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RISKS OF IMPLEMENTING AND USING ARTIFICIAL INTELLIGENCE BY OIL AND GAS SECTOR ENTERPRISES

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Abstract. The article is devoted to the study of risks associated with the implementation and use of artificial intelligence (AI) by enterprises in Ukraine's oil and gas sector. The purpose of the article is to identify the key threats arising in the process of digital transformation of the industry, classify and assess these threats, and develop strategies for managing such risks to ensure the safe, effective, and ethical application of AI technologies.

The research methodology is based on risk analysis methods in accordance with the international ISO 31000 standard, including both qualitative and quantitative risk assessment, the construction of a risk matrix, as well as methods of theoretical generalization, comparative analysis, systematization, and expert evaluation. Scenario modeling tools were applied to predict the potential consequences of risk realization.A systematic approach was applied to assess the risk levels of using AI technologies in oil and gas enterprises.

The study revealed that most risks fall within a high threat level (6–9 points), requiring immediate response. The most critical risks were identified as increased vulnerability to cyberattacks, unreliability of algorithms, data breaches, and social risks related to job reductions and the need for personnel retraining.

A set of strategic recommendations was formulated, covering technical, organizational, legal, economic, and social aspects of risk management. To manage the risks associated with the adoption and use of AI in the oil and gas sector effectively, a comprehensive approach is proposed. This includes phased algorithm testing, ensuring transparency of AI decision-making (Explainable AI), data and access audits, strengthening cybersecurity measures, developing ethical AI codes, implementing retraining programs, and updating the regulatory framework.

The scientific novelty of the research lies in adapting risk management principles to the specifics of a high-risk industry under conditions of digital transformation and in developing a detailed risk matrix that considers technical, informational, economic, social, environmental, legal, and ethical aspects of AI implementation.

The practical significance of the study lies in the development of specific recommendations for industry enterprises aimed at minimizing risks and ensuring the safe and effective use of AI—an especially relevant issue in the context of global competition, cyber threats, and sustainable development requirements.

Keywords: artificial intelligence, risk management, oil and gas sector, digital transformation, cybersecurity, AI ethics.

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РИЗИКИ ВПРОВАДЖЕННЯ ТА ВИКОРИСТАННЯ ШТУЧНОГО ІНТЕЛЕКТУ ПІДПРИЄМСТВАМИ НАФТОГАЗОВОГО СЕКТОРУ

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Анотація. Стаття присвячена дослідженню ризиків, пов'язаних із впровадженням та використанням штучного інтелекту (ШІ) підприємствами нафтогазового сектору України. Метою статті є виявлення ключових загроз, що виникають у процесі цифрової трансформації галузі, їх класифікація та оцінка з подальшою розробкою стратегій управління цими ризиками для забезпечення безпечного, ефективного й етичного використання технологій ШІ.

У процесі дослідження використано методи ризик-аналізу на основі міжнародного стандарту ISO 31000, включаючи якісну та кількісну оцінку ризиків, побудову матриці ризиків, а також методи теоретичного узагальнення, порівняльного аналізу, систематизації та експертного оцінювання. Застосовано інструменти сценарного моделювання для передбачення можливих наслідків реалізації ризиків.Застосовано системний підхід до оцінки рівнів ризику використання технологій ШІ підприємствами нафтогазового сектора.

У результаті дослідження визначено, що більшість ризиків мають високий рівень загрози (6–9 балів), що потребує негайного реагування. Найбільш критичними виявилися підвищена вразливість до кібератак, ненадійність алгоритмів, компрометація даних, а також соціальні ризики, пов'язані зі скороченням робочих місць і потребою в перекваліфікації персоналу.

Сформульовано низку стратегічних рекомендацій, які охоплюють технічні, організаційні, правові, економічні та соціальні аспекти управління ризиками. Для ефективного управління ризиками, пов'язаними з упровадженням та використанням штучного інтелекту в нафтогазовому секторі, запропоновано впровадження комплексного підходу, що включає: поетапне тестування алгоритмів, забезпечення прозорості рішень систем ШІ (Explainable AI), аудит даних і доступу, підвищення рівня кіберзахисту, розробку етичних кодексів ШІ, програми перекваліфікації персоналу та оновлення нормативно-правової бази.

Наукова новизна полягає в адаптації принципів управління ризиками до специфіки високоризикової галузі в умовах цифрової трансформації, а також у побудові деталізованої матриці ризиків з урахуванням технічних, інформаційних, економічних, соціальних, екологічних, правових та етичних аспектів застосування ШІ.

Практичне значення дослідження полягає в розробці конкретних рекомендацій для підприємств галузі щодо мінімізації ризиків та забезпечення безпечного і ефективного використання ШІ, що є особливо актуальним в умовах глобальної конкуренції, кіберзагроз і вимог сталого розвитку.

Ключові слова: штучний інтелект, управління ризиками, нафтогазовий сектор, цифрова трансформація, кібербезпека, етика ШІ.

Introduction. In the current context of digital transformation across key economic sectors, artificial intelligence (AI) plays an increasingly important role in enabling efficient management of production processes, analyzing large volumes of data, and forecasting risks.

Ukraine's oil and gas sector is no exception to this trend: the growing complexity of logistics operations, hydrocarbon extraction, transportation, and processing necessitates the adoption of innovative technologies, among which AI stands out as a leading tool.

The application of AI enables companies to automate complex technical processes, optimize costs, and improve both safety and environmental responsibility in production. International oil and gas companies are actively adopting AI-based solutions: for example, Schlumberger uses a "digital twin" platform to automate drilling design [1]; Shell applies AI to search for new oil fields [2]; BP leverages AI to improve pipeline corrosion monitoring [3]; and TotalEnergies employs AI for production forecasting, predictive maintenance, and anomaly detection in equipment performance [4]. Meanwhile, for Ukrainian enterprises, this process remains challenging due to factors such as an unstable economic environment, limited financial resources, insufficiently skilled personnel, and gaps in the legislative framework.

Scientific studies [5–9] emphasize the benefits of digitalizing the industry, but significantly less attention has been paid to the analysis of risks associated with AI implementation in the specific context of Ukraine's oil and gas sector. These risks can be technical, informational, economic, social, environmental, legal, and ethical. For example, a poorly trained AI model may lead to accidents or financial losses, while the use of employees' personal data may violate privacy regulations.

Therefore, the relevance of this research lies in the need for a comprehensive analysis of AI-related risks in the Ukrainian oil and gas industry, taking into account modern international experience and the internal operational specificities of domestic enterprises. This issue forms the core of the article and serves as the basis for developing a scientifically grounded position on the further implementation of AI technologies in a sector critical to the national economy.

Setting objectives. The aim of the research is to identify and classify the key risks associated with the implementation and use of AI technologies in the operations of oil and gas enterprises in Ukraine, and to develop risk management strategies that ensure safe, effective, and ethical application of AI.

To achieve this goal, the study uses methods of theoretical generalization, comparative analysis, systematization, expert evaluation, and scenario modeling.

Results. The concept of a digital oil field involves the application of information technologies at all stages — from exploration to extraction — which enhances the efficiency and competitiveness of enterprises. The next stage of development is the intelligent oil field, based on the integration of sensor systems, AI, and automation. These systems reduce costs, increase oil recovery rates, and improve company management and growth [10, p. 74].

The main vector in the evolution of digital oil fields is the integration of modern technologies such as AI, the Internet of Things (IoT), cloud computing, and big data analytics, which allow for the optimization of operational processes. The global AI market in the oil and gas industry is expected to grow at an average annual rate of 23.12% between 2024 and 2029. According to Research and Markets, by 2029 the AI market will reach USD 15.01 billion, up from USD 5.305 billion in 2024 [11].

AI enables optimization based on historical data by identifying hidden patterns in large, unstructured datasets. These data come from numerous sources and have complex structures, requiring advanced and continuously improving algorithms for AI applications.

In field development, various AI algorithms are actively used, each with its own strengths and limitations. Artificial Neural Networks (ANNs) demonstrate high efficiency but require high-quality input data to function properly. Fuzzy logic enables modeling without an exact mathematical description of the object but is less accurate than other methods. Genetic Algorithms (GAs) are fairly effective but complex to implement. Particle Swarm Optimization (PSO) is easy to implement but may produce less precise results. The Support

Vector Machine (SVM) method shows good performance, especially when working with small datasets [9, p. 20].

AI plays an increasingly significant role in the oil extraction industry, particularly in data analysis, forecasting, and optimization [5, p. 12779]. Thanks to its ability to capture complex nonlinear patterns, neural networks make it possible to build accurate models based on historical data—something traditional methods struggle to achieve. AI is especially valuable for dynamic production forecasting, where numerous variables and their interdependencies must be considered [6, p. 177]. Algorithms such as backpropagation neural networks, in combination with SVM and genetic algorithms, demonstrate high efficiency in modeling well performance. AI also greatly enhances field development planning: instead of outdated methods like linear programming, neural networks and cluster analysis are used, allowing strategies to be adapted to complex geological conditions. The integration of intelligent technologies contributes to more accurate decision-making, cost reduction, and sustainable sector development—an especially important factor in conditions of uncertainty and rising demands for energy efficiency [7, p. 22].

Compared to the significant number of foreign oil and gas companies actively implementing AI-based solutions, there are relatively few such enterprises among domestic oil and gas companies. For instance, DTEK Naftogaz LLC began implementing AI-based solutions in 2024. The first step was the integration of Microsoft Copilot to optimize business processes. In the future, the company plans to apply AI and machine learning in geological exploration and production, focusing on sustainable development and digital transformation [12].

PJSC “Ukrnafta” leverages decades of experience and accumulated data on Ukrainian subsurface resources to introduce AI technologies in oil and gas production. The company uses neural networks to process large volumes of data, automate routine tasks, and solve complex geological and technical challenges. To ensure a systematic approach to innovation, a Department of Innovative Technologies has been established. Three solutions have already been implemented: rock permeability assessment, automatic correlation of geophysical curves, and recognition of scanned materials. The models are trained on data from 575 wells and research archives dating from 1953 till 2018. The company adapts advanced global practices to integrate AI into business processes, ensuring technological development [13].

Despite its potential advantages, the use of AI comes with numerous risks — technical, informational, economic, social, environmental, legal, and ethical.

One of the main technical risks in the implementation of AI in the oil and gas industry is the unreliability of algorithms in non-standard situations. Algorithms usually perform well within the scope of the data they were trained on, but during emergencies or under complex production conditions, they may fail. In oil and gas production, where even a minor error can lead to explosions, leaks, or large-scale environmental pollution, such unreliability of AI decisions poses a critical threat [14, p. 349].

Another challenge is the lack of transparency in AI systems — the so-called “black box” effect. Most modern algorithms, particularly deep neural networks, do not allow for interpretation of why certain decisions were made [15]. This complicates the investigation of technical incidents, verification of system operations, and determination of responsibility in the event of accidents or losses.

Moreover, integrating AI into oil and gas infrastructure is accompanied by significant challenges, as many enterprises still use outdated technologies. This complicates the implementation of new solutions, necessitates costly upgrades, and delays digital transformation.

The growth of digitalization in the oil and gas industry — through the use of remote sensors, telemetry, cloud solutions, and automated systems — makes companies more

vulnerable to cyberattacks. Successful interference with AI systems may result in the shutdown of critical production or transportation processes, environmental damage, economic losses, or even pose a threat to human lives.

Another danger is data compromise. The leakage of confidential information — such as data on oil fields, drilling plans, or partner contracts — can result in the loss of competitive advantages or legal consequences. This is especially relevant for companies operating internationally.

Additionally, malicious actors may intentionally falsify input data — a process known as “data poisoning” [16, p. 108]. For example, altering pressure or temperature indicators in data collection systems can lead to incorrect AI decisions, which in turn may result in hazardous operational decisions or accidents.

Integrating AI into production processes in oil and gas companies requires significant financial investments. Costs are associated not only with the purchase of equipment or software but also with staff retraining, adaptation of existing processes, and infrastructure maintenance. For medium-sized enterprises, this may prove to be an unaffordable investment, especially amid fluctuating oil and gas prices.

Another risk is the uncertainty regarding the return on investment (ROI) of AI implementation. Due to the complexity of production processes, market instability, and possible regulatory changes, it is very difficult to forecast the economic efficiency of AI adoption. This reduces interest in innovation from investors and managers [14, p. 353].

Moreover, many companies in the oil and gas sector rely on external AI technology providers. Such dependence limits companies' flexibility in choosing technical solutions and creates risks in the event of cooperation termination, sanctions, or instability of the providers themselves.

The widespread adoption of AI and automation in the oil and gas sector leads to a reduced need for workforce, particularly in physical labor and routine technical tasks. This may result in job cuts, affecting regions where the oil and gas industry is a key source of employment, and causing social tension.

Even those employees who retain their jobs often require reskilling. Knowledge in IT, analytics, and working with digital systems is becoming essential, but not all companies are ready to invest in training. This creates risks of losing qualified personnel or reducing overall efficiency.

Resistance from employees toward digital changes should not be underestimated either. Reluctance to adopt new technologies may slow down AI implementation and prevent the realization of its full potential.

Excessive reliance on AI autonomy without proper human oversight can have tragic consequences. If the system fails to detect an error or deviation in equipment operation, it may lead to gas leaks, pipeline depressurization, or environmental pollution, posing both ecological and reputational threats.

In addition, if data analysis or technical condition predictions are incorrect, AI may trigger an unwarranted process shutdown or fail to respond to critical situations.

In many jurisdictions, including Ukraine, the legal framework for using AI in industry is not yet fully developed. This creates legal uncertainty for enterprises, which may find themselves in situations lacking clear rules for liability or regulation of AI operations [17, p. 1565].

Furthermore, automation of processes in the oil and gas sector may unintentionally violate existing occupational safety standards. For instance, tasks previously performed in compliance with safety protocols may be delegated to systems that do not account for emerging risks to employees.

A separate issue is the protection and processing of sensitive data — both personal and

commercial. Failure to comply with data protection laws may result in fines, lawsuits, and a loss of trust from partners.

A serious ethical concern arises around responsibility for actions taken by AI systems. If their operations result in accidents or harm to the environment or people, it is difficult to determine who should be held accountable — the algorithm developer, the operator, or the enterprise as a whole.

Moreover, AI algorithms may contain built-in biases — for example, in decisions regarding resource allocation, hiring, or risk management. This can lead to unfair or ineffective managerial decisions [8].

Finally, the use of AI for employee monitoring — such as through video surveillance or productivity assessment — raises concerns about privacy. Workers may feel pressure or stress due to constant digital oversight, which affects the overall morale within the team.

Table 1 groups the main risks associated with the integration of AI technologies into the operations of oil and gas enterprises and briefly describes their potential consequences.

Table 1

Key Risks Arising from the Integration of AI Technologies into the Operations of Oil and Gas Sector Enterprises

Risk Groups	Risks	Potential Consequences
1. Technical and Technological Risks	1.1 Algorithm unreliability	Incorrect decisions in emergency situations may lead to explosions, oil/gas leaks, injuries to personnel, or production shutdowns
	1.2 Lack of transparency (“black box”)	Complicates incident investigations, makes it difficult to identify causes of accidents or malfunctions, and creates accountability challenges
	1.3 Integration issues	Incompatibility of AI with existing infrastructure, increased costs for upgrades, and delays in implementing technologies into production
2. Cybersecurity and Information Risks	2.1 Increased vulnerability to cyberattacks	Attacks on remote control systems or sensors may paralyze extraction, transportation, or processing operations
	2.2 Data compromise	Leakage of strategic information on reserves, drilling plans, or contracts may lead to loss of competitive advantage or regulatory sanctions
	2.3 Input data falsification (data poisoning)	Artificial distortion of pressure/temperature indicators may result in incorrect decisions, accidents, or resource overuse
3. Economic Risks	3.1 High implementation cost	Requires significant investments in specialized equipment, software, and staff training; high financial barrier for medium-sized enterprises
	3.2 Uncertain payback period	Volatility of oil and gas prices complicates forecasting returns on AI investments
	3.3 Dependence on technology providers	Limited flexibility in adapting solutions; risk of losing access to critical updates or services in case of sanctions or supplier crises

Continuation of the Table 1

4. Social Risks	4.1 Job reductions	Automation of drilling, logistics, and accounting reduces the need for human resources, creating tensions in regions dependent on oil and gas enterprises
	4.2 Need for new competencies	Requires retraining of engineering and technical personnel in IT, analytics, and AI system maintenance
	4.3 Resistance to implementation	Employee refusal to adopt new technologies may hinder digital transformation and reduce modernization efficiency
5. Environmental and Technogenic Risks	5.1 Overreliance on technology	Lack of human oversight may result in missing critical deviations, leading to leaks, environmental pollution, or ecological disasters
	5.2 Faulty prediction or analysis	Errors in data analysis may lead to incorrect assessments of well or equipment conditions, causing emergency shutdowns or environmental threats
6. Legal and Regulatory Risks	6.1 Lack of legal framework	Absence of clear AI regulations causes uncertainty in incident investigations and makes coordination with regulatory authorities difficult
	6.2 Violation of labor protection standards	Automated processes may not comply with current safety regulations, risking fines or operational suspensions
	6.3 Issues with data storage and usage	Improper storage of exploration or personnel data may lead to fines, loss of international partnerships, or revocation of licenses
7. Ethical Risks	7.1 Accountability for decisions	In case of an explosion or leak, it is difficult to determine responsibility — AI developer, operator, or the enterprise — causing conflicts and delays in damage mitigation
	7.2 Potential algorithmic bias	Distortion in management decisions — e.g., resource allocation among facilities or personnel — may cause inefficiency or discrimination
	7.3 Privacy violations	Continuous AI-based employee monitoring leads to moral pressure and legal risks related to labor law

Compiled by the authors

Table 2 presents the risk matrix for the implementation and use of AI by domestic oil and gas enterprises, developed based on ISO 31000:2018 [18]. This standard involves assessing each risk according to two criteria — the likelihood of occurrence (from low to high) and the impact on enterprise operations (from minor to critical). The risk level is determined as the product of these two indicators and is classified as low (1–2), medium (3–4), or high (6–9). The evaluation was conducted by mid- and senior-level managers of several domestic oil and gas companies.

Table 2

Risk Matrix of AI Implementation and Use by Oil and Gas Sector Enterprises

No.	Type of Risk	Likelihood (L)	Impact (I)	Risk Score	Level
1.1	Algorithm unreliability	2	3	6	High
1.2	Lack of transparency	3	2	6	High
1.3	Integration issues	3	2	6	High

Continuation of the Table 2

2.1	Increased vulnerability to cyberattacks	3	3	9	High
2.2	Data compromise	3	2	6	High
2.3	Input data falsification (data poisoning)	2	3	6	High
3.1	High implementation cost	3	2	6	High
3.2	Uncertain payback period	2	2	4	Medium
3.3	Dependence on technology providers	2	2	4	Medium
4.1	Job reductions	2	3	6	High
4.2	Need for new competencies	3	2	6	High
4.3	Resistance to implementation	2	2	4	Medium
5.1	Overreliance on technology	2	3	6	High
5.2	Faulty prediction or analysis	2	3	6	High
6.1	Lack of legal framework	3	2	6	High
6.2	Violation of labor protection standards	2	2	4	Medium
6.3	Issues with data storage and usage	2	3	6	High
7.1	Accountability for decisions	2	3	6	High
7.2	Potential algorithmic bias	2	2	4	Medium
7.3	Privacy violations	3	2	6	High

Compiled by the authors

A visual representation of the risk matrix for AI implementation and use by oil and gas sector enterprises is shown in Fig. 1.

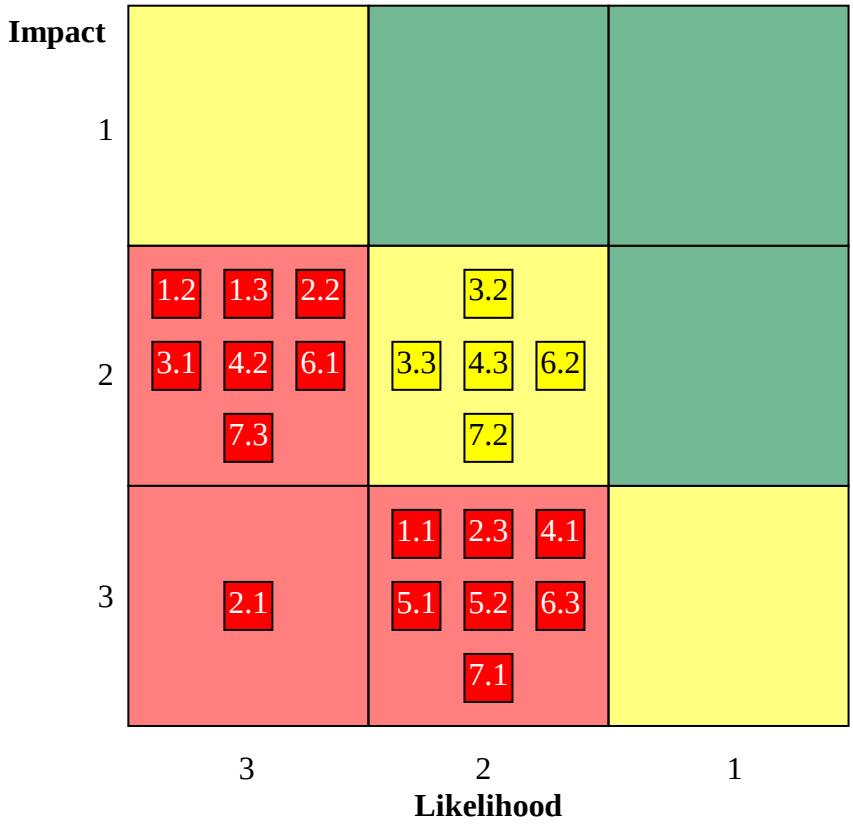

Fig. 1. Visual Representation of the Risk Matrix of AI Implementation and Use by Oil and Gas Sector Enterprises

Compiled by the authors

The figure illustrates that the vast majority of risks associated with the implementation of AI in the oil and gas sector are rated as high (6 or 9 points), indicating the need for systematic and proactive risk management. Among the most critical are increased vulnerability to cyberattacks, algorithm unreliability, data compromise, and social risks such as job reductions and the need for staff reskilling — all of which pose serious threats to the operational stability of domestic oil and gas enterprises.

While medium-level risks are less acute, they still require continuous monitoring and timely responses. The absence of low-level risks highlights the generally high-risk nature of AI implementation in the oil and gas industry.

Effective risk management related to AI adoption in the oil and gas sector requires a comprehensive approach that encompasses technical, organizational, economic, social, environmental, and legal aspects. A primary step involves managing technical risks, which includes rigorous algorithm testing under various scenarios — including emergencies — and the gradual integration of AI into existing infrastructure.

It is essential to use models with high explainability to allow for system decision auditing and to foster greater trust among personnel.

Another critical area is enhancing cybersecurity. This includes implementing modern cyber protection policies such as multi-level encryption and regular system updates. Special attention should be paid to access control for sensitive data and preventing deliberate data manipulation — for example, through anomaly detection in input datasets.

The economic strategy should involve a preliminary assessment of the feasibility and cost-effectiveness of AI implementation, fostering partnerships with technology providers, and developing an adaptive financial model that accounts for external risks.

Social adaptation is also a vital component of the digital transformation process. This includes employee reskilling programs, effective communication about the benefits of new technologies, and active employee involvement in change management. These measures help reduce resistance to innovation and increase overall engagement.

In terms of environmental and technogenic safety, it is important to retain human oversight over critical processes, conduct regular system inspections, and develop contingency plans for unpredictable situations.

Legal and regulatory compliance must also be ensured. This includes monitoring current legislation, formalizing the legal obligations of all project stakeholders, and implementing internal compliance policies regarding data processing.

A separate focus should be placed on ethical governance, prioritizing transparency in decision-making, the protection of employee privacy, and the development of an ethical code for AI usage.

The application of the strategies described above will enable oil and gas enterprises not only to reduce potential threats but also to improve management efficiency, maintain operational resilience, and strengthen their competitiveness amid digital transformation.

Conclusions. In the course of this study, a comprehensive analysis of potential threats associated with AI implementation and use in the oil and gas sector was conducted based on the international ISO 31000 approach. The scientific novelty lies in adapting risk management principles to the specifics of a high-risk industry undergoing digital transformation and in developing a detailed risk matrix that incorporates technical, informational, economic, social, environmental, legal, and ethical aspects of AI use. A systematic approach to risk assessment has been proposed, combining quantitative and qualitative evaluation of likelihood and impact, enabling the identification of critical risk areas and the development of effective management strategies. The theoretical significance of this work lies in expanding current academic understanding of how innovative technologies can be integrated into traditionally conservative industries such as oil and gas.

The practical significance lies in the development of specific recommendations for industry enterprises to minimize risks and ensure safe and effective AI use — an especially urgent need amid global competition, cyber threats, and sustainability requirements.

Future research directions include the development of dynamic models for real-time risk monitoring and forecasting using AI tools themselves, exploration of ethical dilemmas related to delegating critical decisions to machines, and analysis of AI regulatory frameworks at both national and international levels. These efforts will lay the groundwork for establishing reliable institutional and technological foundations for the digital transformation of the domestic energy sector.

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