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Promoting High-Quality Development of Shaanxi's Manufacturing Industry with Digital-Physical Integration as a New Feature

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Abstract: The Third Plenary Session of the 20th CPC Central Committee has arranged for "improving the system for deep integration of the real economy and the digital economy," requiring continuous deepening of the integration of informatization and industrialization and vigorously advancing the high-quality development of the manufacturing industry. On the path of the new era and new guidelines, the key to implementing this arrangement lies in accelerating the popularization and application of a new generation of information technology across all fields and industrial chains, and fully unlocking the value of data elements. Promoting the deep integration of the real economy and the digital economy is a strategic choice to seize the opportunities of the new round of scientific and technological revolution and industrial transformation. It is also an indispensable path for building a modern industrial system and realizing the high-quality development of the manufacturing industry in the new development stage.

Keywords: Digital-Physical Integration; Manufacturing Industry; Digital Transformation; Digital Infrastructure; Industrial Chain Collaboration

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1.Overview of the Current Development of Digital-Physical Integration and Manufacturing Industry in Shaanxi

1.1 Shaanxi's Policies for the Development of Digital-Physical Integration

The Decision of the CPC Central Committee on Further Comprehensively Deepening Reform and Promoting Chinese-Style Modernization, adopted at the Third Plenary Session of the 20th CPC Central Committee, proposes to promote the deep integration of the real economy and the digital economy, and drive the high-end, intelligent, and green development of the manufacturing industry. The report of the 20th CPC National Congress also states that we should develop the digital economy, promote the integration of the digital and real economies, and build competitive digital industry clusters. From an overall perspective, the Party and the country have pointed out that digital-physical integration will give rise to new business forms, new scenarios, and new models, injecting strong impetus into economic and social development. In April 2022, Shaanxi Province issued the Implementation Plan for Accelerating the Development of the Digital Economy Industry in Shaanxi Province (2021-2025). To fully implement the strategic arrangements of the CPC Central Committee and the State Council on the development of the digital economy, as well as the 14th Five-Year Plan for the Development of the Digital

Economy in Shaanxi Province, the plan aims to seize the opportunities for the development of the digital economy industry, further implement the "Digital Shaanxi" strategy, and accelerate the high-quality development of the digital economy industry in Shaanxi Province. Its development directions include digital technology innovation and enabling applications, digital product manufacturing, digital technology application industries, and the digital transformation of the manufacturing industry. In January 2024, Shaanxi further issued the Policy Measures for Promoting the High-Quality Development of the Digital Economy to respond to and implement the decisions and arrangements of the CPC Central Committee and the State Council on developing the digital economy. This document accelerates the construction of new-type digital infrastructure across the province, simultaneously advances industrial digitalization, digital industrialization, data value activation, and digital governance, fosters a sound ecosystem, and empowers high-quality development.

1.2 Current Situation of Digital-Physical Integration Development in Shaanxi Province

Promoting the integration of the digital and real economies is a core path for implementing the national innovation-driven development strategy, accelerating high-quality development, and building a modern socialist country. Shaanxi Province has actively responded to the requirements of the central government, conformed to the trend of economic development, and promoted the integration of the digital economy and the real economy. In recent years, Shaanxi has issued a number of policy documents, including the 14th Five-Year Plan for the Development of the Digital Economy in Shaanxi Province and the Policy Measures for Promoting the High-Quality Development of the Digital Economy. These documents propose to focus on the construction of new-type infrastructure, enhance the supporting capacity for advancing industrial digitalization and digital industrialization, and further promote the in-depth integration of the digital economy and the real economy. At present, Shaanxi has achieved initial results in the development of the integration of the digital and real economies.

We will consolidate new-type digital infrastructure to provide strong support for the development of the integration of the digital and real economies. As of 2024, the number of 5G base stations put into operation in Shaanxi has exceeded 120,000, with a significantly expanded coverage. Key areas such as urban hotspots, industrial parks, and transportation hubs are covered, realizing the coexistence of multiple networks. These base stations cover fields including industrial internet, smart cities, and telemedicine, promoting the wide application of 5G technology in practical production activities. The province has built 22 data centers, which enhance computing power through new data infrastructure and provide strong support for data storage, processing, and application [1]. The Internet of Things (IoT) has driven the intelligent transformation of traditional industries, with a total of 27.667 million end users accumulated in fields such as transportation, agriculture, and energy.

The scale of the digital industry continues to expand and grow stronger. Focusing on the layout of core industrial clusters, Shaanxi has concentrated on hard technology fields such as artificial intelligence, photonics, and third-generation semiconductors, forming multiple industrial clusters worth over 10 billion yuan. For example, Fast Group has significantly improved production efficiency through intelligent unmanned production technology, becoming a national pilot project for digital transformation. In addition, the computing power of Xi'an Future Artificial Intelligence Computing Center reaches 3 billion billion operations per second, ranking second in China, which provides strong support for the integration of the digital and real economies in Shaanxi.

The intelligent transformation of enterprises is advancing rapidly. Shaanxi emphasized the development of the digital economy in its 14th Five-Year Plan, and in the past two years, it has issued a number of policies to clarify the strategic direction of enterprise digital transformation. A total of 1,154 enterprises in the province have passed the national standard certification for the integration of informatization and industrialization, and 12 enterprises have become industrial internet benchmark enterprises. The sales volume of goods sold via public networks increased by 16.6% year-on-year, and the economic benefits of digital transformation are self-evident. Furthermore, Xi'an has been approved as a national pilot city for the digital transformation of small and medium-sized enterprises (SMEs) in the second batch, which validates the province's policies. Shaanxi should maintain strategic agility, strengthen strategic planning, further focus on innovation, enhance application, promote integration, and continuously accumulate new advantages for the development of the digital economy.

1.3 Current Situation of Shaanxi's Manufacturing Industry Development

In recent years, Shaanxi's manufacturing industry has made significant progress in terms of total scale, industrial structure,

and intelligent transformation, continuously promoting economic development.

1.3.1 Overall Scale

In 2024, the gross domestic product (GDP) of Shaanxi Province reached 3.553877 trillion yuan, with a year-on-year growth of 5.3%, which was higher than the national average, indicating a steady economic development trend of the province. The added value of industrial enterprises above the designated size in Shaanxi increased by 7.8% year-on-year, among which the equipment manufacturing industry grew by 7.1%. It is estimated that by 2026, the proportion of the manufacturing industry's added value in GDP will reach 23%, with an average annual growth rate of over 7%. Through technological innovation, digital transformation, and industrial cluster construction, Shaanxi's manufacturing industry has become a core engine for economic growth. In 2024, the scale of the digital economy reached 1.4 trillion yuan; the added value of the equipment manufacturing industry grew significantly; key industries such as semiconductors and new energy vehicles made outstanding contributions; and emerging industries such as photonics and robotics developed rapidly.

1.3.2 Industrial Structure

Shaanxi's manufacturing industry mainly consists of key industries and emerging fields. The province has actively responded to the "Data Element ×" three-year action plan, promoted the transformation and upgrading of traditional manufacturing industries, strengthened the cultivation of leading manufacturing enterprises, and carried out pilot upgrades to drive the overall transformation of the manufacturing industry toward intelligence, high-endization, and greenization [2]. In 2024, Shaanxi achieved remarkable results in manufacturing transformation: the added value of industrial enterprises above the designated size increased by 7.8% year-on-year, and fixed asset investment grew by 5.2%, providing strong support for the province's economy. The growth of new energy and high-tech industries was particularly prominent, with the proportion of clean energy power generation rising to 10.2%. Shaanxi focuses on both traditional manufacturing and emerging industries: For traditional manufacturing, take the capacity expansion base of Shaanxi Automobile Heavy Truck as an example. It has realized efficient mixed-line production through cloud platforms and smart manufacturing technologies, becoming a leader in smart factories in China's heavy truck sector. For emerging industries, green energy is the main focus. Represented by Longi Green Energy, its green and low-carbon transformation projects and pilot production line expansion projects have promoted the intelligent and green development of the photovoltaic industry, leading the domestic industry.

1.3.3 Improvement of Transformation Systems Accelerated by Digital-Physical Integration Policies

To respond to the national strategic deployment of developing the digital economy and promoting digital-physical integration, Shaanxi Province has issued a number of policies from the "14th Five-Year Plan" period to this year. Among them, the "14th Five-Year Plan for Digital Economy Development" clearly defines 139 tasks, of which 14 have been completed and 125 are still in progress. These tasks cover digital-physical integration, new-type infrastructure construction, digital industrial transformation, and other areas.

The province strongly supports enterprises' digital transformation through multiple channels, including financial subsidies, financing support, tax incentives, and talent support. During the transformation process, the government helps enterprises reduce financial pressure in technological upgrading and digital transformation projects through interest subsidies and grants. After enterprises achieve intelligent upgrading, they can reduce production costs and improve product quality, significantly enhancing their competitiveness in the industry. At the same time, in emerging industries, the government assists in promoting the transformation and industrialization of scientific and technological achievements, enabling industries to develop the latest technologies and apply them to other related industries, thereby advancing large-scale digital-physical integration.

2.Problems in Promoting High-Quality Development of Shaanxi's Manufacturing Industry Through Digital-Physical Integration

Based on an analysis of the current status of digital-physical integration and manufacturing development in Shaanxi using the 2024 Statistical Yearbook of Shaanxi Province, it is concluded that Shaanxi has achieved remarkable results in digital-physical integration. However, there are still many problems in the integration of the digital economy and the real economy, which need to be solved as soon as possible to accelerate economic development.

2.1 Incomplete Digital Industry Scale and Inadequate Infrastructure Unbalanced coverage of communication networks

The development level of digital technology in Shaanxi lags far behind that of developed regions such as the Beijing-Tianjin-Hebei region and the Yangtze River Delta. Although Shaanxi has made certain achievements in the overall construction of communication networks, it still needs continuous improvement compared with these regions. The construction of digital infrastructure is the foundation of digital transformation, determining the speed and quality of the digital transformation of the manufacturing industry.

Firstly, the basic capabilities of the digital government need to be enhanced. There are data sharing barriers between government system platforms in different cities and districts, resulting in slow cross-departmental processes. Secondly, the application depth of the industrial internet is insufficient. Currently, the penetration rate of platform applications is far lower than the target of 45%, and small and medium-sized enterprises (SMEs) have low enthusiasm for "migrating to the cloud and accessing platforms" [3]. Finally, 5G network coverage is inadequate. The coverage targets focus on urban areas and key scenic spots, while the rural broadband access rate is much lower than that in developed regions, which hinders the development of smart agriculture and the digital economy.

2.2 Weak Technological Foundation Impeding the Integration of Informatization and Industrialization in Manufacturing

The existing technical equipment and systems of some manufacturing enterprises in Shaanxi are relatively outdated, making it difficult to meet the needs of digital transformation.

Firstly, the digital transformation of the manufacturing industry requires the integration of various advanced technologies, such as cloud computing, big data, artificial intelligence, and the Internet of Things. Shaanxi's manufacturing industry relies heavily on foreign high-end industrial software (e.g., CAD/CAE/CAM/PLM/MES), with weak R&D capabilities for independent and controllable core industrial software and insufficient application depth. In particular, there is a lack of specialized software for specific industries. These technologies are inherently complex, and integrating them to work toward a unified goal during transformation further raises the capability requirements for technical teams. Moreover, different manufacturing industries face diverse scenarios in the production process, leading to variations in the application methods and difficulty of technologies [4].

Secondly, some enterprises have outdated equipment, low automation levels, low numerical control rates and networking rates, and lack the basic conditions for data collection. Taking the integration of informatization and industrialization in manufacturing as an example, the development level of this integration in Shaanxi's manufacturing industry is 49.2, ranking only 10th in China, which is significantly lower than that of developed regions such as Jiangsu (69.2). In terms of key indicators—including the penetration rate of digital R&D and design tools, the numerical control rate of key processes, and the penetration rate of digital operation and management—Shaanxi is obviously below the national leading level.

2.3 Shortage of High-Tech Talents and Unbearable Transformation Costs for Small and Medium-Sized Manufacturing Enterprises

The digital transformation of the manufacturing industry relies not only on interdisciplinary talents who master information and communication technology and are familiar with manufacturing knowledge but also on new systems and production equipment. This is one of the core bottlenecks restricting the depth of the integration of informatization and industrialization—enterprises struggle to find talents who can effectively apply information technology to specific production scenarios. Currently, universities and vocational schools have insufficient integration of theory and practical operations in teaching, resulting in a shortage of such interdisciplinary talents. This is a major challenge faced by most provinces in China. On the other hand, to improve efficiency and achieve high-quality economic development through digital transformation, enterprises need to digitally upgrade both production systems and equipment, and introduce corresponding interdisciplinary talents to meet production and development needs. This requires a large amount of capital and resource investment, which is difficult for SMEs to complete independently.

2.4 Need for Expansion of Digital-Physical Integration Platforms

Shaanxi is a major manufacturing province. The GDP created by the manufacturing industry accounts for approximately 40% of the province's total GDP, and the added value of the manufacturing industry accounts for more than 85% of the added value of the secondary industry. It is the core of the industrial system and plays a key supporting role in the province's economic growth. Shaanxi's manufacturing industry mainly includes the automobile manufacturing industry, energy and chemical industry, high-tech manufacturing, and aviation equipment. These industries have a high degree of dependence on digitalization, and thus have extremely high requirements for integrated industry cloud platforms. However, the current digital-physical integration platforms in the province have some problems.

For instance, data silos prevent management from obtaining comprehensive and real-time data support. When decisions are based on outdated or incomplete information, it is highly likely to lead to decision-making errors [5]. When data cannot be shared, cross-departmental collaboration in production, sales, and supply chains will encounter problems. Information blockages disrupt the overall business processes of enterprises and even the entire industry. This not only affects the development of enterprises but also may prevent customers from selecting their preferred products.

2.5 Need for Enhanced Collaboration in the Manufacturing Industry Chain

The manufacturing industry chain is an interconnected whole, and collaborative cooperation between upstream and downstream enterprises is crucial for improving the efficiency and competitiveness of the entire industry chain. However, there is a large gap in the digitalization level of upstream and downstream enterprises in Shaanxi's manufacturing industry chain, especially for related enterprises in southern and northern Shaanxi. Additionally, there are obvious gaps in the industrial chain: Upstream enterprises mainly focus on energy, chemicals, and non-ferrous metals, but these enterprises have insufficient deep processing capabilities and rely on other provinces for high-end materials.

Midstream equipment manufacturing enterprises (such as those in the aerospace and automobile industries) have a certain foundation but low local supporting rates. Downstream end products are mainly used in military industry and electronic equipment, resulting in low market conversion efficiency. Some enterprises have already started digital transformation, while others still adhere to traditional production models. This leads to difficulties in industry chain collaboration and affects the overall effect of digital transformation [6].

3.Policy Recommendations for Promoting High-Quality Development of Shaanxi's Manufacturing Industry Through Digital-Physical Integration

3.1 Improve Digital Infrastructure Construction and Promote Digital Transformation of the Manufacturing Industry

Massive data is the most prominent feature of the digital economy. The key to the digital economy empowering the high-quality development of the manufacturing industry lies in the reasonable collection, organization, analysis, and summarization of complex data, and then utilizing it as a new type of production factor in manufacturing. The realization of these effects is inseparable from the construction of digital infrastructure. Improving digital infrastructure can be approached from the following two aspects:

First, give full play to the advantages of existing digital infrastructure. The initial investment in digital infrastructure is huge, and the cycle for its construction, operation, and return on investment is relatively long. Therefore, it is practically challenging to build a large number of high-quality digital infrastructure facilities in the short term. Given this, priority should be given to relying on existing foundations (such as the 5G network already built in Shaanxi), focusing on optimizing the layout of communication networks, accelerating the introduction of new technologies, and strengthening the collaborative construction of computing infrastructure to maximize the efficiency of existing resources.

Second, actively guide the penetration of digital technologies such as 5G, big data, cloud computing, and industrial internet into traditional manufacturing. On one hand, carry out automated and intelligent transformation of traditional production equipment. For example, widely apply industrial robots in fields such as automobile manufacturing and mechanical processing to perform high-repeatability, high-intensity, or high-precision operations (such as welding and assembly), which significantly improves production efficiency and product consistency. On the other hand, build a digital production management system that runs through the entire process, realizing comprehensive information-based management from

production planning and dynamic scheduling to quality control. This system enables enterprises to grasp real-time production dynamics, continuously optimize processes, and greatly enhance the flexibility of production and the speed of market response.

By consolidating the foundation of digital infrastructure through the above two paths, we can effectively promote the value transformation of data elements, ultimately driving the manufacturing industry toward digitalization, intelligence, and networking, and creating new business forms and models required for high-quality development.

3.2 Improve Technical Standards and Promote the Integration of Informatization and Industrialization in the Manufacturing Industry

The core challenge for the integration of informatization and industrialization in Shaanxi's manufacturing industry lies in its weak technological foundation—a systemic shortcoming that covers multiple aspects. Shaanxi should focus on strategic emerging industries such as a new generation of information technology, new materials, high-end equipment manufacturing, new energy, and new energy vehicles, select key industrial parks as carriers of innovation clusters, and build a echelon development pattern of "10-billion-yuan improvement, 100-billion-yuan leap, and 1-trillion-yuan growth".

Combined with Shaanxi's advantageous industries (such as aerospace, energy and chemicals, high-end equipment, and electronic information), concentrate resources to overcome core weak links. Encourage the introduction of advanced technologies and solutions from home and abroad, but on the basis of introduction, carry out digestion, absorption, and re-innovation to cultivate basic capabilities suitable for Shaanxi's local conditions. In addition, Shaanxi should accelerate the construction and application promotion of secondary nodes for industrial internet identifiers, and promote the in-depth coverage of 5G internet in key industrial parks and the application of typical scenarios [7].

Adopt a comprehensive strategy of "persisting in long-term key breakthroughs, ecological cultivation, and model innovation", while attaching equal importance to consolidating the foundation of manufacturing technology and improving information technology capabilities, combining technology introduction with independent innovation, and balancing the building of benchmarks and benefiting small and medium-sized enterprises. Only by strengthening core technologies can we truly unlock the huge enabling potential of the integration of informatization and industrialization for the high-quality development of Shaanxi's manufacturing industry.

3.3 Cultivate a Team of High-Tech Talents

Talents are the key to driving the digital economy and empowering the high-quality development of the manufacturing industry. It is necessary to vigorously introduce and cultivate versatile "digital + manufacturing" talents and teams to promote the high-quality development of Shaanxi's manufacturing industry. Specifically, the principle of "introducing external talents and cultivating internal talents" should be adhered to in order to improve the talent team.First, formulate preferential policies from multiple aspects to attract outstanding digital technology talents and management talents at home and abroad to work in Shaanxi, providing talent support for digital platform construction and the digital transformation of the manufacturing industry. For example, in terms of salary and benefits, a certain proportion of salary subsidies can be given based on their work experience and professional and technical level; strengthen the protection of intellectual property rights for digital technology talents and provide them with services and support in patent application and rights protection; in terms of taxation, provide appropriate reductions and exemptions for personal income tax, and grant certain tax incentives to enterprises that introduce digital technology talents. Second, improve the industry-academia integration model for collaborative talent cultivation. On one hand, optimize the professional settings of universities in Shaanxi, promote universities to strengthen the construction of digital technology-related majors, optimize curriculum design, and cultivate professional talents who can adapt to digital platform construction and the digital transformation of the manufacturing industry. Encourage universities to cooperate with enterprises, carry out industry-academia-research cooperation projects, and cultivate digital talents with practical capabilities to provide talent support for the digital transformation of the manufacturing industry. On the other hand, in response to the needs of manufacturing enterprises, carry out digital technology vocational training to improve the digital skills of enterprise employees.

3.4 Build Diversified Digital Platforms and Accelerate the Digital Transformation of the Manufacturing

Industry

Shaanxi Province should seize the strategic opportunity of building a "Digital China" and promote the manufacturing industry to leap toward smart manufacturing with unprecedented efforts. By constructing multi-level and integrated digital platforms, new drivers for Shaanxi's manufacturing industry will be fostered. The specific measures can be carried out as follows:

Concentrate core resources to build a "core hub" for regional digital transformation, which integrates the capabilities of core industrial software such as PLM (Product Lifecycle Management), MES (Manufacturing Execution System), and ERP (Enterprise Resource Planning). This hub will provide key services for manufacturing enterprises in the province, including cloud-based collaborative design, flexible production scheduling optimization, and supply chain visualization [8]. At the same time, establish a "one platform per industrial chain" mechanism, focusing on advantageous industrial chains such as semiconductors, aerospace, and new energy vehicles to achieve precise development. This mechanism will realize the integration of equipment digitalization and physical operations, the accumulation of process knowledge, and the closed-loop of quality traceability, while accelerating upstream-downstream collaborative design, capacity sharing, and networked collaborative manufacturing in the industrial chain.

Activate new manufacturing platforms through technological empowerment: integrate AI into the core of manufacturing by embedding it in various production links, and use it to analyze management data for accurate decision-making and intelligent analysis. With platforms as the foundation, data as the lifeblood, and intelligence as the soul, we should promote the full-factor, full-process, and full-chain digital transformation of Shaanxi's manufacturing industry, and accelerate its advancement toward the high end of the industrial chain and value chain.

3.5 Improve Policy Support

Formulate targeted policies to provide precise support for weak links. In terms of funding: Increase financial support and establish a special fund for the digital transformation of the manufacturing industry to support enterprises in carrying out digital upgrading and innovation. Optimize tax policies by offering tax incentives to enterprises engaged in digital technology R&D and application, so as to reduce the cost of enterprises' digital transformation. Simplify approval procedures to lower the cost of enterprises' digital upgrading[9].Provide high-quality and convenient financial services and resources to offer capital support for enterprise development. In terms of policies and regulations: Formulate and improve policies and regulations that support the digital upgrading of the manufacturing industry, and increase support for innovative enterprises and innovative projects. In terms of intellectual property rights: Establish and improve the intellectual property protection system, safeguard enterprise data security[10], and encourage manufacturing enterprises to actively carry out digital reform, so as to realize the intelligent, green, and service-oriented transformation of the manufacturing industry.

4.Conclusion

As a core path to drive the high-quality development of the manufacturing industry, digital-physical integration has injected key momentum into the transformation and upgrading of Shaanxi's manufacturing industry. Based on the previous analysis of the current development status and existing problems of digital-physical integration and the manufacturing industry in Shaanxi, it can be seen that in recent years, Shaanxi has achieved phased results in policy guidance, infrastructure construction, and industrial transformation: it has clarified the transformation direction by issuing policy documents such as the 14th Five-Year Plan for the Development of the Digital Economy in Shaanxi Province, built more than 120,000 5G base stations and 22 data centers to consolidate the foundation of digital infrastructure, and cultivated benchmark enterprises for digital transformation such as Fast Group and Longi Green Energy. In 2024, the scale of the digital economy reached 1.4 trillion yuan, key industries such as equipment manufacturing and new energy achieved significant growth, and the manufacturing industry has become a core support for the province's economic growth.

However, in the process of promoting the high-quality development of the manufacturing industry through digital-physical integration, Shaanxi still faces multiple bottlenecks that need to be broken through urgently: the unbalanced urban-rural coverage of digital infrastructure and insufficient in-depth application of the industrial internet restrict the efficient circulation of data elements; the weak technological foundation of the manufacturing industry, with high dependence on foreign high-end industrial software, results in a significant gap in the development level of the integration of informatization and

industrialization (49.2) between Shaanxi and developed regions such as Jiangsu (69.2); there is a shortage of interdisciplinary "digital + manufacturing" talents, and small and medium-sized enterprises (SMEs) find it difficult to promote digitalization independently due to excessively high transformation costs; the digital-physical integration platforms suffer from the "data silo" phenomenon, and the digitalization level of upstream and downstream enterprises in the industrial chain varies greatly with weak collaboration capabilities. These problems collectively hinder the full release of the value of digital-physical integration.

In the future, Shaanxi needs to focus on targeted solutions to problems and promote the in-depth development of digital-physical integration through systematic measures. On the one hand, it should continue to improve digital infrastructure, optimize the layout of communication networks, and promote the penetration of 5G and industrial internet into traditional manufacturing. On the other hand, it should form a synergy through technological breakthroughs, talent cultivation, platform construction, and policy support: overcome the shortcomings of core industrial software, build a talent system of "introducing external talents and cultivating internal talents", create an industrial collaboration model of "one platform per industrial chain", and at the same time rely on policies such as special funds and tax incentives to reduce the burden of enterprise transformation. Only in this way can we fully activate the value of data elements, promote the in-depth transformation of Shaanxi's manufacturing industry towards digitalization, intelligence, and greenization, truly realize the leap from a "major manufacturing province" to a "strong manufacturing province", and provide "Shaanxi experience" for the high-quality development of the manufacturing industry empowered by digital-physical integration across the country.

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