Менеджмент

UDC 669:004:658

Jiang Hao
a third-level higher education Candidate
'Doctor of Philosophy' (PhD) in the specialty 073 Management
West Ukrainian National University
Цзян Хао
здобувач третього рівня вищої освіти «доктор філософії»
за спеціальністю 073 Менеджмент
Західноукраїнського національного університету

Scientific advisor:
Мазур Володимир Степанович
кандидат економічних наук, доцент
Західноукраїнський національний університет

ASSESSMENT OF THE DEVELOPMENT OF METALLURGICAL PRODUCTION IN THE CONDITIONS OF THE DIGITAL ECONOMY
ОЦІНКА РОЗВИТКУ МЕТАЛУРГІЙНОГО ВИРОБНИЦТВА В УМОВАХ ЦИФРОВОЇ ЕКОНОМІКИ

Summary. *Introduction. In the current conditions of rapid digital economy development, digital transformation has become one of the key factors in increasing the competitiveness of enterprises. It opens up new opportunities for optimizing business processes, improving management systems, and implementing innovations. The metallurgy industry, as one of the main sectors of the economy, also faces the need to adapt to the new challenges of the digital age, particularly through the enhancement of digital maturity in enterprises.*

Assessing the level of digital development of metallurgical companies is crucial for developing effective strategies for their transformation. It is

important to understand how digital technologies can contribute to improving production processes, modernizing management, and applying innovative approaches to marketing. This not only helps strengthen the companies' positions in the competitive environment but also promotes the sustainable development of the industry as a whole.

Purpose. The purpose of the study is to assess the digital maturity level of Shandong Iron and Steel in order to determine its ability to implement digital concepts, integrate digital resources, support digital technologies, and apply digital scenarios in key areas such as production, management, and marketing. Additionally, the study seeks to develop recommendations for the effective use of digital technologies to enhance competitiveness, optimize business processes, and foster innovation.

Materials and methods. The materials of the research include: 1) the regulatory and legal framework that governs the processes of digital transformation and the implementation of digital technologies in the metallurgical industry, particularly with regard to political, economic, social, and technological aspects; 2) the works of scientists studying digital transformation in industry, particularly in the metallurgical sector, as well as the issues of implementing digital technologies to enhance efficiency and competitiveness of enterprises.

The following scientific methods were used during the research process: theoretical generalization and grouping (to characterize the main components of digital transformation in enterprises and digital management functions in the metallurgy sector, as well as to identify key aspects influencing the effectiveness of digital technology implementation); formalization, analysis, and synthesis (to build a model of digital transformation using Shandong Iron and Steel Group as a case study, as well as to create accounting information regarding the implementation of digital technologies in production, management, and marketing processes of the enterprise); PEST analysis (to assess the external

environment of the enterprise, particularly the political, economic, social, and technological factors affecting the digital transformation processes in metallurgical companies); logical generalization of results (to formulate conclusions and develop recommendations for improving the digital transformation strategy of metallurgical enterprises based on the theoretical and practical outcomes of the study).

Results. The article provides a detailed analysis of the driving forces behind the transformation of enterprise management, particularly the importance of the interaction between internal and external factors in this process. One of the key aspects identified is strategic planning, which determines the direction and provides guidance for the development of enterprises in the digital age. The author conducts a comprehensive assessment of the digital development of Shandong Iron and Steel Group, using the PEST analysis method to study the political, economic, social, and technological aspects of its external environment. Significant achievements were identified in key areas such as digital concepts, integration of elements, technical support, system integration, and the application of scenarios. However, the company faces several challenges, particularly in the areas of intelligent manufacturing, balancing regional development, and system integration.

In response to these challenges, the author proposes strategic recommendations, including strengthening the construction of data platforms, optimizing production processes, and developing technical talent. Special attention is given to the digital transformation of the metallurgical industry, which holds strategic significance for the development of China's digital economy.

Discussion. Future scientific research is proposed to focus on improving digital platforms, integrating new technologies, and optimizing software to support the digital transformation of metallurgical enterprises. Important areas also include the development of digital transformation management strategies,

deeper integration of data and equipment, as well as the evaluation of competitive advantages that may arise from the implementation of digital solutions. These studies will help strengthen the competitiveness of enterprises and ensure their sustainable development in the digital economy.

Key words: *digital transformation, competitiveness, business process optimization, metallurgical industry, strategic planning, production processes, management, innovation.*

Анотація. *Вступ. У сучасних умовах стрімкого розвитку цифрової економіки цифрова трансформація стає одним із ключових факторів підвищення конкурентоспроможності підприємств. Вона відкриває нові можливості для оптимізації бізнес-процесів, удосконалення управлінських систем і впровадження інновацій. Металургійна промисловість, як одна з основних галузей економіки, також стикається з необхідністю адаптації до нових викликів цифрової епохи, зокрема через підвищення цифрової зрілості підприємств.*

Оцінка рівня цифрового розвитку металургійних компаній є важливою для розробки ефективних стратегій їх трансформації. Важливо зрозуміти, як цифрові технології можуть сприяти вдосконаленню виробничих процесів, модернізації управління та інноваційним підходам до маркетингу. Це дозволяє не лише зміцнити позиції підприємств у конкурентному середовищі, але й сприяти сталому розвитку галузі в цілому.

Мета. Метою дослідження є оцінити рівень цифрової зрілості компанії Shandong Iron and Steel з метою визначення її здатності до впровадження цифрових концепцій, інтеграції цифрових ресурсів, підтримки цифрових технологій, а також застосування цифрових сценаріїв у ключових сферах діяльності, таких як виробництво, управління та маркетинг, та розробити рекомендації щодо ефективного

використання цифрових технологій для підвищення конкурентоспроможності, оптимізації бізнес-процесів та впровадження інновацій.

Матеріали і методи. Матеріалами дослідження є: 1) нормативно-правове забезпечення, яке регулює процеси цифрової трансформації та впровадження цифрових технологій у металургійній промисловості, зокрема щодо політичних, економічних, соціальних та технологічних аспектів; 2) праці науковців, що досліджують цифрову трансформацію в промисловості, зокрема у сфері металургії, а також питання впровадження цифрових технологій для підвищення ефективності та конкурентоспроможності підприємств.

В процесі здійснення дослідження було використано наступні наукові методи: теоретичне узагальнення та групування (для характеристики основних складових цифрової трансформації підприємства та функцій цифрового управління в металургійній галузі, а також для визначення ключових аспектів, що впливають на ефективність впровадження цифрових технологій); формалізація, аналіз та синтез (для побудови моделі цифрової трансформації на прикладі Shandong Iron and Steel Group, а також для формування облікової інформації щодо впровадження цифрових технологій у виробничі, управлінські та маркетингові процеси підприємства); PEST-аналіз (для оцінки зовнішнього середовища підприємства, зокрема політичних, економічних, соціальних і технологічних факторів, що впливають на процес цифрової трансформації металургійних підприємств); логічне узагальнення результатів (для формулювання висновків та розробки рекомендацій щодо удосконалення стратегії цифрової трансформації підприємств металургійної галузі на основі теоретичних і практичних результатів дослідження).

Результати. У статті детально проаналізовано рушійні сили трансформації управління підприємствами, зокрема важливість взаємодії внутрішніх і зовнішніх факторів у цьому процесі. Одним із ключових аспектів виявлено стратегічне планування, яке визначає напрямок і забезпечує керівництво для розвитку підприємств у цифрову епоху. Автор провів всебічну оцінку цифрового розвитку компанії Shandong Iron and Steel Group, використовуючи метод аналізу PEST для вивчення політичних, економічних, соціальних та технологічних аспектів її зовнішнього середовища. Виявлено значні досягнення в таких ключових напрямках, як цифрові концепції, інтеграція елементів, технічна підтримка, системна інтеграція та застосування сценаріїв. Проте компанія стикається з рядом викликів, зокрема у сфері інтелектуального виробництва, балансуванні регіонального розвитку та інтеграції систем.

У відповідь на ці проблеми автор пропонує стратегічні рекомендації, серед яких посилення побудови платформ даних, оптимізація виробничих процесів та розвиток технічних талантів. Особливу увагу в статті приділено цифровій трансформації металургійної промисловості, яка має стратегічне значення для розвитку цифрової економіки Китаю.

Перспективи. В подальших наукових дослідженнях пропонується зосередити увагу на удосконаленні цифрових платформ, інтеграції нових технологій та оптимізації програмного забезпечення для підтримки цифрової трансформації металургійних підприємств. Важливими напрямками є також розробка стратегій управління цифровою трансформацією, глибша інтеграція даних і обладнання, а також оцінка конкурентних переваг, що можуть виникати завдяки впровадженню цифрових рішень. Ці дослідження допоможуть зміцнити конкурентоспроможність підприємств та забезпечити їх сталий розвиток у цифровій економіці.

Ключові слова: *цифрова трансформація, конкурентоспроможність, оптимізація бізнес-процесів, металургійна промисловість, стратегічне планування, виробничі процеси, управління, інновації.*

Formulation of the problem. In the macro environment of booming digital economy, it is of great significance to evaluate and analyze the digital development level of steel enterprises, and explore the significance of their digital maturity in accelerating industry transformation. This article will comprehensively evaluate the digitalization progress of Shandong Iron and Steel from four core dimensions: digital concept implementation ability, digital resource integration ability, digital technology support and system integration ability, and digital scenario application ability. Specifically, we will delve into the effectiveness of digital transformation in optimizing production processes, upgrading management systems, and innovating marketing, as well as how digital technology can effectively enhance the competitiveness of enterprises.

Based on the above research, this article will further propose a series of targeted development strategy suggestions, aiming to guide steel enterprises on how to efficiently utilize digital technology, promote their progress towards intelligence and efficiency, and contribute wisdom and strategies to the sustainable prosperity of the steel industry. This not only provides empirical reference and theoretical support for the strategic planning of steel enterprises in the process of digital transformation, but also sets an example for the digital transformation practice of the business community.

Analysis of recent research and publications. Chinese researchers are concerned about how companies can enhance their competitiveness through digital transformation. Cui, C et al. pointed out that enterprises should develop scientific digital transformation strategies based on their own characteristics, optimize business processes, and improve operational efficiency by introducing advanced information technology. Zaman, Q. U, and others explored how to use

digital management tools to promote enterprise innovation. For example, by establishing a digital R&D platform, enterprises can achieve collaborative innovation across departments and fields, shorten product development cycles, and improve innovation capabilities.

Some researchers in other countries believe that digital enterprises should possess the following characteristics: Kovalchuk, Y. A., and others believe that digital enterprises should have highly integrated information flow, flexible production systems, intelligent decision support systems, and global market expansion capabilities. In addition, digital management is divided into three levels: strategic level, tactical level, and operational level, corresponding to the enterprise's strategic planning, resource allocation, and daily operations [1, p. 33]. Jalgasovna, A.G. [2, p. 6587–6602] and others proposed that firstly, enterprises should increase investment in information technology construction and improve their level of information technology; Secondly, enterprises should strengthen their data analysis capabilities and achieve data-driven decision-making; Again, enterprises should promote intelligent production, improve production efficiency and quality; Finally, enterprises should strengthen networked collaboration and achieve optimized resource allocation.

The aim of the article is to assess the digital maturity level of Shandong Iron and Steel in order to determine its ability to implement digital concepts, integrate digital resources, support digital technologies, and apply digital scenarios in key areas such as production, management, and marketing, as well as to develop recommendations for the effective use of digital technologies to enhance competitiveness, optimize business processes, and foster innovation.

Materials and methods. The materials of the research include: 1) the regulatory and legal framework that governs the processes of digital transformation and the implementation of digital technologies in the metallurgical industry, particularly with regard to political, economic, social, and technological aspects; 2) the works of scientists studying digital

transformation in industry, particularly in the metallurgical sector, as well as the issues of implementing digital technologies to enhance efficiency and competitiveness of enterprises.

The following scientific methods were used during the research process: theoretical generalization and grouping (to characterize the main components of digital transformation in enterprises and digital management functions in the metallurgy sector, as well as to identify key aspects influencing the effectiveness of digital technology implementation); formalization, analysis, and synthesis (to build a model of digital transformation using Shandong Iron and Steel Group as a case study, as well as to create accounting information regarding the implementation of digital technologies in production, management, and marketing processes of the enterprise); PEST analysis (to assess the external environment of the enterprise, particularly the political, economic, social, and technological factors affecting the digital transformation processes in metallurgical companies); logical generalization of results (to formulate conclusions and develop recommendations for improving the digital transformation strategy of metallurgical enterprises based on the theoretical and practical outcomes of the study).

Presentation of the main material. Shandong Iron and Steel Group: Shandong Iron and Steel Group Co., Ltd. (referred to as Shandong Iron and Steel Group), with a registered capital of 12 billion yuan and total assets of 1858.36 billion yuan, is the largest special steel production base in China and an important state-owned backbone enterprise in Shandong Province. It was established in 2008 by Jinan Iron and Steel Group, Laiwu Iron and Steel Group, Shandong Jinling Mining Company, Shandong Refractory Materials Group, Shanxin Software Company, Shandong Zibo Yongfeng Company, Shandong Zibo Zhanggang Company and other units under Shandong Metallurgical Industry Corporation. It is a leading enterprise in China's special steel

production [3]. The group has a total of 17 subsidiary companies and 2 A-share listed companies.

The selection of cases plays a crucial role in conducting in-depth case analysis. The selected case company should have representativeness, convenient access to information and data, and high research value. The reason why Shandong Iron and Steel Group was selected as the core research object in this article is mainly based on two core considerations:

Firstly, Shandong Iron and Steel Group has a profound historical background and early market development, and its status as a state-owned enterprise gives it a unique position. The development history of this group can be regarded as a miniature landscape of the overall development of China's steel industry, and also represents the typical path of many steel enterprises [3]. The many major strategic adjustments and reform measures taken by Shandong Iron and Steel Group during critical periods deeply reflect the historical background and economic environment at that time. Especially since the merger and restructuring of Jinan Iron and Steel, Laiwu Iron and Steel, and affiliated units of Shandong Metallurgical Industry Corporation in 2008, Shandong Iron and Steel has risen to the leading position in the steel industry chain of Shandong Province and entered the top ranks of domestic special steel production and manufacturing. Therefore, in-depth analysis of the digital transformation path adopted by Shandong Iron and Steel under the interweaving of multiple internal and external factors is not only highly representative, but also provides valuable reference and inspiration for other enterprises in the same industry.

Secondly, since its successful listing in 2004, Shandong Iron and Steel has maintained a high degree of integrity and transparency in key data such as financial status and operating information, providing researchers with sufficient and easily accessible sources of information [4]. Especially its two major holding subsidiaries, Laigang Co., Ltd. and Jinan Iron and Steel Co., Ltd. (i.e. Shandong Iron and Steel Co., Ltd.), as the core forces driving the digital

transformation of Shandong Iron and Steel, have successfully gone public, allowing Shandong Iron and Steel Group to easily access various detailed information about these two companies since their establishment. Based on the dual advantages mentioned above, this article ultimately selects Shandong Iron and Steel as a typical representative of the digital transformation field in the steel industry for in-depth research, aiming to provide useful reference and guidance for other enterprises in the steel industry through this case.

Shandong Iron and Steel Group, a major player in China's steel industry, operates within a dynamic environment shaped by various political, economic, social, and technological factors. A PEST analysis was conducted to evaluate the external environment in which Shandong Iron and Steel Group operates and identify the key factors influencing its development strategy. Through the analysis of political, economic, social, and technological factors, it is possible to understand how government initiatives, economic trends, changes in consumer social demands, and the latest technological innovations impact the company (tabl. 1).

Table 1

PEST analysis of Shandong Iron and Steel Group

Political	Economic
-The 2021 14th Five Year Plan and 2035 Vision Goal Outline proposed to accelerate digital reform, promote the integration of digital economy and real economy, and establish a digital China. -The "14th Five Year Plan" for the development of the digital economy by the State Council in 2022 clearly states that the digital economy is the main economic form, and proposes the goal of the added value of the core industries of the digital economy accounting for 10% of GDP by 2025. -In 2023, the 'Work Plan for Stable Growth in the Steel Industry' proposes to promote high-end, green and low-carbon, and digital transformation. The industry development environment, industrial structure optimization, and industrial added	-93.9% of enterprises have planned digital transformation and continue to invest, with 24.5% of enterprises investing more than 1% of their revenue. In 2022, enterprises invested 16.54 billion yuan, with an average investment of 38.5 yuan per ton of steel, an increase of 23.9%. The progress of data management is smooth, with 63.3% of enterprises having established data governance organizations and dedicated teams, an increase of 12.2% year-on-year. -Enterprises with a scale of over 5 million tons achieve seamless management and control, integrated production and sales, and seamless business and finance. 78.7% of enterprises utilize information technology to optimize order scheduling, with smart factories and centralized control centers

value increase by more than 4%. -In 2024, the State Council issued the "Action Plan for Energy Conservation and Carbon Reduction from 2024 to 2025", which proposed three key tasks for the steel industry: regulating production capacity, adjusting product structure, and accelerating energy-saving and carbon reduction transformation.	becoming a new trend, and 40% of enterprises applying 3D simulation technology. -Enterprises strengthen the construction of ecological circles and promote information sharing. 53.1% of enterprises collaborate with suppliers on orders, 79.6% experiment with big data models, and 18.4% introduce AI. 79.6% and 57.1% of enterprises have respectively achieved intelligent production management and intelligent operation, enhancing their collaborative and control capabilities.
Social	Technological
As of December 2023, the number of Chinese netizens has reached 1.092 billion, with an increase of 24.8 million and a penetration rate of 77.5%. The huge number of mobile Internet users has accelerated the process of digitalization in China. The digital economy meets the higher-level needs of consumers, and intelligent terminals and multi service mobile information technology profoundly change people's lifestyles and concepts, and also encourage enterprises to provide new services to stabilize the market.	Digital technology plays a significant role in technological innovation and industrial upgrading. China has made breakthroughs in the field of artificial intelligence, covering areas such as healthcare, transportation, manufacturing, and agriculture. In terms of Internet technology and e-commerce, China has the largest number of users in the world, with Alibaba, Tencent and other giants leading the market. Emerging digital technologies such as AI, big data, cloud computing, and the Internet of Things provide technical support and innovation opportunities for enterprises, driving transformation and upgrading. But with rapid technological updates, enterprises need to maintain sensitivity and learning ability, track new technological trends, strengthen independent research and development, and enhance competitiveness.

Source: compiled by the author based on [3; 4]

The political landscape is influenced by China's national plans, including the 14th Five-Year Plan and the 2035 Vision, which emphasize the acceleration of digital reform and the integration of the digital economy. These strategies align with the steel industry's transformation goals, focusing on high-end, green, and low-carbon production, while supporting digital advancements.

Economically, the steel sector is witnessing a significant shift toward digital transformation. Enterprises are heavily investing in digital technologies, with many achieving seamless management through the integration of smart factories, big data, and AI. The rising focus on sustainability and carbon

reduction, driven by national policies like the "Action Plan for Energy Conservation and Carbon Reduction," presents both challenges and opportunities for industry players.

Socially, China's growing digital landscape, marked by over a billion internet users, is reshaping consumer behavior and expectations. This trend accelerates the adoption of digital solutions in business operations. Technologically, innovations in AI, big data, and cloud computing are reshaping industries and offering significant opportunities for upgrading production capabilities. However, the rapid pace of technological advancements requires enterprises to stay ahead in innovation and R&D to maintain competitiveness.

In this analysis, we examine how these factors interact to shape the strategic direction of Shandong Iron and Steel Group, with particular focus on its digital and green transformation efforts in response to the evolving political, economic, social, and technological landscape.

Faced with the rapid development of the digital economy, Shandong Iron and Steel Group seizes the historical opportunity of digital and intelligent transformation in the steel industry. The management focuses on strategic planning and overall planning, elevating digital transformation to an equally important level as the enterprise's development strategy. A detailed overall plan blueprint has been formulated, and continuous investment has been made to implement digital transformation and upgrading projects, build the enterprise's digital ecosystem, and promote high-quality development. According to the 2023 annual report of the group, the investment in digital upgrading and transformation for the whole year reached 1.086 billion yuan, accounting for 1.2% of the annual operating income, and the investment per ton of steel was 54.3 yuan. At the same time, the application density of robots has significantly increased, reaching an average of 65 units/10000 people, an increase of 45% compared to the previous year. In addition, 90% of the ownership companies have established enterprise manufacturing execution systems (MES), energy

management systems, and environmental monitoring systems, achieving effective linkage of control.

In order to promote digital transformation in the system, Shandong Iron and Steel Group issued the "Outline of the Construction Plan for 'Smart Mountain Steel'" in 2020, which clarified the framework, path, and long-term goals of digital transformation, and comprehensively optimized and reconstructed production methods, organizational forms, application technologies, and process flows. At the headquarters level, the group focuses on the construction of "Digital Mountain Steel" and has built an intelligent decision support platform to support the healthy operation of the "steel industry ecosystem"; At the ownership company level, the focus is on smart manufacturing, which has initially achieved the intelligent transformation of production and operation. Through unremitting efforts in recent years, the group has fully launched "cloud models" such as cloud office, cloud marketing, and cloud settlement, promoting effective integration of internal and external resources. Through vertical connections of data such as transactions, logistics, and finance, the group has strengthened strategic cooperation with upstream and downstream enterprises in the steel industry chain, and jointly built the basic framework of the steel industry ecosystem.

In the field of cloud marketing, the group has achieved real-time transmission and tracking of customer order information through a marketing management system, effectively meeting customers' personalized needs for products. In terms of smart manufacturing, the group focuses on the intelligent upgrading of equipment, production, and services, and has cultivated a new model of smart manufacturing that includes process digitization, process flexibility, precise control, and less manual operation, significantly improving production efficiency and product quality. For example, in a steel plant, operators can achieve automatic control of the entire process of converter

smelting by tapping the electronic display screen, greatly reducing manual intervention and improving product quality.

Shandong Iron and Steel Group is well aware that the future development of the steel industry cannot be separated from the support of digital transformation. Therefore, Shandong Iron and Steel Group focuses on the strategic goal of "digital steel" and has carefully built a full scenario digital application intelligent manufacturing system of "point line surface circle". This system fully utilizes the rich data resources and extensive application scenarios of the steel industry, and promotes the process of digital brain replacement, intelligent transformation, and model replacement through the construction of innovative infrastructure. Shandong Iron and Steel Group has constructed an integrated industrial control model for the entire steel process in a low-cost, high-efficiency, and zero risk manner, achieving a leapfrog transformation from traditional manufacturing to intelligent manufacturing and effectively promoting the high-quality development of the steel industry.

In terms of the application of basic intelligent equipment, Shandong Iron and Steel Group continues to expand the application fields of robots and unmanned equipment. Shandong Iron and Steel Group has extensively adopted advanced equipment such as continuous casting slag adding robots, temperature measurement and sampling robots for ironmaking and steelmaking, automatic inspection robots, spray welding robots, welding robots, unmanned cranes, and unmanned material yards, effectively replacing high-risk, high labor intensity, and high repetitive job positions. This measure not only reduces production safety risks, but also significantly improves the intelligence level of the production line.

In terms of digitalization practice on the production line, Shandong Iron and Steel Group has established a fully automatic control system for production processes such as raw materials, ironmaking, steelmaking, and steel rolling using digital technology. By building an AI machine vision raw material particle

size detection system, Shandong Iron and Steel Group has achieved intelligent and automated ball making, greatly improving the qualification rate of ball making. At the same time, the "Digital Simulation System for Blast Furnace Ironmaking Process" independently developed by Shandong Iron and Steel Group has successfully transformed the "closed iron can" of the blast furnace into a visual model, providing accurate data support and intelligent decision-making basis for ironmaking production. Since the system was put into use, the consumption of blast furnace fuel has significantly decreased, bringing considerable economic benefits to the enterprise.

In addition, Shandong Iron and Steel Group has successfully implemented digital projects such as a fully automated "one click steelmaking" system, intelligent control center, intelligent remote operation and maintenance system, and order scheduling system. These projects not only improve the flexibility of production organization and order delivery capabilities, but also achieve real-time monitoring and intelligent maintenance of key equipment. By continuously promoting the construction of smart steel plants, Shandong Iron and Steel Group has achieved excellent results such as 100% CNC rate of key processes, 100% product quality qualification rate, and industry-leading key economic and technological indicators.

In terms of digital factory practice, Shandong Iron and Steel Group has established the first centralized digital control center in the steel industry with the widest business coverage of "intelligent manufacturing, operation, and ecology" cluster style integration. The center has achieved comprehensive end-to-end data asset integration and business process optimization, bringing significant benefits to enterprises in shortening research and development cycles and reducing processing costs. At the same time, Shandong Iron and Steel Group actively promotes the construction of intelligent manufacturing factories and has created multiple national level demonstration scenarios, which has won widespread social recognition and praise for the enterprise.

Finally, in terms of digitalization practices in the industrial chain, Shandong Iron and Steel Group has extensively linked its member enterprises, upstream suppliers, downstream users, and social resources to jointly build an intelligent industrial ecosystem through application practices such as smart marketing, smart logistics, and smart supply chain. Through the deep integration of new generation information technologies such as the Internet of Things and big data with the entire process of steel supply chain business, Shandong Iron and Steel Group has built a smart supply chain with data sharing, intelligent decision-making, multi-party collaboration, global visibility, and controllable resilience. This measure not only achieves closed-loop control of various links in the supply chain, but also enhances the digital collaboration mechanism between enterprises and suppliers, customers, and partners, thereby improving brand competitiveness.

Shandong Iron and Steel Group's digital transformation faces challenges

From a long-term perspective, digital transformation is undoubtedly an effective path to improve operational efficiency and reduce operating costs for enterprises [5, p.611]. However, in the short term, this transformation process requires significant financial support. Taking Shandong Iron and Steel Group as an example, it has invested up to 12 billion yuan in digital transformation over the past decade to achieve comprehensive coverage of basic automation and process automation, and to build an enterprise intelligent manufacturing platform. In this process, whether it is the purchase of digital devices or the construction and maintenance of digital platforms, it poses a severe test of the financial strength of enterprises. Especially for small and medium-sized enterprises with relatively tight funds and limited financing channels, the road to digital transformation is even more difficult.

At the individual application level, the level of intelligence in the production and manufacturing field still needs to be improved. Specifically, the automation level of production planning and process control instructions is still

insufficient, and some production control processes still require manual intervention. In the production and manufacturing process, the maturity of unmanned and less human substitution technologies needs to be improved. The application distribution of industrial robots and unmanned intelligent driving equipment is uneven, and the intelligent transformation of raw material systems and coking systems still needs to be strengthened. In addition, in terms of business management, the information system coverage of internal supply chain management is not yet comprehensive.

In terms of comprehensive integration, with the increasing demand for refined enterprise operation management, seamless integration between marketing business and finance has become an urgent need. At the same time, there is still significant room for improvement in the integration of enterprise product design and production, as well as the integration of enterprise management and control. In the field of integrated production and sales, the proportion of automatic material application planning and automatic scheduling orders needs to be further improved.

In terms of collaboration and innovation, there is still room for improvement in the overall level due to differences in the group's product structure and operational model. The understanding of customer needs in the full cycle management and control of manufacturing and service is insufficient, and the construction of industrial Internet platform and the collaborative application of industrial chain need to be strengthened. The application of big data and artificial intelligence technology in the steel industry is still in its early stages, and the matching degree between technology and actual needs needs needs to be improved. In terms of industrial chain integration, although some enterprises have achieved information sharing and communication internally, the deep integration and innovation of business still need to be strengthened.

The difficulty of data integration has become a major obstacle to the digital transformation of Shandong Iron and Steel. The steel production process

is complex and diverse, involving multiple processes such as raw material transportation, storage, feeding to coking, ironmaking, steelmaking, continuous casting, steel rolling, as well as auxiliary facilities such as energy and power, environmental protection treatment, inspection and measurement. How to effectively collect and analyze massive amounts of data in the production process has become a major challenge. In addition, there are still obstacles to information exchange and integration between internal information systems of enterprises, and data barriers and islanding phenomena restrict the full mining and utilization of data, which in turn affects the deepening of digital transformation and the overall improvement of operational efficiency.

The shortage of digital talents, as composite talents covering multiple fields such as data technology, information technology, communication technology, and operation technology, is widespread in China. According to the "Research Report on the Development of China's Digital Economy: New Forms, New Models, and New Trends" released by the Policy and Economic Research Institute of the China Academy of Information and Communications Technology, the shortage of digital talents in China will reach 15.6 million in 2023. This huge talent gap not only exacerbates the difficulty of recruitment for enterprises, but also drives up labor costs. At present, the cultivation of digital talents in China is still in its infancy, and the relevant curriculum system is not yet perfect. Therefore, even if enterprises undergo digital transformation, they may not be able to efficiently utilize digital technology equipment due to a shortage of talent. At the same time, the high cost of talent further limits more companies from engaging in the wave of digital transformation.

Looking ahead to the future, competition in the steel industry will increasingly evolve into competition between enterprise ecosystems [6, p.6440]. Shandong Iron and Steel Group, with its market leadership and appeal, is committed to building and efficiently operating a digital ecosystem. By using the data storage and processing capacity provided by digital technology and the

physical basis of industrial Internet, the Group designs and operates various application software on the basis of data opening and sharing, and opens it to enterprises in the ecosystem. This not only provides relevant enterprises with the necessary business information, product information, and services, but also promotes collaborative cooperation within the ecosystem and improves the production and operation efficiency of the entire ecosystem.

However, Shandong Iron and Steel Group also faces many challenges in the process of digital transformation. Although its transformation advantages are obvious, there are still problems such as uneven level of intelligent manufacturing, low degree of system integration, single variety of intelligent device applications, and insufficient high-end compound talents. In response to these issues, the group will continue to increase investment, strengthen talent cultivation and introduction work, and promote digital transformation to expand to deeper levels and wider fields. The key to achieving sustained growth and change in the industry lies in actively cultivating and strengthening emerging driving forces. Shandong Iron and Steel Group, given its enterprise characteristics of diverse product types, complex process flow, significant energy consumption, and difficulty in quality control, has gained a deep understanding of the development of digitalization and intelligence, carefully drawn up a blueprint for the development of the company's digital capabilities, and formulated the "Digital Intelligence Mountain Steel" construction plan outline as a grand blueprint for its intelligent transformation.

In recent years, with the deepening development of technological revolution and industrial transformation, the digital economy has become a new engine for promoting high-quality economic development. Shandong Iron and Steel Group actively responds to the call of the times, taking smart management and intelligent production as breakthroughs, and comprehensively accelerates the process of enterprise digital transformation. Relying on the existing information technology foundation, the group fully utilizes the information

potential of key production equipment and mechanical instruments to achieve information interconnection and sharing between process flows, laying a solid foundation for the deep integration of digital technology. Since the launch of digital transformation in 2019, Shandong Iron and Steel has made significant progress in both depth and breadth. By 2023, the digitalization rate of the main process of steel production and manufacturing has reached 88.7%, of which more than 70% of the ownership subsidiaries have achieved digital transformation of core processes and equipment. The digitalization level of the enterprise has significantly improved, and key architectures such as modern data resource system, digital transformation of production system, and digital transformation of enterprise ecosystem have been initially constructed. The steel production process has been streamlined, marketing layout optimized, and cost controllable, successfully reshaping the traditional image of the steel industry.

Starting from the strategic perspective of the group, Shandong Iron and Steel Group has clarified the four basic requirements that intelligent production should follow: "able to release, able to enter, visible, and manageable", as well as the basic principles of "unified planning, unified standards, hierarchical management, and hierarchical investment". At the same time, two core construction paths of "intelligent production and intelligent management" have been established to comprehensively accelerate the in-depth implementation of the group's intelligent manufacturing.

In the field of intelligent production, the group closely focuses on its own characteristics and is committed to building a smart and transparent new metallurgical factory. By implementing a five tiered construction path of "intelligent equipment, intelligent units, intelligent production lines, intelligent factories, and intelligent companies", a closed-loop intelligent manufacturing system has been gradually constructed, achieving comprehensive intelligence from production to marketing, and then to the supply chain.

In terms of intelligent management, in view of the bottleneck problems in the informatization construction of traditional manufacturing enterprises, such as inconsistent platforms, incomplete coverage, low data utilization, and poor interaction, the Group has built a cross tiered, cross system, and cross production line intelligent manufacturing industrial Internet system by breaking the barriers of systems, businesses, and upstream and downstream. This system is linked by core elements such as production, supply, sales, personnel, finance, and materials, promoting the construction of a unified central digital center and regional platforms for subsidiary companies, and achieving optimized allocation of manufacturing resources.

In addition, Shandong Iron and Steel Group attaches great importance to the digital transformation of core processes, and has achieved the intelligent upgrading of basic equipment by promoting the supplementation and improvement of sensors in production sites, the widespread application of industrial robots and intelligent devices. On this basis, advanced technologies such as big data and artificial intelligence have been utilized to build an industrial Internet of Things platform, achieving comprehensive interconnection between people, equipment, and information. This not only optimizes the control of the production process, but also builds intelligent, less manned, and unmanned production workshops and intelligent production lines for each branch, significantly improving the production efficiency and product quality of the enterprise.

The digital transformation of Shandong Iron and Steel Group has shown initial results. At the end of 2022, the group was successfully selected as the unveiling unit of China's National Intelligent Manufacturing Demonstration Factory; From 2021 to 2023, the Group and its affiliated companies have a total of 7 intelligent manufacturing demonstration plants, 17 excellent scenes of intelligent manufacturing and 5 industrial Internet pilot demonstration projects included in the "Intelligent Manufacturing Pilot Demonstration" and "Industrial

Internet Pilot Demonstration" lists of the Ministry of Industry and Information Technology of China. In the field of intelligent manufacturing of steel, the group has applied for a total of 786 relevant patents and obtained 3 national key research and development plans; At the same time, it has also won 39 metallurgical science and technology awards, including 17 first prizes and 22 second prizes. These achievements not only demonstrate Shandong Iron and Steel Group's leading position in digital transformation, but also lay a solid foundation for its future high-quality development [4].

By building an efficient and closely integrated upstream and downstream ecosystem, Shandong Iron and Steel Group has achieved comprehensive information sharing. By utilizing advanced methods such as data analysis and personalized customization, we accurately connect and meet the diverse needs of consumers, thereby providing higher quality products and services. At the same time, Shandong Iron and Steel Group actively interacts with customers, jointly promoting product innovation and achieving significant improvements in product performance. According to authoritative data, the proportion of online collaborative orders between Shandong Iron and Steel and its upstream and downstream partners has reached 65.3% of the total enterprise orders, an increase of 11 percentage points compared to the previous year.

Conclusions from the conducted research. This article delves into the production development dynamics of Shandong Iron and Steel Group in the context of the digital economy era and provides a comprehensive analysis. The article believes that digital transformation has become the core path for the development of metallurgical enterprises. By building a digital platform, implementing intelligent control management, and promoting the intelligence of safety production, enterprises can significantly enhance their competitiveness, optimize management processes, and effectively reduce production costs. Shandong Iron and Steel Group has achieved significant results in exploration

and practice in this field, providing valuable experience and reference for the metallurgical industry.

Digital technology has had a profound impact on the production, operation, and management models of metallurgical enterprises. In order to adapt to this trend, enterprises must develop clear strategic plans, build comprehensive digital platforms, and actively learn from the successful experiences of other enterprises to accelerate their own digital transformation process. This article adopts a case study method and constructs a four-dimensional theoretical framework based on "digital concept implementation, digital element integration, digital technology support and digital system integration, and digital scene application" through in-depth analysis of practical cases of Shandong Iron and Steel Group. This framework provides important reference for the development evaluation of metallurgical enterprises.

Looking ahead, the digital transformation of metallurgical enterprises will be a long-term and arduous task. Enterprises need to strengthen their independent software research and development capabilities, optimize technology applications, deepen the integration of data and equipment, clarify strategic goals and implementation paths, in order to consolidate and enhance their competitive advantages. Only in this way can metallurgical enterprises stand invincible in the digital economy era and achieve sustainable development.

References

1. Kovalchuk, Y. A., & Stepnov, I. M. (2017). Digital economy: transformation of industrial enterprises. Innovations in management, 1(11), 32-43.

2. Jalgasovna, A. G., Abduvakhabovna, N. S., & Ramizitdinovna, T. B. (2023). Analysis and assessment of the sustainable development of fuel and

energy complex enterprises in the conditions of the formation of the digital economy. *Journal of Pharmaceutical Negative Results*, 6587-6602.

3. China United Steel Group Co., Ltd. URL: https://www.ironsteelgroup.com/about-us/ (date of access: 05.12.2024).

4. The Wall Street Journal. Фінансові звіти Shandong Iron & Steel Co. Ltd. URL: https://www.wsj.com/market-data/quotes/CN/XSHG/600022/financials (date of access: 05.12.2024).

5. Cui, C., & Lyu, R. (2024). Operational Performance Evaluation of Iron and Steel Industry in China under the Background of Digital Transformation–An Application of Data Envelopment Analysis. *Highlights in Business, Economics and Management*, *33*, 610-619.

6. Zaman, Q. U., Zhao, Y., Zaman, S., Batool, K., & Nasir, R. (2024). Reviewing energy efficiency and environmental consciousness in the minerals industry Amidst digital transition: A comprehensive review. *Resources Policy*, *91*, 104851.