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Construction of Modern Science and Technology Support System for Advanced Manufacturing Clusters

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Abstract: Advanced manufacturing clusters are crucial for establishing manufacturing power and are key to the construction of modern industrial systems and high-quality industrial development. Inadequate scientific and technological innovation capabilities have severely restricted the development of manufacturing clusters in China. Herein, we summarize international experience in establishing science and technology support systems for advanced manufacturing clusters, and analyze the current status and existing problems of these clusters and support systems in China. We categorize the advanced manufacturing clusters into basic, strategic, and cutting-edge technology industrial clusters based on the characteristics of the industrial development stages. Moreover, we investigate the development directions and propose construction paths for these manufacturing clusters. In particular, the industrial concentration and intelligence level of basic industrial clusters must be improved. Major enterprises should be cultivated for the industrial chain within strategic industrial clusters, and technology innovation and pilot test platforms must be established. As for the industrial clusters of cutting-edge technologies, an innovation ecosystem that integrates universities and scientific research institutes must be established, and the demonstration and application of new technologies should be encouraged.

Key words: advanced manufacturing; industrial cluster; science and technology support system; industrial structure adjustment; common technology innovation platform

1 Introduction

An industrial cluster refers to a set of geographically concentrated and interconnected suppliers, industries, and specialized institutions and associations in a specific field, which may include governments, universities, industry standards setting institutions, vocational training institutions, and think tanks. An advanced manufacturing cluster is an industrial organization formed by the symbiosis of enterprises and relevant institutions associated with advanced techniques and advanced manufacturing based on the general characteristics of industrial clusters. It is characterized by the world's top-ranked cluster scale, complete technological innovation system, relatively complete industrial chain, and good policy environment [1].

In the context of global economic integration, competition between countries has gradually changed from competition between enterprises and industrial chains to competition between industrial clusters and industrial ecosystems [1]. Manufacturing cluster development is one of the basic laws of industrial development [2]; additionally, it is the only approach for the structural adjustment, transformation, and upgrading of the manufacturing industry, whose corresponding development level represents national industrial competitiveness to a certain extent [2]. Advanced manufacturing clusters are typically high-technology industrial clusters, and building a technological support system for industrial clusters is essential for enhancing the innovation capability of industrial clusters and improving the core competitiveness of the industry; it is also the core element for the development of manufacturing industrial clusters.

Research pertaining to the scientific and technological support system of manufacturing clusters focuses on three aspects. (1) From the perspective of constructing the innovation system of manufacturing clusters [1,3], it focuses on the characteristics of the innovation system and the government's governance of the innovation system. (2) From the perspective of the macro development of strategic emerging industries [4,5], it focuses on the regional distribution of innovation resources, the relationship between regional innovation systems and strategic emerging industry clusters, etc. (3) From the perspective of typical industry development [6,7], it focuses on the research of cluster networked collaborative organization, open innovation, and industrial chain collaborative innovation. The author believes that the scientific and technological support system of advanced manufacturing clusters is an innovation network formed based on industrial clusters and comprises core elements such as enterprises, scientific research institutions, and innovation environments; enterprises are the main contributor of innovation, whereas scientific research institutions are the core support. The innovation environment (such as science and technology intermediary services, institutional mechanisms and policy environment, and cultural atmosphere) is key to the growth of the cluster. These three core elements form an innovation network with enterprises as the core and jointly support the development of advanced manufacturing clusters [8]. The scientific and technological support system of advanced manufacturing clusters has the following characteristics: (1) Enterprises, universities, scientific research institutes, new innovation organizations and other subjects are active, master key core technologies in a certain field, and possess capabilities of continuous innovation; (2) It reflects commendable production–education–research collaborative innovation and has a well-functioned upstream and downstream collaborative innovation mechanism of the industrial chain, thus forming a technological innovation system with enterprises as the main body; (3) The service level of science and technology intermediaries satisfies the requirements of cluster innovation, and the policies and systems for supporting innovation are superior, which involves an innovative cultural atmosphere of tolerance, openness, and trust.

Cultivating advanced manufacturing clusters is an important measure to advance manufacturing in China; furthermore, it is an endogenous requirement for establishing a modern industrial system. Currently, a number of industrial clusters with good manufacturing foundation and strong innovation ability have emerged in Beijing–Tianjin–Hebei, Yangtze River Delta, Guangdong–Hong Kong–Macao Greater Bay Area, and other regions, which possess the basic momentum for the development of advanced manufacturing clusters [2]. However, compared with the world's major manufacturing powers, China is still affected by the innovation capacity building of manufacturing clusters. It is necessary to realize the high-quality development of China's manufacturing industry to build a scientific and technological support system for manufacturing clusters, improve the technological innovation capabilities of manufacturing clusters, and

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enhance the international competitiveness of manufacturing clusters. Based on the industrial application field as a starting point, the manufacturing industry clusters are categorized into basic industries, key strategic industries, and cutting-edge technology industries to analyze the current situation and existing problems of the construction of scientific and technological support systems. Additionally, the development direction and construction path of the modern scientific and technological support system of industrial clusters are discussed to provide a basic reference for the high-quality development of the manufacturing industry and the construction of a modern industrial system, as well as to facilitate investigations on macroeconomic management.

2 International experience in construction of scientific and technological support systems for advanced manufacturing clusters

2.1 Science and technology support system for advanced manufacturing clusters in the United States

The agglomeration of scientific and technological resources is promoted through regional advantages. Regional advantages, such as factor endowment, transportation infrastructure, density of scientific research institutions, and technological research and development (R&D) strength, have contributed to the agglomeration of manufacturing in the United States, where the corresponding technology, capital, talent, and industrial agglomeration have formed a relatively complete scientific and technological support system. Owing to the advantages of computer and information technology R&D at Stanford University, Caltech, and other universities in the region, California has formed an industrial cluster that focuses on information technology, Internet services, and software development. By exploiting the abundant oil reserves and convenient transportation conditions in the Gulf of Mexico, Houston has formed a petrochemical industry cluster comprising 29 corporate headquarters from more than 30 major energy companies in the United States and more than 1000 petroleum equipment manufacturers and suppliers [9], thereby promoting the growth of related industries such as oil exploration, refining, and processing.

A production–education–research institute collaborative innovation mechanism is established. The high-technology industry cluster in Silicon Valley has focused on production–education–research institute cooperation with Stanford University, which has transformed the advanced technology of Stanford University with market application prospects into cluster enterprises. Meanwhile, the Boston Biomedical Industry Cluster focused on establishing a university–enterprise cooperation mechanism with universities in the area, such as Boston University, Massachusetts Institute of Technology (MIT), and Harvard Medical School, which have contributed technologically to the development of the industry cluster. In addition, MIT encourages outstanding educators to establish businesses; in fact, more than 3×10^4 companies have been founded by the MIT alumni [9].

2.2 Science and technology support system for advanced manufacturing clusters in Germany

A networked interaction mechanism is established. The German government actively promotes the formation of a highly networked local interaction/exchange mechanism between geographically adjacent and clustered enterprises and various institutions. Energy efficiency innovation clusters in the German Leading Cluster Competition Program are concentrated in Saxony, and more than 110 cluster partners (including 17 large enterprises, 61 small and medium enterprises, and 33 universities and research institutions) have collaborated to jointly develop energy-saving information and communication technologies based on technology alliances, thereby providing a foundation for the construction of a digital society [3].

The innovation and development of clusters is promoted via classified support and cultivation. The German government adopts differentiated policies to support cluster development, including prioritization on a single industry, such as the Bioregional Plan, which aims to promote the industrialization of biotechnology. Meanwhile, the Innovative Competitiveness Cluster Plan advocates cross-industry and cross-regional collaborative innovation. Additionally, the Towards Cluster Plan supports cooperation between regions and establishes a mechanism for mutual cooperation between clusters. However, the German government adopts a classified management method for construction based on the different development stages of manufacturing clusters, establishes specific support plans for less sophisticated technologies/industries and outdated fields, and adopts competitive policies for well-developed technologies and industries [3].

2.3 Science and technology support system for advanced manufacturing clusters in Japan

Innovation institutions is vital to the advanced manufacturing cluster. Universities, research institutes, and other innovative institutions are the primary constituents in Japan’s advanced manufacturing clusters. Cluster innovation activities are introduced by scientists and team members of R&D institutions; they are centered on technology R&D, mediated by technology transfer and transformation, and financial institutions, and ultimately aimed at cultivating technology R&D enterprises [10].

A long-term mechanism for cluster development is established. The Japanese government formulates coherent and time-sensitive policies based on development goals and prioritizes the continuity of relevant policies. Enterprises are supported to perform technological innovation activities through continuous policies such as tax reduction and exemption, as well as through the establishment of national-level science and technological projects. The future development of the manufacturing cluster is prioritized, and a number of key common technology innovation platforms are constructed within the cluster. Close contact is maintained among scientific research institutions, enterprises, universities, industry associations, and management departments, and innovation is realized collaboratively [10].

2.4 Science and technology support system for advanced manufacturing clusters in South Korea

A cluster management system with microclusters as the basic unit is constructed. Microclusters in Korean industrial clusters are specific interest groups formed by joint research institutions and other related institutions, with enterprises as the main body, based on typical key issues encountered by multiple enterprises in specific fields in industrial clusters [1]. R&D breakthroughs and cooperation exchanges pertaining to typical key issues of cluster industries in the form of microclusters [1] prove that the abovementioned system has improved the efficiency of technological innovation and is vital for promoting the development of South Korea’s manufacturing clusters.

Differentiated cluster management strategies are implemented. The Korean government has adopted differentiated cluster management strategies. Prior to 2007, various development guidelines were formulated to promote the investment and settlement of enterprises in a cluster via a business development model. From 2008 to 2009, the integrated management of clusters was introduced to the entire country to construct and manage clusters via innovative cluster institutions. After 2009, the pattern for advanced manufacturing clusters was formed, and the goal of cluster management was specified to enhancing national competitiveness.

3 Development status and main problems of manufacturing clusters and their scientific and technological support systems in China

In 2021, the Ministry of Industry and Information Technology of China released a list of winners for advanced manufacturing cluster finals (Table 1). The 25 selected clusters represent the development level of domestic industrial clusters, involving new-generation information technology, high-end equipment, advanced materials, biological medicine, and other fields. These industrial clusters are primarily distributed in the Yangtze River Delta, Pearl River Delta, Bohai Rim, and the central and western regions, whereas none of the clusters in the Beijing–Tianjin–Hebei region and the northeast region were selected at that time. The overall distribution pattern was dense in the east and the south, and sparse in the west and the north. Most of the selected advanced manufacturing clusters formed corresponded

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to scientific and technological support systems. The enterprises in the cluster enable robust independent innovation, thus forming a pattern in which leading enterprises lead, whereas small- and medium-sized enterprises are developed around the industrial chain to establish a relatively close collaborative innovation network of production–education–research. Various types of industrial clusters exist. Based on the characteristics of China's industrial development stage, industrial clusters are classified into basic, key strategic, and cutting-edge technology industrial clusters in this study.

Table 1. 2019 Advanced Manufacturing Cluster Final Winners by Ministry of Industry and Information Technology.

Region		Field
Yangtze River Delta	Shanghai	Shanghai Integrated Circuit Cluster, Zhangjiang Biomedical Cluster
	Jiangsu	Wuxi Internet of Things Cluster, Nanjing Software and Information Service Cluster, Changzhou New Carbon Materials Cluster, Nanjing New Electric Power (Smart Grid) Equipment Cluster, Suzhou Nano New Materials Cluster, Xuzhou Construction Machinery Cluster
	Zhejiang	Hangzhou Digital Security Cluster, Ningbo Magnetic Material Cluster, Wenzhou Yueqing Electric Cluster
	Anhui	Hefei Intelligent Voice Cluster
Pearl River Delta	Shenzhen and Guangzhou	Shenzhen Next-Generation Information and Communication Cluster, Shenzhen Advanced Battery Materials Cluster, Guangzhou–Shenzhen–Foshan–Dongguan Intelligent Equipment Cluster, Guangdong–Foshan–Huizhou Ultra HD Video and Smart Home Appliance Cluster, Dongguan Intelligent Mobile Terminal Cluster, Shenzhen–Guangzhou High-end Medical Device Cluster
Bohai Rim	Shandong	Qingdao Intelligent Home Appliance Cluster, Qingdao Rail Transit Equipment Cluster
Central Region	Hunan	Zhuzhou Advanced Rail Transit Equipment Cluster, Changsha Construction Machinery Cluster
Western Region	Sichuan	Chengdu Software and Information Service Cluster, Chengdu and Deyang High-end Energy Equipment Cluster
	Shaanxi	Xi'an Aviation Cluster

3.1 Basic industrial clusters and their technological support systems

3.1.1 Development status

The basic industries represented by textiles, building materials, petrochemicals, iron and steel, nonferrous metals, and light industry are the dominant industries of China [2], which were developed earlier with relatively mature and large production capacity, as well as strong upstream and downstream supporting capabilities in the industrial chain. Most of them have formed a cross-regional, multibase belt-like distribution pattern based on industrial clusters and a technological innovation system with leading enterprises as the main body. Based on the iron and steel industry as an example, a river/coastal belt-like distribution pattern was formed by Baowu Iron and Steel Group Co., Ltd. and Hegang Co., Ltd., whereas clusters in the iron and steel industry were formed in Shanghai, Wuhan, and Tangshan. Iron and steel enterprises with high market competitiveness have been established, such as Baoshan Iron and Steel Co., Ltd., Hegang Group Co., Ltd., Anshan Iron and Steel Group Co., Ltd., Shagang Group Co., Ltd., as well as scientific research and metallurgical talent training bases such as Beijing University of Science and Technology, Northeastern University, and General Institute of Iron and Steel Research. Enterprises have established close production–education–research cooperative relations with universities and research institutes. Based on the textile industry as an example, approximately 7×10^4 large and small textile enterprises as well as household industrial units exist in the Shaoxing modern textile cluster in Zhejiang Province. Among them 2858 textile and related enterprises exceed the designated size, thus forming an industrial cluster that integrates purified terephthalic acid, chemical fiber, weaving, printing and dyeing, home textiles, textile machinery, creative design services, professional markets, e-commerce, and international business exchanges. This cluster has become the largest chemical fiber fabric production base as well as printing and dyeing processing base in Asia [11].

3.1.2 Problems encountered

The homogenization of basic industrial clusters in China is prominent. However, problems exist, such as the overcapacity of low-end products, single-variety structures, and low-level repetitive construction [12], as well as low motivation for scientific and technological innovation. This is because most of the basic industries are traditional industries, whose market demand tends to be saturated and technology is relatively mature, resulting in many enterprises competing fiercely with each other. Owing to the implementation of carbon peaking and carbon neutrality strategies, increased environmental constraints, and further increase in labor costs, the sustainable development of basic industrial clusters is affected by significant challenges; thus, the structure must be adjusted, whereas quality and efficiency must be improved. For example, approximately 60 iron and steel enterprises exist in Tangshan City, Hebei Province, which generally feature small scales, low industrial concentration, insufficient R&D and innovation capabilities, and few high value-added products. In recent years, chemical materials and polyolefins have been manufactured rapidly; however, high-end products based on these materials are rarely manufactured, as construction speed and cost advantages are prioritized over value [12].

3.2 Key strategic industrial clusters and their scientific and technological support systems

3.2.1 Development status

Strategic emerging industries represented by information, high-end equipment, new energy, new materials, biology, energy conservation, and environmental protection are currently being developed rapidly in China, whose industrial clusters are being formed and scientific and technological innovation resources are being amassed rapidly. Some clusters have formed a pattern in which leading enterprises promote the common development of small- and medium-sized enterprises; the upstream and downstream of the industrial chain are closely matched. The collaborative innovation mechanism of the industrial chain and the production–education–research cooperation mechanism has been improved gradually, and an industrial collaborative innovation system with enterprises as the main body has emerged [1,11]. In key strategic industrial clusters, a number of large-scale innovation platforms, represented by national innovation centers and new industrial technology research institutes, are being constructed rapidly to serve as links among enterprises, universities, and research institutes. Based on the construction machinery industry cluster in Changsha as an example, the total output value of the cluster in 2019 exceeded 200 billion CNY, which constituted approximately 23% of the national construction machinery industry. The products in the cluster encompass 12 major categories, more than 100 small categories, and more than 400 models and specifications. The leading enterprises include Sany Heavy Industry Co., Ltd., Zoomlion Heavy Industry Co., Ltd., Railway Construction Heavy Industry Group Co., Ltd., and Shanhe Intelligent Equipment Co., Ltd., whereas other supporting enterprises include Xingsha Machine Tool Co., Ltd., Wanxin Precision (Hunan) Co., Ltd., and Qitai Sensing Technology Co., Ltd., as well as up to 416 main engine and parts companies, which have formed a synergistic relationship for collaborative innovation between upstream and downstream. Furthermore, the industrial chain is independent, safe, and controllable. By emphasizing the production–education–research cooperation, a collaborative innovation model was established with Tsinghua University, Zhejiang University, National University of Defense Technology, and the Chinese Academy of Sciences, and components including multiway valves, oil cylinders, and pumps have been further improved. Meanwhile, the functions of the Changsha Construction Machinery Industry Association, as a coordination and management organization of related clusters, has been improved.

3.2.2 Problems encountered

Although the industrial chain has been formed in key strategic industrial clusters, significant disadvantages are present in the key links of the industrial chain, i.e., the core basic components, key basic materials, basic testing and inspection equipment, as well as advanced basic manufacturing processes and equipment (referred to as the "four basics") are not at a high level of autonomy and control, thus restricting the development and expansion of industrial clusters. For example, the core video surveillance products produced by the digital security industry cluster in Hangzhou, Zhejiang Province, have a global market share of approximately 50%. However, its market share of chips, key components, operating systems, and servers is low. The Qingdao Rail Transit Equipment Industry Cluster is the only industrial cluster in China that integrates high-speed rail/subway vehicle production, R&D and manufacturing of key core systems for rail transit, and a collaborative innovation platform for national basic application technologies; however, it is lagging in the development of the "four basics" and still relies on imported products.

The problems related to key strategic industrial clusters and their technological support systems are as follows: First, the independent innovation capability of cluster enterprises is insufficient, and the independent R&D of key common technologies and high-end products is unsatisfactory, where investment in independent innovation is insufficient, and technical originality is inferior. Second, the production–education–research collaborative innovation mechanism and the industrial chain collaborative innovation mechanism among the cluster innovation subjects are unsatisfactory, some of which are "accumulated but not clustered," and enterprises in the industrial cluster are not correlated well; as such, a complete upstream and downstream supporting relationship does not exist in the industrial chain. In addition, the cooperation among enterprises, universities, and research institutes is inadequate, and collaborative innovation in the industrial chain is unsatisfactory; therefore, the innovation platforms within the cluster cannot function as intended in a timely manner. Third, public services such as general technology R&D, inspection and testing, standards, patents, and financing services to support the development of industrial clusters are inadequate; therefore, the support policies for the development of small- and medium-sized enterprises in the cluster have yet to be improved.

3.3 Cutting-edge technology industrial clusters and their scientific and technological support systems

3.3.1 Development status

Some regions have performed R&D on cutting-edge technologies, such as graphene, liquid metal, superconducting materials, artificial intelligence, and hydrogen energy, and formed scattered industrial bases, where the scale of the industry is gradually expanding; furthermore, industrial agglomeration has been indicated. Some industries with relatively high technological maturity have formed the prototype of the industrial chain from technology R&D to mass production to downstream applications. Compared with basic industrial clusters and key strategic industrial clusters, cutting-edge technology industrial clusters have a lower agglomeration degree of innovation resources but allow a more complete scientific and technological support system to be formed. Considering the hydrogen energy industry cluster area as an example, the development of hydrogen energy is currently primarily driven by its application in the transportation field, whose industrial chain is gradually extending to hydrogen production, storage, transportation, hydrogenation, fuel cells, and supporting industries with layouts in Central China, North China, and Northeast China. However, from the overall national perspective, the layout of innovation resources related to hydrogen energy is relatively scattered and the power of innovation units remains feeble.

3.3.2 Problems encountered

First, scientific research resources are scattered and their construction repetitive. Owing to the good development potential of cutting-edge technology industries, developments are being actively deployed by local governments, universities, research institutes, and leading enterprises, which inevitably results in the dispersion and non-optimal use of scientific and technological resources. Second, the R&D and support capabilities of generic technologies are low. The investigation and practice of new technology application scenarios are inadequate owing to time limitations, and most of the results obtained indicate only the application potential. However, to deploy a technology from the laboratory to the market, a long-term process involving key technology R&D, engineering technology development, and market application development must be undergone.

4 Development direction of advanced manufacturing clusters and suggestions for constructive route of modern technology support system

During the 14th Five-Year Plan period and toward 2035, the cultivation of advanced manufacturing clusters in China will focus on two aspects: (1) To strengthen top-level planning, perform industrial layout scientifically and rationally, establish a cross-departmental collaboration mechanism jointly by relevant departments, i.e., the National Development and Reform Commission, Ministry of Science and Technology, Ministry of Finance, Ministry of Industry and Information Technology, and Ministry of Commerce, to promote the cultivation of industrial cluster science and technology support system, while adhering to the differentiated development principle of "customized measures to accommodate local conditions" to avoid the homogenization of industrial clusters and low-level disorderly competition; (2) To fully consider the unbalanced development and differences of different types of industrial clusters, implement policies by category to establish a scientific and technological support system that accommodates the development requirements of different industrial clusters, and promote the manufacturing cluster toward the overall goal of the advanced manufacturing cluster based on the objective laws of the development of industrial clusters.

4.1 Basic industrial clusters

Basic industrial clusters should transform the original development model, which features low-level homogeneous competition as well as severe energy consumption and pollution. By adjusting the structure of industrial clusters, the concentration of basic industries will be more reasonable. Additionally, the following should be performed: optimize the allocation of scientific and technological innovation resources as well as scientific and technological support systems; guide innovation resources to cluster for key enterprises and key products; and improve the innovation capability such that basic industries can eliminate the development predicament.

First, the industrial concentration must be improved, and the technological innovation system consolidated. This supports cross-regional and cross-ownership mergers and acquisitions, optimizes the allocation of innovation resources by relying on leading enterprises, and allows the scientific and technological support system to be adjusted by focusing on product structure optimization, green manufacturing processes, and intelligent manufacturing technology. Furthermore, enterprises will be guided to fully utilize strategies, resources, R&D, procurement, sales, and logistics, and to accelerate the coordination of production capacity layout, thus avoiding repeated investment and construction to promote the optimization of product structure. The advantages of talents, technology, and capital will be realized after the integration of enterprise resources and R&D investments will be increased, thus resulting in new breakthroughs in the R&D of new technologies such as green manufacturing technology and intelligent manufacturing technology, as well as further developments in the industry.

Second, the intelligence level of industrial clusters must be improved, and a platform economy participated by multiple parties with joint establishment, operation, resources, and interest sharing should be established. Enterprises participating in the platform economy form a community with common interests through mutual shareholding and limited alliances, thus eliminating contradictions such as excess capacity, scattered capacity, product homogeneity, and low-cost competitions to reduce the risks caused by corporate mergers and

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acquisitions. An integrated intelligent platform should be established in the basic industry clusters for joint production and operation with the Internet and big data technology to form an intensive operation and management function related to production capacity, as well as to create a commonwealth of production capacity. This will provide innovative preferential policies for enterprises participating in the commonwealth of production capacity and stimulate enterprises to strengthen technological innovation via the platform economy model.

4.2 Key strategic industrial clusters

Most of the key strategic industrial clusters possess engineering integration capabilities and thus exhibit superior product supply capabilities, whose future development shall focus on the mid-to-high end of the global value chain. The principle of "strengthening the chain to complement the chain" will be adopted to create a closely coordinated and interrelated industrial chain between upstream and downstream to achieve a high level of autonomy and control of the industrial chain. An innovation chain is to be deployed around the key links of the industrial chain to cultivate leading enterprises with strong innovation capabilities and enterprises with specialization, refinement, characterization, and novelty. A public innovation platform shall be established, the supply capacity of original technologies shall be improved, and technical innovation service support shall be enhanced to form an innovation network via production–education–research collaboration and industrial chain coupling.

The first step is to cultivate the major enterprises of the industrial chain and create an innovative ecology involving "the traction of major enterprises of the chain with the agglomeration of small- and medium-sized enterprises." For relatively mature industrial clusters such as construction machinery and rail transit equipment, the core technologies in the industrial chain should be prioritized to promote the collaborative innovation of original equipment manufacturers and supporting enterprises. Additionally, the following measures are to be implemented: (1) encourage the major enterprises of the industrial chain to render the supply chain accessible to the cluster supporting enterprises such that a domestic replacement plan can be implemented for key materials, key components, and key equipment; (2) improve the independent and controllable level of upstream and midstream industrial chains, such as materials and devices, to satisfy the requirements of national key projects and major equipment; and (3) improve the cluster industries to accommodate the requirements of the global industrial chain and value chain.

The second step is to establish a major generic technology innovation platform and a pilot test platform to promote both the production–education–research cooperation of industrial clusters as well as collaborative innovation of upstream and downstream of the industrial chain. The objective is to accelerate the key basic materials, key basic components, and other short links in the industrial chain of clusters to achieve independent control and enhance the core competitiveness of industrial clusters; additionally, it prioritizes the construction of major public innovation platforms such as the National Manufacturing Innovation Center, National Technology Innovation Center, and Industrial Technology Research Institute within the industrial clusters to promote the formation of collaborative innovation networks in cluster industries. For third-generation semiconductors, optoelectronics, integrated circuits, and other key areas that have not yet formed industrial clusters, focus should be placed on policy support, financial support, innovative ecological construction, and talent training. Utilizing the national innovation centers and national laboratories as well as the national comprehensive science and technology innovation zones, the development of surrounding "satellite" industrial clusters can be promoted, rendering the industrial chain and innovation chain accessible. It is necessary to improve the innovation ecology, establish large platforms, form a large system and team, and develop innovation demonstration areas that closely integrate technological finance, innovation carriers, application demonstrations, and high-end talents [10].

4.3 Cutting-edge technology industrial clusters

Owing to the immaturity of cutting-edge technologies, the formation of industrial clusters require a significant amount of time. Hence, the following measures are to be implemented: (1) attract scientific and technological talents to collaborate via the construction of innovation platforms to accelerate the transformation of achievements and strengthen industrial incubation, and (2) promote the agglomeration of upstream and downstream enterprises via demonstration and promotion with application scenarios to form collaboration between technology R&D and technology demonstration and application.

The first step is to establish a cutting-edge technological innovation platform and create an innovation ecosystem around universities and research institutes. To satisfy the requirements of industrial development and support universities and research institutes, cooperation with influential enterprises is mandatory to establish cutting-edge technology innovation platforms in areas with intensive scientific and technological innovation resources or their surrounding areas. Additionally, innovation resources are to be secured, and the transformation of cutting-edge emerging technological achievements promoted to promote cutting-edge technology industry chains and industrial clusters with high-quality R&D activities.

The second step is to strengthen the experimental verification and demonstration applications of new technologies to promote the construction of cutting-edge technology industry clusters. Application research of cutting-edge technologies that upgrade the industrial chain and the manufacturing industry should be highlighted and a fault-tolerant mechanism established, to provide application scenarios for new technologies to ensure the application of new products. Industrialization and application demonstration projects should be implemented in key areas, and product application demonstrations should be accelerated to promote high-quality constructions of cutting-edge technology industrial clusters.

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