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The Connotation and Path of the Deep Integration of Artificial Intelligence and Manufacturing Industrys

Xiuwen Jiang

Tianjin University of Technology and Education school of Economics and Management, Tianjin, CO300222, China

Abstract: This paper systematically explores the connotation, current status, challenges, and advancement pathways of the deep integration of artificial intelligence (AI) and the manufacturing industry. The study highlights that deep integration takes data as a key driving factor, leveraging new-generation information technologies such as AI to achieve multidimensional systemic integration across technology, organization, data, and value, thereby propelling the manufacturing industry toward a fundamental transformation toward high-end, intelligent, and green development. Although China has established the world's largest manufacturing system and introduced multiple national strategies to support the development of "AI + manufacturing," significant gaps remain in areas such as independent innovation in core and key technologies, the depth of technological applications, balanced development of digital infrastructure, and the supply of interdisciplinary talent. To address these challenges, this paper proposes countermeasures including strengthening scientific and technological innovation and breakthroughs in key technologies, expanding smart manufacturing application scenarios, improving digital information infrastructure, and establishing interdisciplinary talent development systems. These measures aim to drive the comprehensive and deep integration of AI and the manufacturing industry, empowering high-quality development in manufacturing and enhancing the advancement of new-quality productive forces.

Keywords: Artificial Intelligence (AI), manufacturing industry, deep integration, intelligent.

1. Introduction

The manufacturing industry serves as the cornerstone for establishing and strengthening a nation, playing a pivotal role in developing and expanding the real economy and accelerating the construction of a modern socialist powerhouse. Therefore, it is imperative to vigorously advance the development of advanced manufacturing. The report to the 20th National Congress of the Communist Party of China explicitly stated the need to "promote high-end, intelligent, and green development of the manufacturing sector," providing a strategic direction for China's manufacturing transformation and upgrading. The 2025 Government Work Report proposed to "stimulate the innovative vitality of the digital economy" and "continue to advance the 'AI Plus' initiative, better integrating digital technologies with manufacturing strengths and market advantages." On June 6, the Leading Group Meeting on the Integration of Informatization and Industrialization under the Ministry of Industry and Information Technology called for implementing the "AI Plus Manufacturing" initiative, accelerating intelligent upgrades in key industries, and creating a "next-generation" version of smart manufacturing. On September 9, the State Council held a press conference as part of its themed series on "achieving high-quality implementation of the 14th Five-Year Plan. "This press conference introduced efforts to vigorously promote new industrialization and consolidate the foundation of the real economy during the 14th Five-Year Plan period. By 2024, China's manufacturing sector had maintained its position as the world's largest for 15 consecutive years, demonstrating significant scale advantages. Data-driven and intelligent technologies, represented by artificial intelligence, are comprehensively advancing new industrialization toward digitization, intelligence, green development, and integrated growth. However, current industrial digitalization and intelligence remain in their early stages. In terms of overall competitiveness, China's manufacturing sector still faces the challenge of being large but not strong, with relatively weak independent innovation capabilities in core technologies and most industries occupying mid-to-low positions in the global value chain. Amid a complex and evolving global competitive landscape, China urgently needs to seize opportunities presented by the Fourth Industrial Revolution, actively promote deep integration of AI and manufacturing, empower industrial transformation through scientific and technological innovation, and enhance international competitiveness and sustainable development capabilities.

2. Literature Review

Artificial intelligence (AI), digital technologies, and the digital economy have consistently been hot and key topics of research in both academic and policy circles. A review of existing literature reveals that current research primarily focuses on three areas: First, the measurement of AI and analysis of its economic and societal effects. Scholars have constructed theoretical and econometric models to examine the impacts and mechanisms of AI on economic and social development, including economic growth, income distribution, employment displacement, international trade, and industrial structure [1-3]. For instance, Cai Yuezhou and Chen Nan analyzed the effects of AI on economic growth across various sectors of the national economy and its implications for employment, based on the technological-economic characteristics of AI [4]. Second, the technical mechanisms, industry applications, and governance of generative AI. Following the explosive popularity of ChatGPT in late 2022, the volume of Chinese-language literature themed around "generative AI" surged. Third, the integrated development of AI and the real economy [5]. This strand of literature emphasizes the construction of multi-dimensional indicator systems to explore the conceptual

connotations, integration mechanisms, levels, effects, driving factors, challenges, and countermeasures of digital-real economy integration. Hong Yinxing and Ren Baoping defined the connotations of deep integration between the digital and real economies and analyzed existing problems and improvement pathways [6]. Zhu Lan examined the connotations and operational mechanisms of deep integration between AI and manufacturing [7] and further analyzed enabling factors such as AI engineering capabilities, task scenarios, data acquisition, and integration support elements to promote such integration. Ren Baoping et al. argued that the strategic focus of AI-empowered high-quality development lies in deep integration between AI and manufacturing as the mainline, smart manufacturing as the primary direction, and scenario-based applications as the driving force to build a high-level industrial empowerment system. However, the aforementioned studies predominantly emphasize macroeconomics, labor markets, and income distribution. In the realm of digital technologies, existing research often treats digital technologies or the digital economy as a holistic entity without distinguishing between different technologies such as AI, blockchain, big data, and cloud computing. Moreover, there is a lack of analysis on the mechanisms and pathways of deep integration between AI and manufacturing [8]. Therefore, this paper focuses on the integrated development of AI and manufacturing, investigating the mechanisms and pathways of their deep integration. Based on this, it proposes targeted countermeasures to address current challenges

3. China's Development Roadmap for "Artificial Intelligence + Manufacturing"

China's development of "Artificial Intelligence + Manufacturing" follows a systematic and well-structured advancement pathway. Guided by national strategies, it employs a multi-tiered policy framework and implementation mechanism to ensure that AI technologies effectively empower the transformation and upgrading of the manufacturing sector, while providing robust support for the achievement of long-term economic and industrial goals.

The "Made in China 2025" initiative, released in 2015, established intelligent manufacturing as the core direction for modernizing China's industrial system for the first time, explicitly proposing to promote the deep integration of cutting-edge technologies such as artificial intelligence (AI) with traditional manufacturing. The "New Generation Artificial Intelligence Development Plan" issued by the State Council in 2017 further elevated AI development to a national strategic priority, setting a "three-step" development roadmap through 2030 and designating intelligent manufacturing as a key application domain. Entering the 14th Five-Year Plan period, two pivotal documents reinforced this strategic framework: The "14th Five-Year Plan for Intelligent Manufacturing Development (2021)" explicitly called for the comprehensive integration of emerging technologies—including AI, big data, and 5G—into manufacturing processes to build advanced intelligent manufacturing systems. On August 26, 2025, the State Council unveiled a landmark policy titled "Several Opinions on Deepening the Implementation of the 'AI Plus' Initiative," advancing previous deployments through refined targets, expanded industry coverage, and strengthened infrastructure support. Key policy highlights include: achieving over 70% AI application penetration in six critical sectors—such as next-generation smart terminals and intelligent agents—by 2027; raising this ratio to above 90% by 2030 to make the intelligent economy a core growth engine; and establishing a thriving intelligent economic and social system in China by 2035.

Table 1. Guided by national strategy

Time	Policy	Elaborate on the key points
2015	Made in China 2025	For the first time, intelligent manufacturing was established as the core direction for modernizing China's industrial system, laying the foundation for cross-sector integration.
2017	New Generation Artificial Intelligence Development Plan	Elevate AI development to the national strategic level and formulate a phased roadmap.
2021	The 14th Five-Year Plan for Intelligent Manufacturing Development	Promote high-end, intelligent, and green manufacturing; accelerate the integration of AI, big data, and 5G technologies.
2024	AI Plus Action Plan	Prioritize 'AI Plus Manufacturing' as a national strategic focus; deploy large-scale AI models, machine vision, predictive maintenance, and intelligent control systems to enhance operational efficiency and product quality."
2025	《AI Plus Initiative 2025》	Prioritize 'AI Plus Manufacturing' as a national strategic imperative; deploy large-scale AI models, machine vision systems, predictive maintenance technologies, and intelligent control solutions to elevate operational efficiency and product quality.

Data Source: Compiled based on information from the websites of the Ministry of Industry and Information Technology and other relevant authorities.

4. Connotations of the Deep Integration between Artificial Intelligence and Manufacturing Industry

According to statistics from the Ministry of Industry and Information Technology, China's core artificial intelligence (AI) industry reached RMB 500 billion in scale in 2022, with nearly 4,000 related enterprises. Next-generation AI technologies have emerged as a critical driver and key enabler for optimizing and upgrading the manufacturing sector while enhancing total factor productivity. Currently, China has maintained its position as the world's largest manufacturing country for 13 consecutive years, having established a modern industrial system featuring a comprehensive range of sectors, a complete structural framework, and relative independence [9]. The country's industrial and supply chains demonstrate internationally advanced coordination capabilities, with significantly enhanced resilience, sustained release of development potential, and marked improvements

in the overall competitiveness of manufacturing enterprises. In recent years, the deep integration of AI technologies with manufacturing has enabled widespread applications across multiple fields, including speech recognition, industrial robotics, virtual reality, and intelligent vehicles, accelerating the intelligent transformation of the manufacturing sector. Since the implementation of China's Smart Manufacturing Initiative a decade ago, remarkable achievements have been made in smart manufacturing development. Powered by AI advancements, manufacturing enterprises are undergoing profound transformations in organizational forms and industrial models, giving rise to new business paradigms such as networked collaboration, platform-based design, personalized customization, and intelligent production. To date, nearly 340 national standards for smart manufacturing have been issued, with continuous improvements to the standards system. This has fostered a development pattern centered on enterprise innovation, supported by industry-wide collaboration and regional coordination.

5. Key Challenges in the Integration of Artificial Intelligence and Manufacturing in China

5.1. Significant Improvement in Innovation Capacity for Key Core Technologies

Compared to other countries, China's manufacturing sector is distinguished by its immense scale. While leading enterprises within the industry have actively explored digital transformation pathways and continuously promoted deep integration with next-generation information technologies, the majority of firms—particularly small and medium-sized enterprises (SMEs)—remain in the preliminary stages of practical application and technological convergence regarding cutting-edge innovations [10]. These enterprises still exhibit relatively weak core competitiveness across key operational links such as design, R&D, and manufacturing. The technological patents independently developed and innovated by China's manufacturing sector predominantly fall into peripheral application categories, with a notable absence of core technology patents. Application models and solutions for smart manufacturing, industrial internet, and industrial big data primarily originate from leading enterprises in advanced manufacturing nations such as the United States, Japan, and European countries [11].In comparison, although China has established the world's largest manufacturing system, its innovation practices in the deep integration of artificial intelligence with manufacturing still lag behind, failing to form a systematically mature paradigm with distinct Chinese characteristics.

5.2. Low level of technological application

Although next-generation information technologies (NGITs) such as artificial intelligence (AI), big data, and cloud computing have achieved preliminary applications in China's manufacturing sector, significant challenges persist. Notably, the degree of technological integration remains low, while application scope stays relatively confined, resulting in inadequate smart manufacturing capabilities. The advancement of AI technologies requires not only computational power and algorithmic support but also massive volumes of high-quality data [12]. Key barriers to deeper NGIT-manufacturing convergence include insufficient enterprise willingness to supply production factors, prevalent industrial big data security risks, limited scenarios for deep data utilization, and constrained value creation potential. These factors collectively underscore the urgent need to strengthen the integration of NGITs with manufacturing processes, while substantially expanding both the depth and breadth of technology-driven industrial upgrading.

5.3. Inadequate digital information infrastructure

Digital information infrastructure (DII) represented by 5G, data centers, and artificial intelligence serves as a critical enabler for China's traditional manufacturing sector to achieve digital transformation. Currently, due to disparities in DII development levels and investment intensity, a pronounced regional imbalance exists between eastern and western China in deploying these new-generation infrastructures, with particularly acute inter-regional allocation inefficiencies [13]. Moreover, unlike traditional industry data, industrial data encompasses multiple dimensions including manufacturing processes, production metrics, operational logs, and user information, characterized by diverse sources and numerous stakeholders. Any breach could pose severe security threats to both enterprises and end-users, necessitating enhanced security services for DII to ensure data protection.

5.4. Severe shortage of interdisciplinary professionals

Smart manufacturing encompasses all stages of manufacturing activities including production, management, design, and service. Its development demands not only IT-specialized professionals but also urgently requires interdisciplinary talent with multidisciplinary expertise spanning mechatronics, industrial software, and automation control. Currently, the structural contradiction between talent supply and demand has emerged as a critical bottleneck restricting enterprises' intelligent transformation [14]. A significant gap exists between China's current university talent cultivation models and actual industrial requirements, with educational outputs misaligned with market needs, resulting in existing talent quality failing to meet enterprises' developmental realities. Consequently, most firms face compound challenges including insufficient high-tech talent support, high upfront investment costs, and substantial return uncertainty.

6. Strategic Recommendations for Promoting Deep Integration of Artificial Intelligence and Manufacturing Industries

From the perspective of industrial foundations, China possesses a complete industrial base with significant competitive advantages in industrial chains compared to the United States and Germany. On the demand side, China's massive population scale creates an enormous domestic market, while simultaneously providing abundant human resources for the development of smart manufacturing. To advance the deep integration of artificial intelligence and manufacturing industries, the following development recommendations are proposed.

6.1. Increase investment in scientific and technological innovation to achieve breakthroughs in critical technologies

Innovation serves as the core driver of social progress and, for enterprises, constitutes the key element in building core competitiveness. To seize the commanding heights of global smart manufacturing, it is essential to systematically identify critical technical challenges and system integration bottlenecks across manufacturing processes and AI industrial applications, thereby forming a catalog of key core technologies requiring breakthroughs. Continuous enhancement of basic research capabilities must be prioritized to achieve breakthroughs in AI's core technologies, ensuring technological autonomy and control. This requires a systematic grasp of industry trends and critical generic technologies to develop targeted technology (technological breakthrough) roadmaps [15]. Enterprises should actively leverage central and local policy support, comprehensively utilizing government funds and policy instruments to maximize their guiding and leveraging effects. The dominant role of enterprises in scientific innovation must be further strengthened through deep collaboration between leading companies, national laboratories, and research institutions, supporting industry-university-research synergy to elevate AI engineering capabilities, expand industrial applications of AI, and drive innovative breakthroughs and deep integration of AI technologies in manufacturing.

6.2. Deepen the promotion and application of smart manufacturing technologies to foster new paradigms of intelligent industrial transformation

To advance the transformation and upgrading of the manufacturing sector, it is imperative to accelerate the deep integration of artificial intelligence (AI) with manufacturing, focusing on application scenarios at the workshop, factory, supply chain, and industry levels. This requires continuously expanding the breadth and depth of AI applications to permeate the entire manufacturing process and all production factors. Priority should be given to both process-based and discrete manufacturing industries, with intensified efforts to promote new models and business forms such as networked collaborative manufacturing, intelligent design, smart operation and maintenance services, and mass customization. Particular support should be extended to leading manufacturing enterprises to drive continuous innovation in cutting-edge areas, including integrated collaboration platforms, human-machine interaction, shared manufacturing, and industrial large-scale AI models[16]. By constructing intelligent operation platforms and enabling seamless data connectivity and system interoperability, these initiatives will facilitate the intelligent and efficient transformation of manufacturing. Simultaneously, accelerated cultivation and demonstration of new smart manufacturing models should be pursued to help more enterprises achieve quality and efficiency improvements, collectively advancing the high-quality development of China’s manufacturing sector.

6.3. Strengthen the construction of digital information infrastructure to consolidate foundational support and safeguard capabilities

Policy support should be further strengthened to encourage deeper collaboration between manufacturing enterprises and telecom operators. This will drive the proactive upgrade and transformation of diverse networks, including industrial internet, IoT, 5G, and gigabit optical networks, while optimizing internal and external enterprise network architectures and enhancing the data acquisition capabilities of on-site sensing devices. These efforts will comprehensively elevate overall efficiency in enterprise data collection, transmission, processing, and analysis. Following the implementation approach of "large enterprises building platforms and SMEs leveraging them," domestic conglomerates, industry-leading enterprises, and industrial parks should be supported to spearhead the development of industrial internet platforms. This will accelerate seamless interconnection across various business systems, promote cloud adoption among large, medium, and small enterprises across the industrial chain, and facilitate efficient data integration and sharing at the chain-wide level. Strengthened research and preparedness for industrial protocols and security vulnerabilities are essential. A coordinated, three-tier (national-provincial-enterprise) security protection mechanism should be established, guiding cybersecurity firms to deliver superior, high-efficiency security services. These measures will continuously enhance the security assurance level of industrial control networks in smart manufacturing.

6.4. Emphasis should be placed on cultivating interdisciplinary talent to provide intellectual support for the manufacturing sector

As the digital transformation accelerates across industries, China’s talent gap in digitalization is projected to continue widening. In the field of smart manufacturing, human resources represent the most critical strategic asset. Smart manufacturing integrates multidisciplinary knowledge systems spanning mechanical engineering, materials science, robotics, and other domains. However, a notable gap exists between current university talent cultivation models and the practical demands of smart manufacturing enterprises, necessitating effective alignment through industrial practice. Consequently, enterprises should serve as the primary entities responsible for cultivating smart manufacturing talent, particularly interdisciplinary and applied professionals. They should actively advance industry-university-research collaborative training mechanisms, driving universities to deepen integration of production and education with science and technology innovation [17]. This includes strengthening discipline-specific talent development aligned with industrial requirements. Enterprises must also diligently implement talent recruitment policies, attract top professionals in the field, and establish scientific, rational employment systems alongside comprehensive talent support frameworks to provide robust intellectual support for China’s manufacturing sector digital transformation.

7. Conclusion

Promoting the deep integration of artificial intelligence (AI) with the manufacturing sector represents both a critical pathway for achieving high-quality development in China's traditional manufacturing industries and a strategic imperative for sustaining long-term economic growth. While China's manufacturing sector boasts a comprehensive industrial system and substantial scale, numerous structural challenges and practical constraints persist in advancing this integration, necessitating continuous exploration and innovation through enterprise-driven practice. The research findings presented in this paper aim to provide theoretical references and practical insights for manufacturing enterprises to facilitate the fusion of AI technologies with manufacturing systems.

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