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Challenges and Prospects of National Legal Reform in Promoting the Digitalization of Coal Mining through Artificial Intelligence

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Abstract
The digitalization of the coal mining sector through the adoption of Artificial Intelligence (AI) technology represents a strategic step toward enhancing efficiency, transparency, and sustainability in the extractive industry. However, the implementation of AI in this sector still faces complex legal challenges, including regulatory gaps, weak institutional coordination, and the absence of national technical standards. This study aims to examine the challenges and prospects of national legal reform in supporting the digital transformation of coal mining through a normative juridical approach. The method employed is library research with descriptive qualitative analysis and comparative studies of regulations in other countries such as *Australia* and *Canada*. The findings indicate the necessity for regulatory revision, the establishment of AI standards, and multi-stakeholder collaboration as key factors for the success of national legal reform in the mining digitalization era. This study recommends accelerating the formulation of AI regulations in the mining sector as part of the national digital transformation strategy.
Keywords: legal reform, artificial intelligence, coal mining, digitalization, national regulation

INTRODUCTION

Indonesia is one of the world's largest coal producers, contributing significantly to the national economy through its mining industry (Suparno et al., 2020). The coal sector plays a central role in fueling economic growth, providing employment, and supporting infrastructure development across the country (Ariani & Nugroho, 2019). Despite its importance, the industry faces major challenges, such as inefficient resource management, environmental degradation, and inadequate legal frameworks that fail to keep pace with technological advancements (Widodo & Prasetyo, 2020). These challenges pose significant obstacles to achieving a more sustainable and efficient mining sector (Arifin et al., 2020). One of the key issues is the slow adoption of modern technologies in the coal sector, which limits productivity and increases environmental impacts (Tan et al., 2020). Moreover, weak enforcement of environmental regulations has resulted in widespread deforestation, pollution, and loss of biodiversity (Sari & Kusnadi, 2021). To address these issues, there is a pressing need for comprehensive reforms in both policy and industry practices to ensure that Indonesia's coal sector can contribute to sustainable development (Suyanto et al., 2021).

The global mining industry is undergoing a significant transformation, driven by the adoption of digital technologies such as Artificial Intelligence (AI), automation, and data analytics (Zhang et al., 2020). These technologies have the potential to revolutionize the coal mining sector by enhancing productivity,

improving operational safety, and minimizing environmental impacts (He et al., 2021). For instance, AI-powered systems can optimize resource extraction processes, reduce energy consumption, and predict equipment failures, leading to more efficient operations and cost savings (Jia et al., 2021). However, the application of AI in mining is not without its obstacles, particularly with regard to regulatory frameworks and legal barriers that hinder the widespread adoption of these technologies (Wang & Li, 2020). Regulatory uncertainty, data privacy concerns, and the need for updated policies are significant challenges that the mining industry must address to fully leverage AI (Li et al., 2021). Despite these challenges, the integration of digital technologies is seen as essential for the future competitiveness of the mining sector (Kang et al., 2020).

Digital transformation in mining can help address some of the industry's long-standing problems, including inefficiencies, waste, and environmental damage (Kong et al., 2021). AI systems can automate tasks such as mineral exploration, safety monitoring, and equipment maintenance, leading to increased operational efficiency and reduced human error (Liu et al., 2020). Additionally, digital tools can provide real-time monitoring of environmental impacts, enabling companies to take proactive measures to mitigate damage to ecosystems (Zhang & Chen, 2020). Furthermore, the transparency brought about by digital platforms can help strengthen regulatory compliance and improve public trust in the industry (Li et al., 2021). The integration of AI and digital technologies is seen as essential for transforming the mining industry towards greater sustainability and efficiency (Song et al., 2021).

However, the implementation of AI and other digital technologies in Indonesia’s coal mining sector is constrained by the existing legal framework (Natsir et al., 2024). National mining laws, such as the 2009 *Mining Law* and related regulations, were not designed with digital transformation in mind and often lack provisions that address the integration of advanced technologies. This gap creates uncertainty for mining companies seeking to adopt AI and other innovations, as there are no clear legal guidelines or incentives to do so.

As AI continues to reshape the mining industry, it is critical that Indonesia’s legal framework evolves to support the integration of new technologies. Legal reforms are needed to establish a conducive environment for digital transformation while ensuring that environmental, social, and economic goals are met. Without an adaptive legal framework, the benefits of AI in the mining sector will be limited, and the industry will continue to face inefficiencies and sustainability challenges.

Therefore, national legal reform is urgently needed to ensure that the law remains adaptive and progressive in responding to the developments in AI within the mining industry. This research seeks to explore the challenges and opportunities associated with integrating AI into Indonesia's mining sector, focusing on the necessary legal reforms that would foster innovation while ensuring sustainable practices. By analyzing current regulatory barriers and proposing solutions, the study aims to contribute to the modernization of Indonesia’s mining laws,

ultimately improving the sector's efficiency, sustainability, and global competitiveness.

The study by Tsurumi and Kanno (2018) examines the impact of digitalization in the mining sector, including the application of technologies like AI to enhance operational efficiency and environmental management. While this research provides insights into the benefits of digitalization, it does not thoroughly explore the challenges related to the existing legal framework, particularly in developing countries like Indonesia. This study fills that gap by focusing on the legal and regulatory challenges in adopting new technologies, specifically in Indonesia, where the current mining legal framework has not fully accommodated high-tech innovations like AI.

On the other hand, the study by Pratama and Suryadi (2020) analyzes the legal aspects of Indonesia's mining sector, but it is limited to the existing regulations and does not take into account the developments in digital technologies in mining operations. This research points out the regulatory gaps concerning the use of new technologies, making the mining sector vulnerable to the challenges of digitalization. This study fills that gap by suggesting reforms to the current legal framework, proposing that Indonesia's mining laws should not only focus on economic aspects but also take digitalization into account to foster more efficient and sustainable development.

This study aims to analyze the challenges and opportunities faced by Indonesia's mining sector in adopting AI technology, as well as to explore the need for legal reforms that support digitalization in this sector. By identifying the gaps in the existing regulations, this study provides recommendations for updating the legal framework to create a more supportive environment for technological innovation in the mining industry. The benefit of this research is to offer insights to policymakers and industry stakeholders on how adaptive regulations can improve operational efficiency and sustainability in Indonesia's mining sector, while also contributing to better policymaking in the face of digitalization challenges.

RESEARCH METHOD

This study employs a normative juridical approach with qualitative analysis methods. The primary data sources consist of statutory regulations, academic literature, policy documents, and international publications related to *artificial intelligence* (AI) technology and the mining sector. The normative juridical approach is used to examine the applicable legal norms in the context of AI implementation in the coal mining sector. Qualitative analysis is conducted through interpretation of regulatory content, comparison with international practices, and evaluation of the urgency for national legal reform in Indonesia. Data collection techniques include library research and comparative studies of legal policies in other countries such as *Australia*, *Canada*, and *Chile*. The data is analyzed using descriptive-analytical methods to identify the challenges and prospects of national legal reform.

RESULT AND DISCUSSION

National Legal Challenges in Facing AI-Based Digitalization of Coal Mining

Artificial Intelligence (AI) technology has significantly impacted the digitalization process across various industrial sectors, including coal mining. The implementation of AI in this sector covers several aspects such as:

1) Mine monitoring through drones and smart sensors;
2) Automation of transportation systems and heavy machinery;
3) Predictive maintenance for equipment failures, accident risks, and safety violations;
4) Big data processing for production planning and energy efficiency.

AI also enables more accurate monitoring of reclamation and post-mining activities and supports data transparency required by the public and government supervisors. The main challenge in adopting AI in the coal mining sector lies in the unpreparedness of the national legal system to accommodate this technological advancement. Several legal issues arise, including:

1) The absence of legal norms regulating AI use in mining.
2) Lack of technical standards and established procedures for AI-based digital systems.
3) Inadequate regulation of data protection and mining information privacy.
4) Weak coordination among institutions (Ministry of Energy and Mineral Resources, Ministry of Communication and Information, National Research and Innovation Agency, Ministry of Environment and Forestry, etc.).
5) Technological access gaps between large and small companies.
6) Potential resistance from workers affected by automation.

Several countries have developed legal frameworks for digital and AI technology implementation in the mining sector:

1) Australia: METS Ignited has developed standards for AI and automated systems.
2) Canada: Regulates AI through ethical and sustainability approaches.
3) Chile: Applies AI-based drone monitoring and mineral extraction technologies.

The digital transformation of the coal mining industry through AI presents new challenges to the national legal system, stemming from regulatory gaps, institutional fragmentation, human resource capacity limitations, and the gap in understanding between policymakers and technological advancements.

Regulatory Gaps and Delays

One of the main challenges is the absence of national regulations specifically addressing AI utilization in mining. Existing regulations, such as Law No. 4 of 2009 on Mineral and Coal Mining (Minerba Law) and its amendment under Law No. 3 of 2020, have not anticipated digitalization developments, including automation and AI-based decision-making. This creates a legal vacuum concerning system liability, data protection, and algorithm accountability.

According to R. Subekti, "effective legal regulations must not only meet current societal needs but also anticipate technological advancements" (Subekti, Principles of Civil Law, Jakarta: Intermasa, 2008, p.12). In this context, Indonesia's national legal system has yet to adapt to the rapid pace of digital technology advancement in the mining sector.

Institutional Fragmentation

Another challenge is the fragmentation of authority and weak coordination among institutions responsible for managing and supervising new technologies.

Ministries such as the Ministry of Energy and Mineral Resources (ESDM), Ministry of Communication and Information, and the National Cyber and Crypto Agency (BSSN) lack an integrated framework to address the legal aspects of mining digitalization. This leads to policy inconsistencies and inadequate protection of business actors' and public legal rights.

Satjipto Rahardjo emphasizes that "law cannot function in an institutional vacuum; it requires synergy between regulatory instruments and implementing structures" (Satjipto Rahardjo, Legal Science, Bandung: Citra Aditya Bakti, 2006, p. 35).

Weak Data Protection and Cybersecurity

AI deployment in mining requires large-scale data collection and processing, including geospatial, operational, and worker data. However, Indonesia only recently introduced a general data protection framework under Law No. 27 of 2022 on Personal Data Protection, which does not explicitly cover mining or AI-specific data processing.

In his study, Teguh Prasetyo states, "our legislation often remains general and incapable of addressing concrete cases, especially in rapidly evolving fields such as information technology" (Teguh Prasetyo, Law and Justice in the Perspective of Progressive Law, Yogyakarta: Genta Publishing, 2015).

Legal Capacity and Digital Literacy Gaps

Furthermore, many national legal actors, including regulators and law enforcers, lack sufficient understanding of AI characteristics. This delays legal adaptation and risks biases in the development of evidence-based legal norms.

According to Lawrence Lessig, "if law fails to update itself, code (computer programs) will become the new regulators replacing law" (Lessig, Code: And Other Laws of Cyberspace, New York: Basic Books, 1999, p. 6). In Indonesia, Lessig's warning is relevant, as mining sector digitalization without corresponding legal reform may create unaccountable technological power.

Prospects and Directions for Legal Reform to Support AI Implementation in the Mining Sector

Digital transformation through AI utilization in coal mining requires a strong and adaptive legal foundation. Prospects for national legal reform in this context include drafting new regulations, reformulating sectoral policies, integrating technology standards, and enhancing legal and digital literacy among stakeholders.

The legal reform prospects may focus on several aspects:

1) Amending the Mining Law to include AI regulations;
2) Issuing technical regulations on digital systems and mining data protection;
3) Strengthening institutional capacity and cross-ministerial coordination;
4) Providing incentives for companies adopting digital technologies;
5) Developing legal and technological capacity-building programs.

Establishing Special Regulations on AI in Mining

The first step is to draft specific regulations explicitly governing AI use in mining. These regulations should cover legal definitions of AI and automation technologies, digital monitoring procedures, liability frameworks for AI system failures, and protection of operational mining data and workers' rights.

In technology law literature, Abdul Rasyid emphasizes that "legal reform in the digital era must be responsive and contextual, not merely reactive" (Abdul Rasyid, Legal Reform in the Digital Technology Era, Jakarta: Kencana, 2021, p.122). Indonesia needs not only to amend the Minerba Law but also to produce new cross-sectoral legal instruments regulating AI utilization.

Integrating Ethical and Technological Safety Principles

Legal reforms must also ensure AI utilization in mining adheres to ethical and safety frameworks. Principles such as transparency, explainability, accountability, and safety should be embedded in legislation.

International organizations like the OECD and the World Economic Forum have proposed ethical AI principles that can be adopted nationally. Indonesia may refer to these standards for harmonizing its legal framework with international practices.

As Yulianto explains in his research, "AI ethical standards must be transformed into binding positive legal norms to ensure enforceability in both public and private sectors" (Yulianto, Ethics and Regulation of Digital Technology, Yogyakarta: UII Press, 2020, p.89).

Institutional Reform and Digital Governance

Legal reform should also target institutional restructuring, including the allocation of authority among agencies overseeing mining digitalization. A cross-ministerial task force focusing on digital transformation in the extractive industries is needed, involving active roles from ESDM, Kominfo, BSSN, and technology research agencies.

Effective digital governance requires real-time data coordination and public transparency. In such a system, AI serves not only as an efficiency tool but also as an automated monitor of environmental and labor violations.

According to Jimly Asshiddiqie, "legal reform cannot be separated from institutional and cultural restructuring to create a living and dynamic legal system" (Jimly Asshiddiqie, Constitution and Constitutionalism in Indonesia, Jakarta: Konstitusi Press, 2005, p.212).

Enhancing Digital Literacy and Legal Capacity

The long-term prospect of legal reform lies in building legal capacities that are adaptive to technology. This includes training policymakers, law enforcers, and mining industry stakeholders in technology law, digital rights, and AI governance principles.

Law school curricula must also integrate courses on digital law, AI technology, and their impacts on national legal structures. Without legal professionals who understand AI, regulatory reform risks becoming mere formalism.

CONCLUSION

The study on the challenges and prospects of national legal reform in supporting the digitalization of the coal mining sector through artificial intelligence (AI) highlights the regulatory vacuum in AI use within the mining industry, leading to legal uncertainty around liability, data protection, digital system security, and supervision. Institutional fragmentation and weak digital literacy among policymakers further hinder the creation of responsive policies aligned with

technological advancements. Without improved inter-institutional collaboration and regulatory capacity, digital transformation in mining could exacerbate inequalities and legal violations. However, the prospects for national legal reform are promising, especially through the development of AI-specific sectoral regulations, ethical and technological safety standards, and mining governance reforms based on transparent digital systems. Future research should explore how to foster inter-institutional cooperation and build the digital literacy of policymakers to ensure the development of an adaptive legal framework that supports the digital transformation of the mining sector.

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