2024. A key milestone of this transformation was the inauguration of the Pertamina Digital Hub on December 11, 2024, as an evolution of PIEDCC, built on three main pillars: Remote Surveillance for remote operations monitoring, Digital Factory for developing digital analytics solutions, and the Technical Orchestration Center for orchestrating technical reliability across operations (PT Pertamina (Persero), 2025).

Although digital infrastructure continues to be strengthened, the complexity of Pertamina's business presents six overlapping main risk clusters, which require specific AI-based DSS capabilities as mapped in Table 1.

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Table 1: Mapping of Business Risk Profile and AI-Based DSS Technology Requirements at PT Pertamina (Persero)

Business Risk Cluster	Specific Problem Manifestations	Required System Capabilities	Proposed AI/DSS Technology
1. Operational	Production machinery failure, pipeline leaks, refinery facility disruptions, and delayed asset maintenance.	Prediction of equipment failure before fatal damage occurs (predictive maintenance).	Machine Learning and Deep Learning based on IoT sensor data.
2. Financial	Global crude oil price volatility, foreign exchange fluctuations, interest rates, and investment funding needs.	Cash flow projection and simulation of revenue sensitivity to market shocks.	Predictive Analytics integrated with Monte Carlo simulation.
3. Supply Chain	Delayed raw material deliveries, energy transportation disruptions, supplier incapacity, and stock deviations.	Accurate demand forecasting and early detection of logistics deviations and supplier performance.	Time-Series Forecasting and Anomaly Detection.
4. Safety and Environment	Workplace accidents, potential facility fires/explosions, and leak and environmental pollution incidents.	Early warning system for workplace hazards and real-time monitoring of emissions or leaks.	Machine Learning and environmental sensor analytics.
5. Technology and Cybersecurity	Cyberattacks on critical infrastructure, corporate data theft, and manipulation of digital information.	Identification of network intrusions and access activity patterns that deviate from normal conditions.	Anomaly Detection based on network traffic monitoring.
6. Human Resources and Governance	Digital competency gaps, procedural nonconformity, weak oversight, and accountability of AI decisions.	Automated extraction of compliance reports and weighting of corporate risk priorities.	Natural Language Processing (NLP) and multi-criteria DSS.

Gap Analysis between Theory and Empirical Implementation

The meeting point between the ideal framework of AI-based DSS and the empirical condition of PT Pertamina (Persero), as revealed from public information, identifies four strategic gaps that must be bridged:

a. **Cross-Functional Data Integration Gap:** Theoretically, AI-based DSS requires integrated data flows from all lines of the organization. However, Pertamina's

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structure, which encompasses various subholdings and business units, has diverse information system characteristics. Based on the public information reviewed, there is not yet adequate evidence that all cross-functional risk data (production, finance, HSE, and supply chain) have been consolidated into a single AI-based DSS engine that produces integrated corporate mitigation recommendations.

b. **Historical Analysis versus Real-Time Prediction Gap:** Conventional methods such as risk matrices, AHP, and Monte Carlo simulation are useful for evaluating impacts, but require manual updates when market conditions change (Hidayatullah et al., 2025). In contrast, AI algorithms can dynamically update risk probabilities as new data streams arrive, enabling a far more responsive early warning system.
c. **Prediction-to-Managerial-Decision Translation Gap:** An algorithmic prediction of a high probability of equipment failure does not automatically produce a mitigation action decision. Management must still weigh repair costs, spare part availability, shutdown schedules, and the impact on energy supply continuity.
d. **Human Resource Readiness and Governance Accountability Gap:** AI adoption requires analytical literacy at the managerial level as well as clarity of legal accountability. As affirmed by Firmansyah et al. (2026), the use of AI recommendations in the decision-making of the board of directors of a limited liability company continues to place legal and fiduciary responsibility on the authorized management.

In addition, an evaluation of the technological balance shows that AI-based DSS offers strategic advantages in the form of accelerated automated risk identification, the ability to predict operational disruptions, ease of urgency-based risk prioritization, efficiency in manual analysis time, and continuous monitoring. However, its application also has inherent limitations, namely high dependence on the quality of historical data, large infrastructure investment requirements, the potential for prediction errors if models are not rigorously validated, cyberattack risks, the need for specialist experts, and the potential for excessive reliance on algorithms (automation bias).

Strategic Recommendation Architecture and Implementation Roadmap

To optimize the foundation of the Pertamina Digital Hub while closing the four gaps, eight strategic recommendations are formulated for PT Pertamina (Persero):

1. **Development of an Integrated DSS-AI Ecosystem:** Connecting the risk analytics module directly with the capabilities of the Pertamina Digital Hub to consolidate

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production, processing, distribution, finance, HSE, and supply chain data into a single corporate oversight framework.

2. **Operationalization of Predictive Analytics for an Early Warning System:** Developing ML and Predictive Analytics models to predict critical equipment failures, simulate oil price and exchange rate volatility, project raw material delivery delays, identify potential workplace accidents, and detect energy distribution anomalies.
3. **Design of a Corporate Risk Priority Dashboard:** Developing a unified visual interface that displays a risk heatmap based on likelihood and impact (low, medium, high, and critical categories), a corporate risk level index, historical trends across quarters, and a list of initial mitigation recommendations for high-priority risks (such as global energy supply disruption, global oil price fluctuations, regulatory compliance, cyber threats, and oil spill risk).
4. **Hybridization of AI with Conventional Risk Management Methods:** Integrating ISO 31000:2018 as the risk governance framework, AHP for determining strategic criteria weights, and House of Risk (HOR) for mapping the root causes of supply chain risk, while AI acts as an accelerator for predictive computation and anomaly detection.
5. **Strengthening Data Quality and Cyber Resilience:** Implementing strict data governance covering input standardization, cleansing, and validation across business units, accompanied by layered cybersecurity protection through data encryption, role-based access restrictions, periodic backups, and network security audits.
6. **Acceleration of Human Resource Competency:** Conducting continuous training programs that not only produce analytics and AI experts, but also equip line managers with the ability to interpret algorithmic outputs into corporate strategic policy.
7. **Enforcement of AI Governance and the Human-in-the-Loop Principle:** Establishing internal policies on algorithm validation, periodic model audits, and the division of authority. Strategic decisions with a major impact on safety, finance, and operational continuity must go through management validation and approval (human-in-the-loop).
8. **Phased Execution Based on Pilot Projects:** Implementation is carried out gradually in business units with high risk urgency and adequate data readiness, in accordance with the five-phase roadmap in Table 2.

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Table 2: Phased Implementation Roadmap for AI-Based DSS at PT Pertamina (Persero)

Phase	Strategic Program	Target Output (Deliverables)
Phase 1	Audit of cross-functional data readiness and quality, and identification of high-priority risks.	System architecture requirements map and validated data catalog.
Phase 2	Development of AI algorithm models and integration of the data pipeline with the Digital Hub.	Functional prototype of the AI-based DSS.
Phase 3	Limited trial (pilot project) in selected business units with the highest risk exposure.	Model accuracy evaluation report and benefit feasibility.
Phase 4	Full development of the corporate risk priority dashboard and cross-unit system integration.	Tested and secure operational DSS-AI system.
Phase 5	Comprehensive performance evaluation, large-scale HR training, and expansion of corporate-wide application.	Improved capability and maturity of risk management.

To ensure implementation effectiveness at each phase, the company needs to establish seven Key Performance Indicators (KPIs), complete with baselines and measurable targets, covering: (1) prediction accuracy and model error rate; (2) speed of early risk detection; (3) number of risk events successfully prevented or reduced; (4) reduction in operational disruption duration (downtime); (5) effectiveness of mitigation action completion; (6) verifiable cost savings; and (7) level of compliance with AI procedures and governance.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The integration of Artificial Intelligence (AI)-based Decision Support Systems (DSS) delivers a fundamental transformation in business risk mitigation, from a reactive approach based on historical evaluation toward risk management that is proactive, predictive, and measurable. The synthesis of recent literature (2021–2026) confirms that combining Machine Learning, Predictive Analytics, Natural Language Processing, and Anomaly Detection algorithms with conventional risk management methods (such as ISO 31000:2018, AHP, House of Risk, and Monte Carlo simulation) provides a far more comprehensive analytical framework than replacing conventional methods entirely.

In the case study of PT Pertamina (Persero), the launch of the Pertamina Digital Hub and its three main pillars (Remote Surveillance, Digital Factory, and Technical Orchestration Center) has built a highly relevant digital monitoring foundation. However, based on a review of public information, integrating all corporate business risks—including

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operational, financial, supply chain, safety, environmental, cybersecurity, and human resources and governance risks—into a single AI-based DSS still requires strengthening in cross-functional data integration, real-time prediction updates, human resource literacy readiness, cybersecurity, and decision accountability. Phased implementation through pilot projects and control based on the human-in-the-loop principle are key to ensuring that technological efficiency remains aligned with accountable corporate governance.

Recommendations

For the Management of PT Pertamina (Persero): It is recommended to prioritize the standardization and integration of data quality across business units within the Pertamina Digital Hub ecosystem as the foundation for developing an AI-based DSS prototype. Implementation should begin with a pilot project in high-risk sectors, accompanied by strengthened cybersecurity, enhanced analytical capabilities of human resources, and the establishment of AI governance regulations that ensure transparency and the human-in-the-loop principle.

For Future Research: Given that this study uses publicly available information and documents, further research is recommended to utilize the company's primary operational data and to conduct empirical testing of AI-based DSS algorithm models so that the system's effectiveness in reducing business risks and losses can be measured quantitatively.

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