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Innovative research on information technology-driven digital transformation in manufacturing enterprises

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Abstract

In the context of Industry 4.0 and digital transformation, the path and mechanism of information technology reconstructing the management mode of production and manufacturing enterprises have been studied. The current research analyzes the management impact of this technology on manufacturing enterprises and points out its effectiveness in this sphere. The object of the study is China's smart factories. The purpose of the study is to determine how these information technologies affect the management of various links in the manufacturing industry. The following methods have been applied: analysis, induction, measurement, comparison, statistics. The research results include an analysis of the policies formulated by the governments of Germany, Russia, and China to promote the digital transformation of advanced technologies in the manufacturing industry, as well as the innovative application of information technology in enterprise management production, logistics, sales, decision-making, and other aspects, and its successful application in smart factories in China. The feasibility of empowering enterprise management processes through the introduction of new information technologies has been demonstrated. The study indicates that the application of information technology in the manufacturing industry has a positive impact. Through technology in enterprise management, various innovative scenarios can be achieved, and advanced technology can be promoted in related industries in the future to improve management efficiency and reduce costs. Through the deep integration of technology and management, the successful practice of Chinese manufacturing industry provides a feasible paradigm for global digital transformation.

Keywords

Information technology, artificial intelligence, AI, enterprise management, Innovation, Supply Chain Management, Production management, smart Factory, Industrial Internet of Things

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Инновационные исследования по цифровой трансформации производственных предприятий, основанных на информационных технологиях

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Аннотация

В контексте Индустрии 4.0 и цифровой трансформации изучены пути и механизмы информационной технологии для восстановления модели корпоративного управления производством. Проанализированы управленческие последствия технологии для производственных предприятий, отмечена эффективность ее применения в этой области. Объектом исследования выступает китайская интеллектуальная фабрика. Цель исследованиязаключается в том, чтобы определить, как эти информационные технологии влияют на управление всеми звеньями обрабатывающей промышленности. Использованы следующие методы: анализ, индукция, измерение, сравнение, статистика. Основные результаты исследования включают анализ политики правительств Германии, Российской Федерации и Китая по содействию цифровой трансформации передовых технологий в обрабатывающей промышленности, а также инновационное применение информационных технологий в цепочках корпоративного управления в производстве, логистике, продажах, принятии решений и других звеньях, а также их успешное применение на китайских интеллектуальных заводах. Продемонстрирована целесообразность расширения возможностей процессов корпоративного управления путем внедрения новых информационных технологий. Результаты исследования показывают, что применение информационных технологий в обрабатывающей промышленности оказывает положительное влияние, реализует различные инновационные сценарии через технологии в корпоративном управлении. В дальнейшем это будет способствовать продвижению передовых технологий в соответствующей отраслевой практике, повышению эффективности управления предприятиями и снижению затрат. Благодаря глубокой интеграции технологий и управления успешная практика производства в Китае обеспечивает жизнеспособную парадигму для глобальной цифровой трансформации.

Ключевые слова

Информационные технологии, искусственный интеллект, ИИ, корпоративное управление, инновации, управление цепочками поставок, управление производством, умная фабрика, промышленный интернет вещей

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INTRODUCTION

In the context of global digital transformation new information technologies development has provided new application scenarios for management innovation in manufacturing enterprises, becoming a key digital tool for solving traditional management pain points. The widespread application of emerging technologies such as artificial intelligence (hereinafter referred to as AI), Big Data, cloud computing, and the Internet of Things (hereinafter referred to as IoT) in the production and manufacturing sphere has completely changed the traditional production and operation modes of enterprises, while optimizing production, logistics, and marketing management processes, shortening production cycles, improving production efficiency, reducing account turnover cycle, and enhancing the competitiveness of enterprises in the market.

Information technology helps enterprises achieve automation and intelligence in the production process, while promoting collaborative operation of various links in the supply chain through data sharing, optimizing resource allocation, and driving innovation in enterprise management models.

Information technology has become the core engine of management innovation in modern intelligent manufacturing enterprises, which can effectively improve operational efficiency, enable data-driven decision-making, and drive the industry toward high-end and development. With technological iteration and the digital ecology improvement, the application of information technology in enterprise management will move towards the integration path of cutting-edge technologies such as AI, digital twins, and Industrial IoT with enterprise management. Next-generation information technologies such, as Large Language Models (hereinafter referred to as LLMs) will be deeply integrated into the industrial sphere, and the application scenarios and empowerment of the industry will become a value community for enterprise digital transformation. In the future, it is necessary to continue to deepen the coordinated development of technological innovation and management reform.

RESEARCH MATERIALS AND METHODS

Innovation theory and the technology acceptance model serve as the methodological foundation for enterprise digital transformation, and information technologies such as AI, Big Data, and the IoT are crucial tools for managing innovation. The integration of digital technologies such as AI and data management is applied in enterprise management innovation [1]. Innovation is the core driving force of economic development, and the new production methods proposed by J. Schumpeter's Innovation theory refer to ways to improve production efficiency, reduce costs or enhance product quality through technological innovation, process optimization, or tool improvement [2]. The new organizational form refers to enhancing information flow and decision-making efficiency, flexibility, and innovation capability by changing the organizational structure, management mode, or collaboration mode of enterprise. F. Davis' Technology Acceptance Model emphasizes that users' acceptance of technology depends on perceived usefulness and perceived ease of use, and innovative technology promotion needs to focus on user experience and needs [3]. The study comprehensively explores the innovative application of information technology in enterprise production management, supply chain management, and marketing management through a literature review, case studies, and data analysis.

THE KEY APPLICATION OF INFORMATION TECHNOLOGY IN MANUFACTURING MANAGEMENT

Germany as an industrial powerhouse has proposed Industry 4.0, a strategy aimed at transforming manufacturing towards intelligence by fully utilizing information and communication technology and the combination of virtual systems in cyberspace, Cyber Physical Systems (CPS). In essence, this is the Fourth Industrial Revolution led by intelligent manufacturing, or revolutionary production methods. Russia has formulated the Industrial Policy Strategy of the Russian Federation before 2030, proposing to enhance the competitiveness of the manufacturing industry through technological innovation and digital transformation, and promote "Industry 4.0" technologies such as AI, the IoT, and robotics[1].

Digital Economy of the Russian Federation National Program promotes key areas of digital economy development, including the digital transformation of the manufacturing industry[2]. 6 key innovative technologies – AI, robotics the IoT, augmented reality (hereinafter referred to as AR), new manufacturing technologies, and communication technologies – are identified as the core ones driving the digital transformation of the manufacturing industry.

The Made in China 2025 Strategy proposes to accelerate the integration and development of next-generation information technology and manufacturing technology and promote the integrated application of the industrial Internet, cloud computing, and Big Data in the entire process of enterprise Research and Development (R&D) design, production manufacturing, operation management, sales services, and the entire industrial chain [4]. Consequently, in the process of digital transformation in the manufacturing industry, the supporting role of information technology is indispensable, and the enterprise management of leading smart factories extensively involves multiple advanced technologies.

Next, we examine the core information technologies and their applications in enterprise management (Table 1).

Table 1

Scenarios of Information Technology Application in Manufacturing Management

Information technology	Enterprise management application scenarios
AI is a technology that simulates human intelligence to achieve machine autonomous learning and decision-making	– strategic management utilizes AI to efficiently analyze data, predict trends, optimize decisions, and enhance competitiveness, thereby providing strategic recommendations for enterprises; – production management utilizes machine learning to optimize production planning, quality control, and equipment maintenance; – in terms of customer management, Natural Language Processing (NLP) technology is employed to achieve intelligent customer service through automatic question-and-answering (Q&A) systems and problem-solving tools; – knowledge management provides enterprise-level knowledge bases, cross-organizational document analysis, and the text data processing such as contracts and reports

[1] National Strategy for the Development of Artificial Intelligence through 2030. Access mode: http://static.kremlin.ru/media/events/files/ru/AH4x6HgKWANwVtMOfPDhcbRpvd1HCCsv.pdf (accessed 07.11.2025).

[2] Ibid.

Continuation of Table 1

Information technology	Enterprise management application scenarios
The IoT utilizes interconnected devices and sensors to collect, transmit, and analyze data, achieving intelligent management of devices and systems	– production management achieves interconnectivity between equipment, products, and systems through technologies such as device sensors and 5G; – real time monitoring of equipment status, energy consumption, and production efficiency is conducted during the production process in production management; – supply chain management utilizes Radio-Frequency Identification (RFID) and positioning devices to track logistics and inventory status of materials and products
5G provides high-speed, low latency, and high-capacity network connectivity while data encryption ensures the secure transmission of information	– production management supports remote control, real-time monitoring, and large-scale device interconnectivity for industrial robots and equipment; – mobile apps, as application and management software, provide real-time interaction, high-definition video, network conference, edge computing, and other under 5G network tools; – Automated Guided Vehicle (AGVs) in warehouse management achieve precise navigation and efficient material transportation through 5G technology
Big Data is a collection of data that exhibits significant characteristics in terms of scale, complexity, and diversity, making it difficult for traditional data processing tools find to handle. The characteristic is summarized as the 5V, using tools such as Hadoop, Spark, Flink, Kafka, etc.	– various sensors, equipment, and systems in production management obtain critical real-time data during the production process, transmitting it to a Big Data platform for processing, analysis, and predictive analytics; – in sales management, data from CRM and sales processes is collected, processed, and analyzed to identify consumer demand and market trends, thereby optimizing decision-making; – data is collected from procurement, production, warehousing, sales, and other links in supply chain management to reduce inventory costs and improve logistics efficiency for enterprise
VR/AR are technologies where VR creates a completely virtual environment, while AR overlays digital information onto the real world	– Human Resource Management uses VR/AR technology to simulate employee operations and provide training; – AR technology is used to guide equipment maintenance and repair tasks; – virtual prototyping accelerates product design and evolution
The application of blockchain technology adopts distributed ledger technology to ensure data security and transparency through decentralization and encryption	– track the source and logistics status of products in the supply chain management process to achieve transparency and traceability of the supply chain; – the contract management process is used for smart contracts for digital identity authentication and contract signing; based on smart contracts, automated fund management ensures transparency and security of transactions

End of Table 1

Information technology	Enterprise management application scenarios
Cloud computing provides computing resources and services through the Internet, including storage, computing and analysis; it can be deployed in both public and private cloud modes; the most common service models are Software as a Service (SaaS) and Platform as a Service (PaaS)	– collaboration management facilitates teamwork across various business departments within enterprise, enabling the storage, processing, and sharing of system data via cloud platforms; – in terms of information management, cloud platforms provide flexible computing resources, data storage, and application services to help enterprises achieve a comprehensive modernization of their information systems
Digital Twins simulate and optimize physical devices or production lines by constructing virtual models	– equipment optimization management involves building virtual models of physical devices or production lines for simulation and performance analysis; – production optimization supports predictive maintenance and process efficiency by updating virtual models with real-time operational data
Robotics technology utilizes automated robots to perform production tasks, including industrial and collaborative robots	– logistics and warehouse management achieve automation, intelligence, and efficiency of logistics and automated high-bay warehouses through AGVs, sorting and picking robots; – deploying industrial robots in production management to achieve automation of the production process; – in scenarios of high-speed or repetitive operations in quality management, systems equipped with high-resolution cameras and sensors integrate with AI algorithms to assist workers in product quality inspection
Application software refers to systems designed to support specific business functions, such as Business Intelligence (BI), Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), Product Lifecycle Management (PLM), Supply Chain Management (SCM), Outer-Approximation Programming (OA), etc.	– enterprise resource planning optimizes resource allocation through ERP systems; – production management utilizes MES to monitor manufacturing processes; – product lifecycle management manages product design and iteration through PLM software

Compiled by the author on the materials of the study

In the digital age, with the continuous development and technology innovation, emerging technologies such as AI, Big Data, and cloud computing are gradually being applied in the manufacturing industry. Information technology is penetrating into various aspects of the manufacturing industry at an unprecedented speed and depth, becoming a key force in promoting the transformation and upgrading of the manufacturing industry, improving management efficiency and competitiveness.

Intelligent manufacturing is a new production mode based on the deep integration of next-generation information and communication technology (ICT) and advanced manufacturing technologies, which runs through various aspects of manufacturing activities such as design, production, management, and service. It has functions such as self-perception, self-learning, self-decision-making, self-execution, and self-adaptation. Intelligent manufacturing is characterized by using intelligent factories as carriers, core processes intelligentization, and end-to-end data flow supported by robust network interconnection [5].

PRACTICE OF EMPOWERING INTELLIGENT FACTORY MANAGEMENT INNOVATION WITH INFORMATION TECHNOLOGY

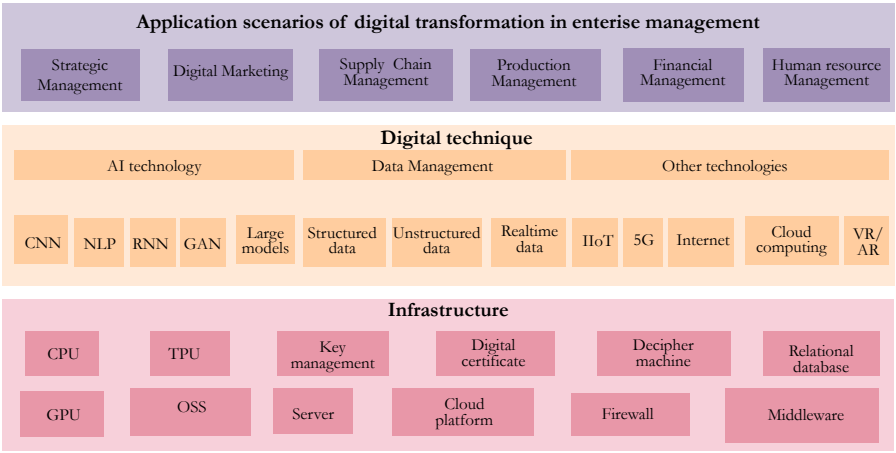
A Smart Factory utilizes various modern information technologies to coordinate various physical and digital processes across the manufacturing supply chain and the entire factory, including procurement, production, logistics, and sales and marketing. The main goal of intelligent manufacturing is to improve operational performance and respond quickly to supply and demand fluctuations. The Smart Factory enables coordination and cooperation between humans and machines, which essentially involves human-computer interaction where innovative technology enhances the user experience. In 2024, China's smart factory industry is focused on investment in smart equipment, accounting for 79.84%. Next are systems and software (15.4%), and services (4.76%)[3].

Manufacturing enterprises utilize digital technologies and tools such as the IoT, Computer-Aided Manufacturing (CAM), and digital Manufacturing Execution Systems (MES) to transform raw materials, components, energy, information, and data into products or services at scale. This includes specific scenarios such as multi-factory and multi-site collaborative scheduling, production process optimization, and intelligent quality inspection management. Deep neural networks are networks with a large number of layers that enable the simulation of complex hierarchical dependencies in data [6].

AI agents utilize advanced algorithms and data analysis techniques to simulate intelligent human behavior and autonomously complete specific tasks. These agents can collect and analyze real-time operational and production data, developing scientific management strategies based on specific business scenario requirements, and use this information. Compared to traditional management methods, AI agents possess higher levels of automation and stronger data analysis capabilities, which enables them to better optimize resource allocation, improve decision-making efficiency, and enhance overall operational perfomance.

The Figure below shows the technical and management application scenarios of a typical Smart Factory, which includes infrastructure such as servers, Tensor Processing Unit (TPUs) and Graphics Processing Unit (GPUs) computing power, key management, digital certificates, operating systems, relational databases, cloud platforms, firewalls, and middleware, which provide the underlying technical support for digital transformation. It also relies on the IoT, 5G, and the Internet to enable data interconnection and support the processing of structured, unstructured, and real-time data using AI technologies such as CNNs, NLP, RNNs, GANs, and large models. These technologies drive digital transformation across core business functions, including production, marketing, supply chain, and financial management.

[3] East Money Information Co., Ltd. Smart Factory industry chain. Access mode: https://caifuhao.eastmoney.com/news/20241101110048077879620 (accessed 07.11.2025).



Note: GPU – Graphics Processing Unit; TPU – Tensor Processing Unit; CNN – Convolutional Neural Network; RNN – Recurrent Neural Network; GAN – Generative Adversarial Network; NLP – Natural Language Processing.

Compiled by the authors on the materials of the study

Figure. Application scenarios for digital transformation of enterprise management

PRODUCTION PLANNING AND MANAGEMENT

A production plan is a comprehensive arrangement made by an enterprise for production tasks, specifically outlining the variety, quantity, quality, and schedule of products. In terms of production management, intelligent scheduling is achieved through AI algorithms and Big Data analysis. Based on factors such as market demand, equipment status, and raw material supply, optimal production plans are automatically generated. The enterprise has achieved information sharing and collaborative work among departments such as production planning, material management, quality management, and sales and marketing through information systems, thereby improving operational efficiency. Let us outline the main production stages.

1. Sales demand forecasting. Enterprises need to predict sales orders based on historical data and market conditions, while preparing production schedules based on signed contracts. This is the primary requirement for developing production schedules.

2. Procurement plan formulation. Materials for the production process must be prepared in advance, as ordering of raw materials requires a certain period of time. Developing accurate purchase and delivery plans is a critical link in production and a key component of the supply chain.

3. Production and manufacturing process. Humans remain at the center of all production activities. With the help of information technology, the collaborative efforts of production, technical, and management personnel can achieve a high degree of automation, intelligence, and autonomy in the production process.

4. Maintaining reasonable inventory. Lean production emphasizes inventory optimization, controlling costs, and improving efficiency. It is essential to ensure a balance between procurement, production, sales, and inventory.

The production plan is formulated based on three elements of customer requirements such as delivery time, quality, and cost. At the same time, it ensures the precise preparation, allocation, and utilization of the three key production factors such as materials, labor, and equipment.

PRODUCTION PROCESS MONITORING AND QUALITY MANAGEMENT

Digital technologies such as sensors, the Industrial Internet of Things (IIoT), and automation control systems are applied to the production process. Sensors are installed on key equipment and process nodes along the production line to enable real-time monitoring of the operating status of production equipment and product quality processes. The system performs real-time data collection from temperature, pressure, and velocity sensors for various physical parameters and transmits this data to the central control system through the IIoT.

Management personnel can visually monitor the real-time status of the production site through monitoring software. Once equipment abnormalities or quality deviations are detected, the system immediately issues an alarm. By utilizing Big Data analytics and issues technology, enterprises can mine a large amount of production data, identify root causes of quality problems, and take targeted improvement measures to achieve continuous quality improvement.

Sany Heavy Industry is the first lighthouse factory in China's heavy industry, connecting 12 thousand pieces of production equipment through an IIoT platform. By leveraging advanced human-machine collaboration, automation, AI, and IoT technologies, it has increased labor productivity by 85%, shortened the production cycle of large machinery from 30 to 7 days, and reduced manufacturing costs by 28%[4]. Equipment failures can be predicted and repaired proactively as the predictive maintenance system can forecast equipment failures 72 hours in advance.

SUPPLY CHAIN MANAGEMENT AND COLLABORATIVE INNOVATION

The supply chain in the manufacturing industry closely connects raw material suppliers, manufacturing production enterprises, logistics centers, sales channels, and end customers, forming an efficient operational ecosystem. Information technology enables information sharing and collaborative operations across the entire supply chain through data and application integration, based on the Supply Chain Management (SCM) platform.

By utilizing digital technologies such as the IoT, Big Data, AI, and automation equipment, as well as digital software tools such as ERP, CRM, TMS and WMS, we manage the entire process of product traceability from raw material procurement to sales, including multi-level supplier management, automated high-bay warehouses, intelligent logistics, batch-based quality traceability, and other segmented scenarios. The supply chain organically integrates multiple key flows – commercial, logistics, information, and capital – to effectively manages these scenarios and processes.

The Chinese automobile and battery manufacturer BYD Auto (hereinafter referred to as BYD) focuses on internal self-sufficiency in Supply Chain Management while expanding external supply channels, forming a unique "self-supply and external supply" system[5].

[4] Sany Heavy Industry. Intelligent Manufacturing. Access mode: https://www.sanygroup.com/digitization (accessed 07.11.2025).

[5] BYD Automobile's Multi-Supplier System. Access mode: https://baijiahao.baidu.com/s?id=1819561786392449617&wfr=spider&for=pc (accessed 07.11.2025).

BYD is deeply engaged in independent Research and Development (R&D), covering the entire value chain of core components such as batteries, motors, and electronic controls from research and development to production and sales, forming a complete vertical supply chain system. BYD's vertical supply chain system is its unique competitive advantage, ensuring the production needs of the enterprise and providing rich choices for external partners.

Table 2 shows the publicly released financial report data of BYD, analyzing the trends of four operational capability indicators, inventory and accounts receivable, in the past five years. Quantitative indicators reflect the improvement of management efficiency.

Table 2

BYD Company's Operational Capability Indicators from 2019 to 2024

Analysis indicators	2019	2020	2021	2022	2023	2024
Inventory turnover (days)	109.700	98.800	84.820	73.940	67.17	59.740
Accounts receivable turnover (days)	131.400	97.880	64.510	31.870	30.09	28.760
Inventory turnover rate (times)	3.280	3.644	4.244	4.869	5.36	6.026
Accounts receivable turnover rate (times)	2.741	3.678	5.580	11.300	11.96	12.520

Compiled by the authors on the materials of the source[6]

Inventory turnover rate, inventory turnover days, accounts receivable turnover rate, and accounts receivable turnover days are important financial indicators that reflect the operational efficiency of enterprise. These indicators demonstrate the performance of enterprises in logistics, capital flow, commercial flow, and production planning from different perspectives. Based on the Table 2 data analysis, inventory turnover days decreased from 109.7 days in 2019 to 59.74 days in 2024, and the related indicator inventory turnover rate increased to 6.026 times in 2024.

These indicators reflect that the faster the inventory circulation speed of the enterprise, the higher the logistics efficiency, and the more efficient the supply chain operations [7]. Accounts receivable turnover rate and days reflect the speed of capital recovery. The Table data shows that the accounts receivable turnover rate decreased from 131.4 in 2019 to 28.76 in 2024, and increased to 12.52 in 2024, indicating that the faster the capital recovery, the better the liquidity, and the healthier the supply chain's cash flow [8]. The comparison of operational capability indicators reflects the improvement of management during the digital transformation process.

At present, China has built more than 30 thousond basic-level smart factories, which cover more than 80 % of the manufacturing industry and have become a key force in promoting digital transformation. Among them, more than 1.2 thousond advanced-level smart factories that have achieved interoperability, and sharing of production and operation data, precise control of key production processes, and collaborative management. The scale is relatively larger and the technical level is higher. Futhermore, over 230 excellence-level smart factories represent the high level of China's smart factories, including nearly 2 thousond excellent scenarios such

[6] East Money Information Co.,Ltd. BYD Auto Main Indicator Annual Report. Access mode: https://emweb.securities.eastmoney.com/pc_hsf10/pages/index.html?type=web&code=sz002594&color=b#/cwfx (accessed 07.06.2025).

as intelligent warehousing, online intelligent detection, digital product research and development design, intelligent scheduling, and traceability analysis.

DISCUSSION

With the deep application of information technology such as the IoT, Big Data, AI, cloud computing, and others, the management models of manufacturing enterprises are undergoing profound changes. Technology-driven management innovation brings enormous potential to enterprises but also presents significant challenges. Enterprises take targeted measures to ensure successful transformation and maximize the value of innovation.

Enterprises face risks such as system attacks, data leaks, tampering, loss, or abuse in information management applications. Enterprises adopt public and private cloud platforms, as well as encryption technology, firewalls, intrusion detection systems, and other means to prevent data leakage and establish a comprehensive data security management system.

The introduction of new technologies may change the way employees work. Some staff members may lack the digital skills required for operation and maintenance, resulting in skill gaps and resistance. Automated systems have replaced some manual positions, causing employee dissatisfaction or a wave of resignations. In addition to implementing tiered training and introducing digital talents, enterprises also establish a "technology-plus-management" teams to drive digital transformation. The adoption of information technology follows the principles of the Technology Acceptance Model (TAM), which enhances users' perceived usefulness and ease of use.

In the current geopolitical climate, technological sovereignty has become a critical component of national strategic security. Since digital transformation requires significant investment from enterprises, governments are providing preferential policies and financial subsidies. At the national level, while providing preferential policies and financial subsidies for enterprises, high-tech enterprises are encouraged to adopt an independent and controllable domestic technology ecosystem to reduce the risk of sanctions.

CONCLUSION

The innovative application of information technology in the manufacturing enterprises management has proven highly effective, as demonstrated through practical case analysis and theoretical exploration. In the production process and quality management, enterprises have achieved real-time monitoring and intelligent scheduling of the production process, greatly improving production efficiency. Futhermore, collaborative supply chain management reduces logistics costs and shortens order lead cycles.

Although information technology has brought significant management improvements to manufacturing enterprises, it also presents various risks during implementation. Information and data security threats jeopardize system integrity, while rapid technological evolution and challenges in personnel adaptation pose risks to the sustainable development of enterprises. They must prioritize system integration planning, strengthen data security, and foster continuous employee training and communication. By effectively mitigating these risks, organizations can ensure that information technology continues to play a positive role in management innovation.

Information technology is undoubtedly a powerful driving force for promoting management innovation and enhancing competitiveness in manufacturing enterprises. With the continuous development and maturity of emerging technologies such as 5G, AI, and blockchain, IT applications in manufacturing enterprises will become more profound and extensive. In the future, enterprises should seize these technological opportunities, explore innovative models, strengthen risk management, and optimize management processes to achieve high-quality, sustainable development of manufacturing enterprises.

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