Application of Artificial Intelligence and Big Data in the Sustainable Development of Mineral Resources: Economic Decision-Making and Environmental Management

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Abstract: Mineral resources are non-renewable and serve as a crucial energy guarantee supporting the development of human economy and society. Promoting the sustainable development and utilization of mineral resources through scientific and effective economic decision-making while also considering ecological and environmental protection has become a global consensus. In recent years, the rapid development of artificial intelligence (AI) and big data technologies has driven the deep transformation of various industries and provided more efficient management tools for economic decision-making and environmental management in the sustainable development of mineral resources. This paper briefly elaborates on the background and significance of the study, clarifies the important roles played by AI and big data technologies in the sustainable development of mineral resources, and discusses their specific application scenarios and implementation strategies with economic decision-making and environmental management as examples. The aim is to further promote the transformation and upgrading of the mining industry, improve production efficiency, and achieve green, low-carbon, and sustainable development.

***Keywords*:** Sustainable development of mineral resources; artificial intelligence and big data; economic decision-making; environmental management

1. Introduction

In recent years, information technologies represented by artificial intelligence and big data have grown explosively, empowering various industries and significantly improving social productivity, attracting widespread attention around the world. This year's government work report also clearly emphasized the continued advancement of the "AI+" initiative, supporting the broad application of large models, and striving to promote AI empowerment across thousands of industries to drive the development of new quality productive forces.

The mineral resources industry is a vital sector of the national economy, closely related to national energy security, economic development, and long-term social stability. At the same time, it is a typical resource-intensive industry. Empowering the entire process of production and operations through AI and big data technologies can significantly improve work efficiency, reduce energy consumption and costs, and minimize carbon emissions and environmental pollution. These technologies can also play important roles in enhancing production safety, preventing liability accidents, and on-site supervision and control.

China is the world's largest producer, importer, and consumer of mineral resources. It faces many challenges such as continued international resource volatility, rising domestic extraction costs, shrinking resources, environmental constraints, and ecological development demands. Relying on AI and big data technologies to promote the sustainable development and utilization of mineral resources has become an inevitable path for the industry's development. Studying economic policies and environmental management measures for the sustainable development and utilization of mineral resources has become a hot topic in industry research.

2. The Role of Artificial Intelligence and Big Data Technologies in the Sustainable Development of Mineral Resources

2.1 Enhancing the Level of Mineral Resource Exploration and Development

With its powerful data processing and analytical capabilities, artificial intelligence can rapidly construct three-dimensional geological models and accurately locate ore bodies by integrating multi-source data such as geological data, remote sensing images, and geophysical information. Deep integration of AI technology with geological big data analysis and the establishment of machine learning models can greatly enhance the prediction capabilities regarding the location, reserves, quality, and minability of mineral resources, guiding exploration practices. This helps reduce unnecessary

excavation, improve mining efficiency, lower energy consumption, save mining costs, reduce environmental damage, and promote the sustainable development of mineral resources. For example, the Hunan Geological Survey Institute utilized AI algorithms to establish a multidimensional correlation model of "rock mass morphology–alteration zoning–mineralization characteristics," improving the efficiency of delineating lithium-niobium-tantalum ore target areas by 40%. Chang'an University expanded internationally by addressing the geological conditions of Pakistan. Through the integration of large volumes of satellite data and machine learning algorithms, the university developed an intelligent recognition model for alteration minerals adapted to local conditions and created a mineralization anomaly extraction technology, significantly improving the efficiency of copper and gold resource exploration.

2.2 Better Support for Corporate Economic Decision-Making

AI and big data technologies can provide enterprises with massive data resources, helping them make more informed economic decisions. With the widespread application of front-end sensors and Internet of Things (IoT) technologies in the mining sector, various types of data can be collected in real-time, comprehensively summarized and analyzed, and visualized to support production planning, output adjustment, technological upgrades, and safety management—thus contributing to the sustainable development of mining enterprises. Currently, many domestic mining companies are independently or jointly developing intelligent integrated management platforms based on the five key elements of mining operations—extraction, drilling, machinery, transportation, and communication—using IoT, big data, and AI technologies. These platforms systematically integrate data across the entire production, warehousing, transportation, and business operation chain, combining sensing, information processing, monitoring, and management functions. This has not only greatly improved operational efficiency in mines but also provided robust data support for corporate economic decision-making.

2.3 Improving Operational Efficiency and Safety Levels

The application of AI and big data technologies in mining production activities can significantly enhance operational efficiency. With the aid of situational awareness and AI technologies, mining areas and operation sequences can be more precisely located, reducing blind operations and increasing work efficiency. The use of smart mining equipment and unmanned mining trucks can replace traditional manual excavation and transport methods, effectively improving efficiency and greatly reducing safety risks associated with manual labor. For instance, China Pingmei Shenma Group developed a gangue sorting system powered by AI technology, which improved efficiency by 60% and reduced coal ash content. Technologies such as real-time monitoring, robotic inspection, automatic equipment diagnostics, and intelligent video recognition can ensure normal equipment operation and reduce downtime. Relying on situational awareness and AI algorithms also allows for early risk prediction and timely warnings, thereby increasing operational safety.

2.4 Enhancing Environmental Management in Mineral Resource Activities

In recent years, China has placed great importance on ecological and environmental protection. President Xi Jinping has put forward the development concept that "lucid waters and lush mountains are invaluable assets" and elevated ecological civilization construction to a national strategy. Mineral resource activities generate large amounts of industrial waste such as wastewater, waste gas, and solid waste, which can cause pollution to soil, water, and air. Strengthening environmental management in mining development has become a key task for achieving sustainable development. With the support of AI and big data technologies, environmental management in mining can be significantly improved, aiding ecological restoration efforts and promoting the sustainable development of mineral resources. For example, AI technologies can optimize production processes and reduce energy consumption, while big data can be used to analyze the environmental impact of mining activities and formulate green transition strategies. One large mining enterprise leveraged an AI system to improve the responsiveness of crushers and conveyor belts, enhance transport efficiency, and significantly reduce diesel consumption.

3. Major Application Scenarios of Artificial Intelligence and Big Data Technologies in Empowering Economic Decision-Making for the Sustainable Development of Mineral Resources

Currently, in mining scenarios, artificial intelligence (AI) and big data technologies play a vital role in supporting data analysis, management recommendations, and economic decision-making for the sustainable development of mineral resources.

3.1 Production Scheduling and Cost Control

AI and big data technologies collect massive amounts of on-site data and build large-scale data models. Through

machine algorithms, they conduct comprehensive analyses of the entire mineral resource development process, providing suggestions for production optimization, equipment maintenance, and management adjustments. These insights help optimize enterprise production scheduling strategies, such as real-time analysis and recommendations based on ground pressure monitoring reports for stress relief, or energy consumption monitoring to support cost-efficiency suggestions. In practice, BHP continuously improves the technical indicators of its copper flotation process by integrating AI and big data technologies. It has also optimized systems such as ventilation and drainage to reduce production consumption and achieve cost reduction and efficiency gains.

3.2 Market Analysis and Investment Decision-Making

Leveraging AI and big data technologies enables real-time collection of data on mineral price fluctuations, policy changes in major mineral-producing countries, and changes in external supply and demand relationships. By establishing big data models for mineral resource development, enterprises can accurately forecast future price trends of key mineral resources, conduct market analysis and judgment, and make informed economic decisions. For example, China National Coal Group (China Coal) established the Yikuangyun Big Data Platform, which integrates data from over 4,300 large, medium, and small coal mines across the country. It also incorporates financial data, relevant laws and regulations, and regularly updates visualized comprehensive recommendations, providing analytical support for investment decisions.

3.3 Supply Chain and Safety Production

By applying AI and big data technologies to comprehensively collect and deeply integrate various types of data related to production, warehousing, and transportation in mineral resource activities, enterprises can build supply chain big data models. These models offer suggestions for adjusting production plans and inventory management, helping reduce inventory pressure, shorten production cycles, and prevent production interruptions. AI can also automatically generate real-time analysis and management recommendations for unsafe environmental factors and unsafe employee behaviors, as well as real-time analysis and management of employee health data. This further supports enterprises in making safe production decisions.

4. Major Application Scenarios of Artificial Intelligence and Big Data Technologies in Supporting Environmental Management of Mineral Resource Development

4.1 Real-Time Environmental Monitoring and Pollution Early Warning

Artificial intelligence (AI) and big data technologies utilize various front-end sensors—including those monitoring temperature, humidity, water bodies, and gases—alongside drone inspections and satellite remote sensing, to collect diverse data types. These technologies enable real-time monitoring of environmental indicators such as soil, water, and air quality in mining areas, allowing for timely identification of pollution or safety hazards and issuing early warnings. The collected data also supports post-mining restoration efforts. For example, Shanxi Coal Group has applied big data modeling to analyze deformation dynamics in mined-out areas, assess abnormal activity frequency and deformation trends, and provide early warnings—via sound and light signals—of geological disasters such as landslides, collapses, surface subsidence, and unstable high and steep slopes. Hubei Xingfa Phosphate Mine leverages IoT, big data, and AI systems to monitor wastewater and exhaust gas emissions, automatically detect environmental pollution problems such as excessive heavy metals in water or hazardous gas concentrations, and respond by adjusting system parameters, thereby reducing the environmental impact of mineral resource development.

4.2 Pollution Source Identification and Ecological Environment Management

AI and big data technologies are widely applied in identifying pollution sources in mining areas. By collecting various types of on-site data through front-end systems, these technologies conduct comprehensive analysis of existing mining ecosystems to accurately identify pollution sources—such as heavy metals in soil, vegetation, and water, or dust pollution from heavy vehicle traffic—enabling enterprises to formulate targeted environmental management strategies. Moreover, AI and big data also contribute positively to ecological restoration efforts. Big data analytics helps optimize wastewater treatment parameters and scientifically adjust chemical dosages. Air quality dispersion models can be built to analyze the types and components of pollution sources and scientifically formulate emission reduction plans to reduce dust diffusion in mining areas. By integrating soil pollution data and vegetation growth indicators, tailored ecological restoration and management plans suitable for the mining context can be developed.

4.3 Sustainable Mineral Resource Development and Ecological Balance Optimization

AI and big data technologies can significantly promote the sustainable development and utilization of mineral resources. Empowered by these technologies, advanced sorting techniques such as Nuclear Magnetic Resonance (NMR), X-ray sensor-based sorting, and CCD optical sorting are used to reprocess waste rock and slag, thereby improving resource recovery efficiency. Coarse waste rock after secondary sorting can be reused as aggregate or backfill material, fostering circular economy development and supporting sustainability. By combining satellite imagery and ground monitoring data, AI can assess vegetation recovery and biodiversity changes in mining areas, providing evidence for ecological compensation policies, better leveraging policy-driven initiatives, and promoting the orderly development of mineral resources along with scientific environmental protection. For example, the national key research project "Northern Slope of the Tianshan Mountains: Energy–Society–Ecology" focuses on the sustainable development of mineral energy and environmental protection. It has developed a machine learning–based ecological carbon sink inversion model used to calculate carbon emissions from coal mining in Xinjiang, enabling dynamic evaluation of carbon sink capacity and providing strong support for policy formulation.

5. Conclusion

In an era where artificial intelligence technology is developing at a rapid pace, fully empowering traditional mineral resource development with AI and big data technologies has become an essential path for transformation and upgrading within the industry. This paper discusses the role of mainstream AI and big data technologies in the sustainable development of mineral resources, and presents typical applications from two perspectives: economic decision-making and environmental management. Looking ahead, as AI technology continues to advance, its importance and impact in the field of mineral resource development will become even more pronounced. Enterprises should proactively adapt to the new normal of development, actively embrace and effectively utilize new technologies to promote healthy, green, and sustainable development.

References

[1] Ma Jie, Wang Wei, Li Yajian, et al. Innovative Application and Prospects of Artificial Intelligence Technology in Geological Mineral Exploration and Management [J]. Science and Innovation, 2025, (06): 194–197. DOI:10.15913/j.cnki.kjycx.2025.06.054.

[2] Luo Liting. Sustainable Development Path of Mineral Resources under the Background of Ecological Civilization Construction — Taking Hubei Province's Turquoise Resources as an Example [J]. Environmental Protection, 2025, 53(04): 78–79. DOI:10.14026/j.cnki.0253-9705.2025.04.012.

[3] Huang Qinggang. Discussion on the Application of Artificial Intelligence in Mine Surveying and Navigation Technology [J]. World Nonferrous Metals, 2025, (03): 184–186.

[4] Luo Jianming, Zhu Haibo. Design and Implementation of an AI-Assisted Geological Mineral Resource Evaluation System [J]. World Nonferrous Metals, 2024, (22): 90–92.