Construction and Optimization Path of a Refining Management System for Large Black Metal Mining and Processing Enterprises

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Abstract: Against the backdrop of intensifying global mining competition and tightening resource-environment constraints, large-scale ferrous metal mining and processing enterprises urgently need to break through efficiency bottlenecks and ecological pressures through management innovation. This study takes the refined management system as a starting point, systematically analyzing its construction logic and optimization pathways: based on four core elements — strategic orientation, process optimization, technological empowerment, and ecological synergy — and drawing on empirical exploration from Lincheng Xingye Mineral Resources Co., Ltd., it proposes optimization strategies such as dynamic adjustment mechanisms, data-driven decision-making, and life-cycle management. The findings demonstrate that the refined management system can significantly enhance resource comprehensive utilization rates, reduce production costs, and achieve dynamic balance between mine environmental restoration and industrial development, providing theoretical support and practical paradigms for high-quality industry development.

***Keywords*:** ferrous metal ore; refined management system; process optimization; ecological synergy; data-driven

1. Introduction

Against the backdrop of the accelerated transformation of global mining towards green and intelligent development, large-scale black metal mining and beneficiation enterprises are facing multiple challenges such as tightening resource constraints, upgrading environmental protection requirements, and intensified market competition[1]. The traditional extensive management model is no longer able to support sustainable development needs. The refined management system has become a key path to breaking efficiency bottlenecks, reducing operating costs, and achieving comprehensive resource utilization by integrating strategic planning, process optimization, technological innovation, and ecological synergy. Existing research mostly focuses on optimizing a single link, lacking in-depth exploration of the systematic construction and dynamic optimization mechanism of management systems. This article takes Lincheng Xingye Mineral Resources Co., Ltd. as an empirical case and combines mining engineering and management science theories to systematically analyze the framework and optimization strategies for constructing a refined management system. The aim is to provide theoretical reference and practical guidance for the transformation and upgrading of the industry.

2. Theoretical framework for refined management system of large-scale black metal mining and beneficiation enterprises

The refined management system is the core tool for mining enterprises to achieve high-quality development[2]. Its essence is a comprehensive management model based on data, centered on processes, and supported by technology. This model promotes the transformation of enterprises from experience driven to scientific decision-making through four characteristics of standardization, datalization, dynamism and synergy: standardization emphasizes the standardization and replicability of work processes, datalization relies on the industrial Internet platform to achieve real-time collection and analysis of all factor information, dynamism requires flexible adjustment of the management system with market and policy changes, and synergy focuses on resource integration and efficiency improvement across departments and links.

The construction of a management system needs to revolve around four core elements. Strategic orientation is top-level design, which requires embedding quantitative goals such as comprehensive resource utilization rate and safety production level into long-term enterprise planning to ensure that management direction is consistent with sustainable development requirements; Process optimization is the implementation path, which requires the use of methods such as value stream mapping analysis to standardize and reconstruct the entire chain of exploration, mining, beneficiation, and processing, eliminating non value added links; Technological empowerment is the supporting means, and the application of intelligent sensors, digital twins, and automation equipment can achieve transparency in the production process and precision in decision-making; Ecological synergy is a boundary constraint that requires the establishment of a dynamic

balance mechanism between mining environment restoration, land reclamation, and community development, internalizing ecological costs, and promoting the transformation of enterprises from "resource miners" to "ecological guardians".

3. Practical exploration of refined management system of Lincheng Xingye Mineral Resources Co., Ltd

3.1 Enterprise Overview and Industry Status

Lincheng Xingye Mineral Resources Co., Ltd. is a large-scale black metal mining and beneficiation enterprise in North China, mainly engaged in the mining and deep processing of iron ore and diabase, with an annual production capacity of 5.2 million tons and a stable iron concentrate grade of over 66%. Its regional market share exceeds 35%. The company relies on the integrated industrial chain of "exploration mining selection processing" to form a model of efficient resource utilization and coordinated development of circular economy. It has been successively rated as a national level green mine and a first-class enterprise for safety production standardization in Hebei Province. It ranks among the top in the industry in terms of comprehensive resource utilization rate and proportion of environmental protection investment. Its management practice has typical demonstration significance for similar enterprises.

3.2 Management System Construction Path

The company promotes refined transformation through a four-dimensional framework of "strategy process technology ecology". At the strategic level, formulate the 14th Five Year Plan, clarify the equivalent goals of "increasing resource utilization by 20% and reducing unit energy consumption by 15%", and include green mining in the performance evaluation of management. In terms of process optimization, the lean production concept is introduced, and the mining process is reconstructed through value stream mapping analysis to shorten the blasting shipping cycle by 15%; Adopting the stage mining room method to optimize the layout of the mining area and reduce the impoverishment rate by 3.2 percentage points; The introduction of high-frequency vibrating screen and magnetic separation column combined technology in the beneficiation process has increased the recovery rate of iron concentrate to 92%. In terms of technical empowerment, the 5G+industrial Internet platform was deployed and more than 2000 intelligent sensors were integrated to realize real-time monitoring and fault early warning of equipment status, and the overall efficiency of equipment was increased by 18%; Using digital twin technology to construct a three-dimensional ore body model, guiding precise mining and reducing resource waste. In the ecological synergy mechanism, a "mining while repairing" system is established, and the mining area is reclaimed using soil spraying and vegetation concrete technology, with a reclamation rate of 90%; Developing tailings preparation technology for building aggregates, with an annual consumption of 1.2 million tons of tailings, reducing solid waste emissions by 40%, and achieving a win-win situation of economic and ecological benefits.

3.3 Implementation Effectiveness and Experience Summary

Through the implementation of a refined management system, the company's unit production costs have decreased by 12%, the safety accident rate has dropped to 0.3 incidents per year, the comprehensive utilization rate of resources has increased to 85%, and the proportion of environmental protection investment has reached 6.8% of revenue. The core experience lies in the combination of management leadership and full participation, and the stimulation of grassroots innovation through the "lean improvement proposal system"; Establish a "PDCA+data-driven" closed-loop mechanism and dynamically adjust management strategies every quarter; Focusing on the deep integration of technology and management, avoiding the one-sided tendency of "heavy hardware, light process", and providing a replicable transformation path for the industry.

4. Optimization path of refined management system for large-scale black metal mining and beneficiation enterprises

Large scale black metal mining and beneficiation enterprises need to deepen the optimization of their refined management system from four aspects: technological integration, process reconstruction, ecological strengthening, and mechanism innovation. At the level of technology integration, it is necessary to accelerate the deep integration of industrial Internet, big data and artificial intelligence technology, build an intelligent decision-making platform covering the whole chain of "geological exploration mining design production scheduling equipment operation and maintenance", and achieve accurate improvement of resource mining efficiency and equipment failure prediction through real-time data collection and algorithm model optimization[3]. In terms of process reengineering, value stream analysis should be used as a tool to identify and eliminate non value added links, such as optimizing blasting parameters and shipping paths to reduce energy

consumption, or using modular beneficiation processes to shorten process cycles. At the same time, cross departmental collaboration mechanisms should be established to break information silos and improve overall process response speed. In terms of ecological enhancement, the standard system for mine ecological restoration should be improved, carbon footprint accounting should be included in management indicators, tailings resource utilization technology should be promoted, and enterprises should be encouraged to transform towards a "zero waste" model. In the field of mechanism innovation, it is necessary to establish a dynamic adjustment mechanism of "strategy execution feedback", visualize management objectives through digital dashboards, and establish a performance evaluation system based on the combination of KPI and OKR, strengthen the awareness of full staff participation and continuous improvement, and ultimately form a modern management system of "data-driven, technological empowerment, ecological priority, and full staff lean".

5. Conclusion and Prospect

The construction and optimization of a refined management system for large-scale black metal mining and beneficiation enterprises is an inevitable choice in line with the industry's trend towards green and intelligent transformation. This article systematically demonstrates the practical value of the four-dimensional path of strategic orientation, process optimization, technological empowerment, and ecological synergy through theoretical framework construction and empirical research of Lincheng Xingye Mineral Resources Co., Ltd. In the future, enterprises need to continue to deepen the integration and innovation of digital technology and mining scenarios, strengthen full lifecycle resource management, improve policy support and standard systems, promote the upgrading of refined management models from "local improvement" to "system reconstruction", and ultimately achieve the coordinated progress of economic, ecological, and social benefits, providing a Chinese solution for the sustainable development of global mining.

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