Regional Distribution and Reconstruction Strategies of New Industrial Spaces at Multiple Spatial Scales in Shandong Province China

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Abstract

New industrial space is a new industrial area dominated by high-tech zone and economic development zone in China. Shandong is the front of China's reform and opening up, with relatively complete types of new industrial spaces. With the deepening of China's reform and opening up, these new types of industrial spaces with different backgrounds, different functions and spatial overlapping are in urgent need of multi-scale spatial reconstruction, so as to give play to the advantages of regional policy superposition, to promote industrial development and spatial restructuring, and to improve the industrial and regional competitiveness of Shandong. From four dimensions of scale, structure, dynamics and share, and seven levels of the number of parks, registered enterprises, foreign capital utilization, fixed asset investment, financial revenue, industrial production and its economic benefits, this paper constructs the evaluation index system of new industrial spaces, and classifies the new industrial spaces in Shandong Province at the dual spatial scales of city and county (district) by means of the principal component analysis and cluster analysis. Then, this paper analyzes the dynamic structure of evolution of Shandong's new industrial spaces from the aspects of national policy, hierarchical government, technological innovation, transportation and information, and explores the reconstruction mechanism of Shandong's new industrial spaces. Finally, based on the micro perspective of value chain and enterprise analysis, this paper puts forward the reconstruction strategies and corresponding policy measures of Shandong new industrial spaces at multiple spatial scales of province, interlocking metroplis and city.

Keywords

New Industrial Space, Regional Distribution, Reconstruction Strategy, Multiple Spatial Scales

1. Introduction

The concept of new industrial space first appeared in Scott's book named *new industrial space: flexible agglomeration of industries and regional development in North America and Western Europe*, which Scott wrote in 1988. He defined the new industrial space as: flexible agglomeration area of industries (Zeng, 2004). There is no strict definition of new industrial space in China, but the new industrial space is a concept compared with the traditional industrial space before the reform and opening up. With the reform and opening up, China has developed various new industrial spaces with different functions, covering Economic and Technological Development Zones, Bonded Zones, Export-oriented Processing Zones, High-tech Industrial Development Zones (Hi-tech Zone), National New District and National Free Trade Zones. These new industrial spaces, which have promoted the industrialization and urbanization of China, have many nested relations, such as overlapping, inclusion, etc. Among them, Economic Development Zones and High-tech Zones are the two main types of new industrial space. Shandong is a coastal province neighboring Hebei, Henan and Jiangsu province, and has relatively complete types of new industrial spaces. In 2019, Shandong Free Trade Zone was established, and in the same year, Qingdao SCO Economic and Trade Demonstration Zone was established. At present, there are many types and large scale new industrial spaces in Shandong province. However, in multiple spatial scales such as provincial, regional and prefectural scales, the regional organization of new industrial spaces in Shandong is relatively loose, and the clustering development mechanism based on local characteristics and advantageous industries needs to be improved. How to make full use of and integrate the unique functions of every type of new industrial space in different regions within the province to form modularization, regionalization, specialization and clustering of regional economy, is a practical problem that needs to be solved urgently. In this context, it is urgent to restructure all kinds of new industrial spaces in Shandong Province, so as to promote industrial development and enhance regional competitive advantage.

Industrial space reconstruction is a dynamic process of regional industrial organization, restructuring and network connection, including: industrial selection, structure optimization and spatial organization. The subject of industrial space reconstruction has always been a research field of common concern in geography, planning, management, economy, social science and other disciplines. From the perspective of spatial scale, the existing achievements mainly focus on the micro inner city scale (Zheng & Qiu, 2005; Li, 2008; Chai et al., 2010; Wang et al., 2018a, 2018b) and the meso urban (including suburban) scale (Shi, 2011; Ma et al., 2012; Yun et al., 2013; Gao et al., 2017; Li et al., 2017; Jolly et al., 2020), and some scholars have studied the industrial space reconstruction in macro provincial or larger spatial scale (Li et al., 2009; Guo, 2017; Athukorala & Narayanan, 2018; Hudalaha et al., 2019; Hu et al., 2019; Liu et al., 2020; Zhuang & Ye, 2020; Luo et al., 2020). From the perspective of research, it includes: anal-

ysis of Industrial park network based on ecological theory (Fan et al., 2017; Song et al., 2018; Cerceaua et al., 2018); reconstruction of urban industries based on spatial transformation (Ma et al., 2012); The functional transformation and spatial reconstruction of new urban areas based on the theory of space production (Ding et al., 2019; Zhuang & Ye, 2020); reconstruction of regional industrial spaces from the perspective of scale reconstruction and governance (Li et al., 2017) and regional industrial space reconstruction from the perspective of flow space (Sun & Wu, 2019). Some scholars explore the impact of spatial path dependence on industrial spatial layout and organization from the perspective of evolutionary economy (Yang et al., 2021); Some scholars have explored urban industrial spatial reconstruction from the perspective of urban land planning and land development & utilization (Tang & Ho, 2015; Li et al., 2018; Zhang et al., 2018; Wang et al., 2018a, 2018b; Gao & Chen, 2020; Lee & Jung, 2020; Xiao et al., 2021). We believe that inter-regional function networking based on value chain is the essence of industrial space reconstruction. But, most of the research focus on the dynamic evolution of regional tangible industrial distribution, and the research on invisible inter regional industrial function networking is relatively few. This study, based on elaboration of the spatial pattern of new industrial spaces in Shandong province, attempts to explore the reconstruction mechanism and reconstruction strategies of new industrial spaces in Shandong, from multiple spatial scales and from the perspective of industrial networking.

At present, the fourth industrial revolution led by 5G technology and artificial intelligence is rapidly changing the industrial location and organization pattern of industrial spaces. The edge light-out factory and coproduction based on network will reshape all kinds of new industrial spaces at all levels (Lopes Nunes et al., 2017; Li & Found, 2017; Erdoğan, 2019). Technology innovation promotes the change of management mode from place-based governance to network governance (Hudalaha et al., 2019). Under this new technological background, this study, from multiple spatial scales and from the perspective of value chain and flow space, attempts to explore the spatial pattern and reconstruction mechanism of new industrial spaces in Shandong, driven by emerging technologies, and puts forward the corresponding reconstruction strategies and policy measures. The theoretical contribution of this research lies in qualitative exploration of the reconstruction mechanism of regional new industrial spaces under the new technological conditions such as 5G technology, artificial intelligence and industrial Internet, and systematic construction of the theoretical analysis framework of reconstruction of regional new industrial spaces; The deficiency of the study is that, owing to the difficulty of obtaining the data of industrial networking at different spatial scales, the exploration of reconstruction mechanism of regional new industrial spaces, still stay in qualitative analysis, lacking the necessary quantitative analysis and data support.

The article is orgnized as follows: firstly, it briefly expounds the development of new industrial spaces in Shandong from the perspective of evolution; Second-

ly, it introduces the research methods and data sources, including: the construction of index system and the use of research methods; Thirdly, on the basis of quantitative analysis, this paper elaborates the regional pattern of new industrial spaces in Shandong, from the prefecture and county scales, including: the clustering of new industrial spaces in prefecture and city scales and the regional distribution pattern of new industrial spaces in district and county scales; Fourth, the paper explores the regeneration and reconstruction mechanism of new industrial spaces in Shandong under the new technological environment, from the multiple spatial scales of province, United metropolitan area and prefecture; finally, based on the goal of improving the overall competitive advantage of Shandong region, this paper puts forward the strategies and policy measures of restructuring of new industrial spaces in Shandong province.

2. Methodology and Data Sources

2.1. Index System Construction and Data Sources

From four dimensions of scale, structure, dynamics and share, and seven levels of the number of parks, registered enterprises, foreign capital utilization, fixed asset investment, fiscal revenue, industrial production (output value) and economic benefits, the evaluation index system of Shandong new industrial spaces is established to depict the characteristics of them (see Table 1). Economic Development Zones and High-tech Zones are the main bodies of new industrial spaces in Shandong. According to the management authority, they can be divided into two types: national level and provincial level. The data required for this study are mainly the data of national and provincial Economic Development Zones and High-tech Zones in Shandong. Among them, the scale data mainly comes from *Shandong Statistical Yearbook* in 2004, 2010 and 2016; Structural indicators, dynamic indicators and share indicators are mostly derived indicators based on the above basic indicators. As the two scales of prefecture-level city and county are taken as the basic regional unit to analyse, basic database is generated for subsequent principal component analysis and cluster analysis by means of merging the original data of two types of all new industrial spaces in the same city or county in Shandong Province.

2.2. Methodology

From the scales of both prefecture-level cities and counties, the evaluation index system of Shandong new industrial spaces is established, and the basic databases of 17 prefecture-level cities and 97 counties in Shandong Province are established. Firstly, based on principal component analysis (PCA), this paper extracts the principal components from the basic database of 17 cities in Shandong Province, and obtains the score coefficient matrix of each principal component of 17 cities in Shandong Province, which is used to reveal the characteristics of new industrial spaces in scale, structure, dynamics and share of 17 cities. Based on the effective principal components extracted, cluster analysis and classification

Table 1. Index system of Shandong new industrial spaces (source: author's work).

index	Dimentions of index	Concrete indicators	
Number of Parks	Scale index A_1	Total number of industrial parks A_{11}	**
	Struture index A_2	Number of high tech parks A_{21}	*
		Number of industrial parks in urban area A_{22}	*
Registered enterprises	Scale index B_1	Total number of registered enterprises B_{11}	**
	Struture index B_2	Proportion of foreign enterprises B_{21}	**
		Proportion of high tech enterprises B_{22}	**
		Proportion of registered enterprises in High-tech Parks B_{23}	*
		Proportion of registered enterprises in urban parks B_{24}	*
	Dynamic index B_3	Annual growth rate of registered enterprises from 2004 to 2010 B_{31}	**
		Annual growth rate of registered enterprises from 2010 to 2016 B_{32}	**
Utilization of foreign capital	Scale index C_1	Total amount of foreign capital actually utilized C_{11}	**
	Struture index C_2	Proportion of foreign capital utilization in High-tech Parks C_{21}	*
		Proportion of foreign capital utilization in urban parks C_{22}	*
	Dynamic index C_3	The average annual growth rate of foreign capital utilization from 2004 to 2010 C_{31}	**
		The average annual growth rate of foreign capital utilization from 2010 to 2016 C_{32}	**
Investment in fixed assets	Scale index D_1	Total investment in fixed assets D_{11}	**
	Struture index D_2	Proportion of fixed assets investment in High-tech Parks D_{21}	*
		Proportion of fixed assets investment in urban parks D_{22}	*
	Dynamic index D_3	Average annual growth rate of fixed assets investment from 2010 to 2016 D_{31}	**
		Average annual growth rate of fixed assets investment from 2010 to 2016 D_{32}	**
	Share index D_4	The proportion of fixed assets investment in the city's D_{41}	**
revenue	Scale index E_1	General public budget revenue E_{11}	**
	Struture index E_2	Proportion of financial revenue of High-tech Parks E_{21}	*
		Proportion of financial revenue of urban parks E_{22}	*
	Dynamic index E_3	Annual growth rate of fiscal revenue from 2004 to 2010 E_{31}	**
		Annual growth rate of fiscal revenue from 2010 to 2016 E_{32}	**
	Share index E_4	The proportion of fiscal revenue in the city's fiscal revenue E_{41}	**
Industrial production	Scale index F_1	Total output value of industries above designated size F_{11}	**
		Main business income of industries above designated size F_{12}	**
	Struture index F_2	Proportion of total industrial output value of High-tech Parks F_{21}	*
		Proportion of total industrial output value of urban parks F_{22}	*
	Dynamic index F_3	Annual growth rate of industrial main business income from 2004 to 2010 F_{31}	**
		Annual growth rate of industrial main business income from 2010 to 2016 F_{32}	**
	Share index F_4	Proportion of total industrial output value in the city's F_{41}	**

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economic performance	Scale index G_1	Proportion of industrial main business income in the city's F_{42}	**
		Total profits and taxes of industries above designated size G_{11}	**
		Rate of profit and tax to industrial output value G_{12}	**
	Struture index G_2	Proportion of industrial profits and taxes in High-tech Parks G_{21}	*
		Proportion of industrial profits and taxes in urban parks G_{22}	*
		Profit and tax rate of output value of High-tech Parks G_{23}	*
		Profit and tax rate of output value of Economic and Technological Development Zone G_{24}	*
		Profit and tax rate of output value of urban parks G_{25}	*
		Profit and tax rate of output value of suburban parks G_{26}	*
	Dynamic index G_3	Average annual growth rate of profits and taxes of industries above designated size from 2004 to 2010 G_{31}	**
		Average annual growth rate of profits and taxes of industries above designated size from 2010 to 2016 G_{32}	**
	Share index G_4	Proportion of industrial profits and taxes above designated size in the city's G_{41}	**

Note: **refers to the indicators included in both city scale and county scale; *refers to the indicators only included in the city scale.

of new industrial spaces in 17 cities of Shandong Province are carried out, and differential strategies and policy measures for reconstruction of new industrial spaces in Shandong Province are put forward. Secondly, PCA is used to extract the principal components from the basic database of 97 districts and counties in Shandong Province, and the score coefficient matrix of each principal component of 97 districts and counties is obtained. According to the load factor structure of each principal component, the attribute and name of each principal component are summarized and determined. Based on the score value of each principal component of 97 districts and counties, and with the help of GIS technology, this paper explores the overall distribution of Shandong new industrial spaces and its formation reasons at the district and county level, and puts forward the reconstruction strategies and policy measures of Shandong new industrial spaces at the district and county level.

3. The Historical Evolution and Current Characteristics of New Industrial Spaces in Shandong Province

In a broad sense, new industrial spaces include all kinds of economic and technological development zones, bonded zones, export-oriented processing zones, high-tech industrial development zones, state-level new districts and free trade zones. New industrial spaces are the most active area of urbanization and economic growth in Shandong Province. All kinds of new industrial spaces are born in a specific historical background and have different functional orientations. In 1984, in order to attract foreign investment and promote regional economic

growth, China set up national economic and technological development zones in Qingdao, Yantai and Weihai. In 1988, it set up coastal open zones in Shandong Peninsula, and all kinds of economic and technological development zones developed rapidly. In the 1990s, in order to promote technological innovation and the development of high-tech industries, all kinds of high-tech zones in Shandong developed rapidly. Qingdao, Yantai, Jinan and other central cities experienced multiple stages of development, showing a "one zone, multiple parks" development mode (fragmented spaces). In 2012, in order to promote the implementation of China's marine strategy and promote the overall development of Shandong Province, *Huangdao West Coast National New District* was established in Qingdao; in 2019, Shandong Free Trade Zone was established. Qingdao, Jinan and Yantai are located in three new industrial spaces; in the same year, *the SCO Economic and Trade Demonstration Zone* at the national level was established in Jiaozhou, a suburb county of Qingdao. Shandong has relatively complete types of new industrial spaces, including 14 national high-tech zones, 8 provincial high-tech zones, 21 national economic development zones and 116 provincial economic development zones, which are distributed in most districts and counties (cities) of Shandong, and become an important force to promote local social and economic development.

4. Regional Distribution of New Industrial Spaces at Multiple Spatial Scales in Shandong Province

4.1. Classification of New Industrial Spaces in Shandong Province at the Prefecture-Level City Scale

Based on the index system of new industrial spaces and the database at city scale in Shandong Province, seven effective principal components were obtained by principal component analysis, and the cumulative variance contribution rate reached 85.6%. By analysing the factor load structure of each principal component, it is found that the load factors of principal component 1 include: scale index E11, B11, G11, D11, a11, F12, C11; Based on this, principal component 1 is defined as the scale index to reflect the overall scales of new industrial spaces in Shandong. The load factors of principal component 2 include: C22, G22, E22, F22, D22 (Urban proportion) and E21, D21, A21, F21, G21 (high tech Park proportion). According to this, principal component 2 is defined as structural index. Similarly, according to the load factor structure of principal component 3 and principal component 4, they are defined as efficiency index and share index respectively. As the load factors of principal component 5, principal component 6 and principal component 7 are all only 1 - 2, and the loads are mostly less than 0.6, there is relatively little effective information. So, the analysis of them will be omitted here. Based on the seven effective principal components, the cluster analysis of 17 cities in Shandong Province is carried out, and **Figure 1** is obtained. The figure indicates that the new industrial spaces of 17 cities in Shandong Province are divided roughly into four types (at the 20 dotted line). According to
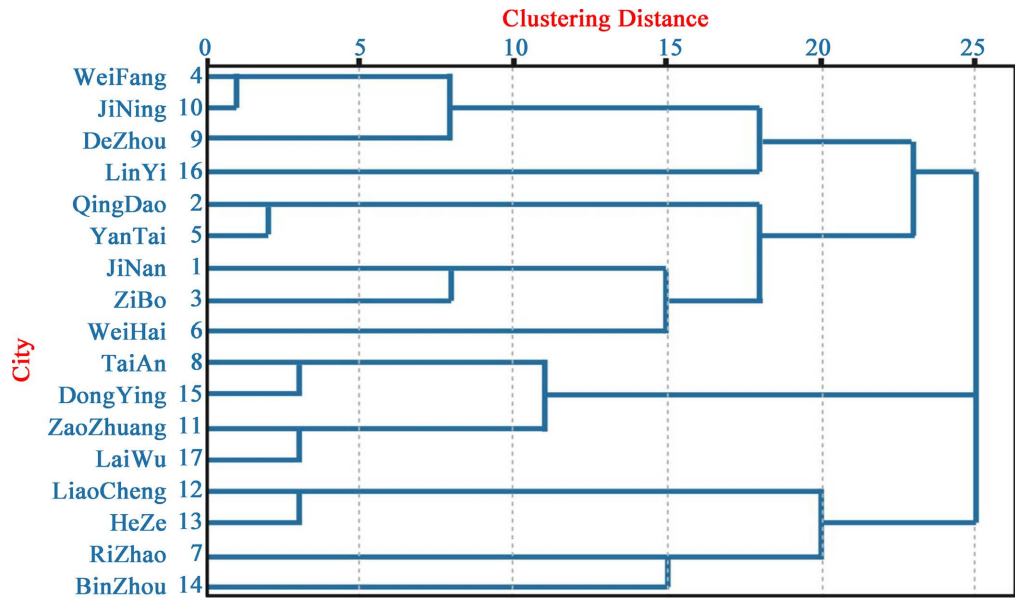
Figure 1. Classification of New Industrial spaces at City Scale in Shandong Province (source: author's work).

the score coefficient matrix of 17 cities in Shandong Province, this paper further reveals the structural characteristics of new industrial spaces in Shandong Province, and further subdivides the four types of new industrial spaces in 17 cities into eight sub categories (roughly at the 15 dotted line in Figure 1). It should be noted that Weihai and Jinan, Zibo, Rizhao and Liaocheng, Heze and Binzhou are clustered at a large inter group distance. So, considering the similarities between Weihai and Rizhao in geographical location, land area and foreign capital utilization, etc., they are divided into one category. Accordingly, Table 2 is obtained.

4.2. The Spatial Distribution of New Industrial Spaces at the District and County Scale in Shandong Province

Based on the administrative zoning and available data of Shandong province in 2016, 97 basic regional units were obtained by merging the data of new industrial spaces in the same district and county. Based on the index system of new industrial spaces at district and county scale and 97 basic databases of districts and counties, the principal component load factor matrix is obtained by principal component analysis (see Table 3).

It can be seen from Table 3 that: principal component 1 is the scale index, which comprehensively reflects the scale level of new industrial spaces in each district and county. Principal component 2 is the dynamic index, which comprehensively reflects the economic vitality of new industrial spaces in each district and county. Principal component 3 is the share index, which comprehensively reflects the role and status of new industrial spaces in local economy. According to the scores of 97 districts and counties in three principal components, the above results are visualized with the help of GIS technology to reveal the

Table 2. Types and their characteristics of new industrial spaces at city scale in Shandong Province (source: author's work).

Types of new industrial spaces	The city belonged	Economic characteristics
Strong center -strong region	Qingdao Yantai	Similar high values of principal component 1 indicating similar large economic scales of new industrial spaces. Principal component 2 is highly similar, indicating that layout of new industrial spaces in urban and suburb counties is relatively balanced. both urban and suburbs have strong economic strength. High tech zones occupy a certain proportion.
	Jinan Zibo	Similar relatively high Principal component 1 indicating similar relatively large economic scales of new industrial spaces. Principal component 2 is highly similar, indicating relatively balanced layout of NIS in urban and suburbs. The economic strength of suburban counties is relatively weak. High tech zones occupy a certain proportion.
	Weihai Rizhao	Principal component 2 is highly similar, indicating that layout of new industrial spaces in urban and suburb counties is relatively balanced. Similar low value of principal component 4, indicating the similarity in location conditions and foreign capital utilization.
Weak center -strong region	Weifang Jining	Relatively large economic scales of new industrial spaces. Relatively balanced layout of new industrial spaces in urban and suburb counties. Large scope of suburb counties. Relatively strong economic strength of new industrial spaces in suburb counties. Relatively weak economic strength Oof NIS in urban area.
	Dezhou Linyi	Relatively small economic scales of new industrial spaces. Relatively balanced layout of new industrial spaces in urban and suburb counties. Large scope of suburb counties. Similar low value of principal component 4, indicating the low economic proportion of new industrial spaces in local economy.
Weak center-small region	Tai'an Dongying	Relatively small economic scales of new industrial spaces. Relatively small scope of suburb counties.
	Zaozhuang Laiwu	Relatively small economic scales of new industrial spaces. Relatively small scope of suburb counties. Urban areas account for a large proportion.
Weak center-large region	Heze Liaocheng Binzhou	Balanced distribution of new industrial spaces between urban and suburb counties. Both the urban area and suburb counties have relatively weak economic strenghth. The development of high-tech parks lags behind. Similar low value of principal component 4, indicating the low economic proportion of new industrial spaces in local economy.

Table 3. Principal component load factor matrix at district and county scale (source: author's work).

	principal component		
	1	2	3
Public revenue	0.943	0.101	0.119
Industrial main business income	0.931		
Total industrial profits and taxes	0.928	0.103	
Number of registered enterprises	0.918	0.137	
Investment in fixed assets	0.913	0.157	0.119
Total output value of industries above designated size	0.902		0.109
Number of parks	0.901		
Number of High-tech enterprises	0.868		

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Actually utilized foreign capital	0.852	0.130	
Number of foreign invested enterprises	0.851		
Annual growth rate of fixed assets	−0.251	0.747	0.120
Annual growth rate of fiscal revenue	−0.289	0.636	
Average annual growth rate of industrial income	−0.379	0.613	
Annual growth rate of industrial profits and taxes	−0.334	0.556	−0.270
Annual growth rate of registered enterprises	−0.118	0.468	−0.182
Proportion of financial revenue of the parks in local economy	−0.156	0.114	0.726
Proportion of total industrial output value of the parks in local economy		0.287	0.648
Proportion of fixed assets investment of the parks in local economy	−0.181	0.385	0.615
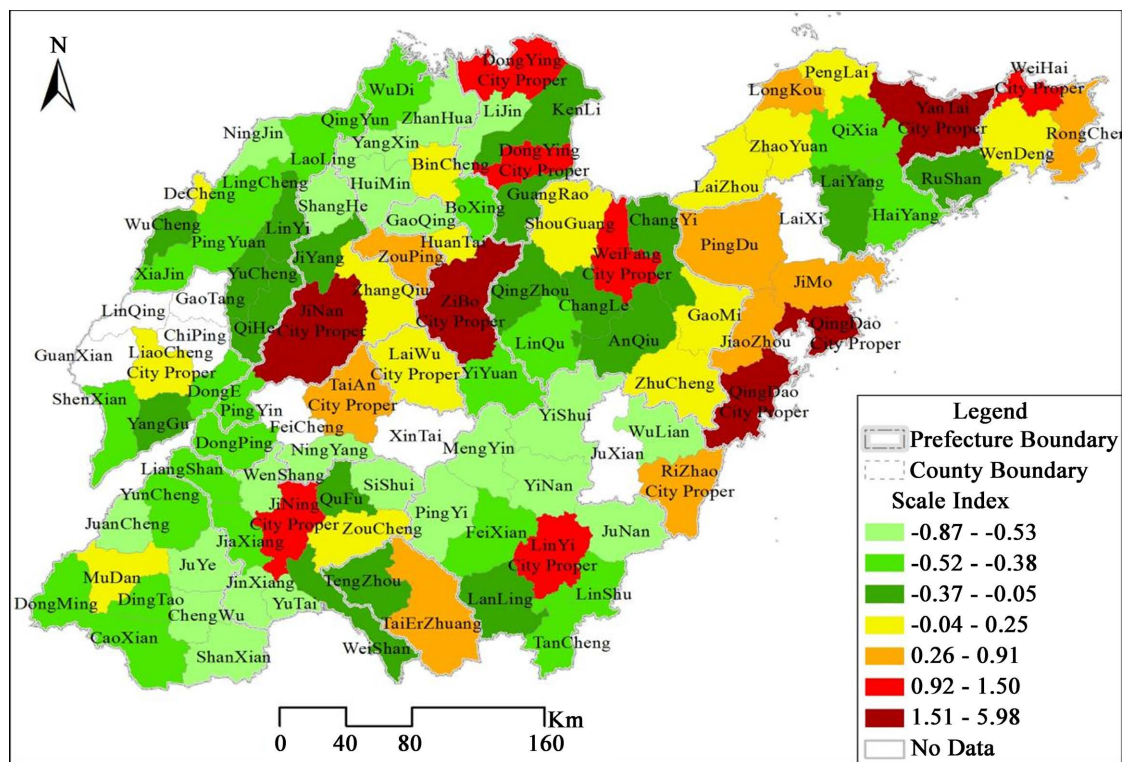
Figure 2. Regional pattern of new industrial spaces at district/county scale in Shandong Province (source: author's work).

regional pattern of new industrial spaces at district and county scale in Shandong (see **Figure 2**). It can be seen from **Figure 2** that at the macro level, Shandong's new industrial spaces have a good development in Jiaodong Peninsula, with outstanding performance in foreign capital utilization, industrial production, asset investment, fiscal revenue and development of high-tech industries, which is closely related to the natural environment, geographical conditions and opening history of Shandong Peninsula. At the medium level, the development

of new industrial spaces in urban areas is relatively good. New industrial space development of sburb counties surrounding Jinan, Zibo, Weifang and other big cities is also more prominent. Although Zhucheng and Gaomi county (adjacent to Qingdao), Qihe and Yucheng county (adjacent to Jinan), Zoucheng, boxing and Guangrao county (adjacent to Zibo) and Weishan county (adjacent to Zaozhuang) are far from their administrative centers of each region, their performances of new industrial spaces are outstanding compared with other suburban counties due to their proximity to the surrounding big cities. This provides a scientific basis for adjustment of administrative zoning and reconstruction of industrial spaces within the province.

5. Regeneration and Reconstruction Mechanism of Shandong New Industry Spaces

Under the background of flow space supported by mobile Internet and high-speed rail network, the growth process of new industrial spaces is a dual agglomeration process of physical space and virtual space (Luo, 2020). The new industrial spaces are no longer regional units with a specific boundary, but a social spatial relationship structure in a larger regional scope and under the framework of multi-scale relationship. The new industrial spaces need functional networking in multi-scale spaces. There are two patterns for the development of new industrial spaces: one is the local production pattern based on international division of labor. Second, local innovation pattern based on science and technology resources. Industrial spatial restructuring can take place at both the macro scale (Jacobs', like mechanisms) and the micro scale (Marshall mechanisms) (Adlera et al., 2019). China's new industrial space is essentially a kind of policy space. Its policy attribute is more obvious than the functional attribute. It is the policy stimulus that leads to the functional development. Its development and evolution are accompanied by the process of reform and opening up. The national policy stimulus has given birth to a variety of new industrial space types with different functions. It was born in different international and domestic backgrounds, so it has different functional positioning. The improvement of infrastructure and business environment led by provincial, municipal and county governments is the direct driving force for the growth of new industrial spaces. Shandong has almost all types of new industrial spaces, but different levels of cities have different types of structures of new industrial spaces. At present, the new industrial revolution led by 5G technology and artificial intelligence is rapidly changing the orientation of industrial location and the mode of industrial spatial organization. Technological innovation leads to start-ups and spin-offs of enterprises, industrial upgrading and business mode innovation. These factors directly promote reconstruction of new industrial spaces at different scales. Hierarchical governments, R & D institutions, production enterprises, service companies and enterprise groups that integrate R & D, production and service are the main actors in reconstruction of new industrial spaces. The purpose of re-

construction of new industrial spaces is to promote functional networking between different spatial patches, form a nested structure system with multiple spatial scales, and improve the industrial and regional competitiveness.

At the provincial level, it is very important to select, cultivate and strengthen the nuclei spaces to occupy the strategic niche, including: the industrial nucleus based on anchor companies, the innovation nucleus based on R & D institutions, and the policy nucleus based on the distribution function. These nuclei spaces have a wide range of international and domestic functional links, and become the organizational core of reconstruction of the provincial new industrial spaces. Restructuring of provincial new industrial spaces based on the multi-source industrial nucleus and innovation nucleus, can produce a synergistic resonance effect in the provincial scope. The development of provincial enclave parks based on policy nucleus can produce policy diffusion effect. Key investment and polarized development are the objective laws of industrial and regional movement. The metropolitan area which links the international and radiates the domestic has become an important region for the growth of new industrial spaces. Through zoning adjustment and scale reconstruction, construction of inter-locking metropolitan areas based on integrating utilization of port, high-speed rail and policy (Free Trade Zone) resources can effectively support reconstruction of new industrial spaces within the area, form the hub-spoke industrial configuration based on anchor companies, and form the regional development pattern with incubation of High-tech start-ups in the nuclei and accelerating growth of High-tech start-ups in the peripheries.

At the city scale, adjustment of administrative zoning based on the center-hinterland theory can remove institutional obstacles for restructuring of new industrial spaces within the city. In the central urban area, based on availability of human resources (Ng et al., 2019), government-led urban renewal and spatial transformation can embed various types of new industrial patches. In the suburbs, expansion of new industrial spaces, such as Economic Development Zone, High-tech Zone and national new district, mostly has the nature of functional zoning and planning, resulting in multi-point growth of modular and specialized parks. In the suburban urbanized areas, dominated by the law of land value, the traditional industrial mall (such as Haier industrial park) is turning to the 3D urban heterogeneity based on technological innovation and tenant mix ecologies (Scott & Hoon, 2017). The formal and informal reconstruction of suburban new industrial spaces is enriching the industrial ecology of new urbanized area and promoting transformation and upgrading of new industrial spaces. At the urban level, evolution of national policies and hierarchical government planning jointly gave birth to the fragmented spatial structure of High-tech Zones, forming a "one zone, multiple parks" development pattern (Zhao & Li, 2013). In suburban counties, growth of new industrial spaces is mostly based on the advantages of local characteristics and its connection with central cities. Due to the special location conditions, the new industrial spaces of a few suburban counties not only

expands outward, but also carries out functional transformation and upgrading at the same time, and carries out interconnection and functional reconstruction with the new industrial spaces of central urban area, promoting transformation of suburban counties to suburban urbanized area and metropolitan development of central cities as a whole. The industrialization process formed by the external expansion of new industrial spaces, internal spatial transformation and regional reconstruction jointly promotes the process of regional urbanization, functional optimization of provincial urban system, construction of interlocking metropolitan areas, and reconstruction of urban system at city level, based on transformation and renewal of inner city and growth of edge cities (see Figure 3).

6. The Strategies and Policy Measures of Reconstruction of Shandong New Industrial Spaces

The new industrial space is an important carrier of modern industrial development. Industrial space reconstruction is the cross-border construction process of industrial symbiosis at different spatial scales (Song et al., 2018), that is, the forming process of relational network space integrated with structural network space, intention network space and relative network space (Tornroos et al., 2017), targeting to improve the overall competitiveness of hierarchical regions. The hierarchical governments, R & D institutions and production enterprises are the main actors of industrial space reconstruction. Specialized parks (modular and segmented industrial clusters based on value chain decomposition (Shi, 2011) are the most basic regional units (patches) of spatial reconstruction.

6.1. Industrial Selection Based on National Strategic Needs and Comparative Advantages of Shandong

The purpose of industrial space reconstruction is to cultivate and strengthen the characteristic and advantageous industries that can meet the national strategic needs and to improve the international and domestic competitiveness of the whole industrial chain. According to the national needs of strategic special project (made in China 2025) and the new industrial revolution based on 5G technology and artificial intelligence, combined with the comparative advantages of Shandong innovation resources and the spatial distribution of characteristic industries, the characteristic industries such as artificial intelligence, information technology, high-end equipment manufacturing, marine biomedicine, new materials and new energy, should be cultivated and developed. Based on the provincial characteristic and advantageous industrial chains, Qingdao, Yantai, Jinan, Zibo and other innovation centers need to be constructed as strategic fulcrums, cultivating the innovation nucleus based on R & D function and the industrial nucleus based on anchor companies, and strengthening the linkages between the innovation nucleus, industrial nucleus and policy nucleus. Actively link the international innovation nucleus of the same kind. Through construction of science and technology incubator in the International innovation Tower, the
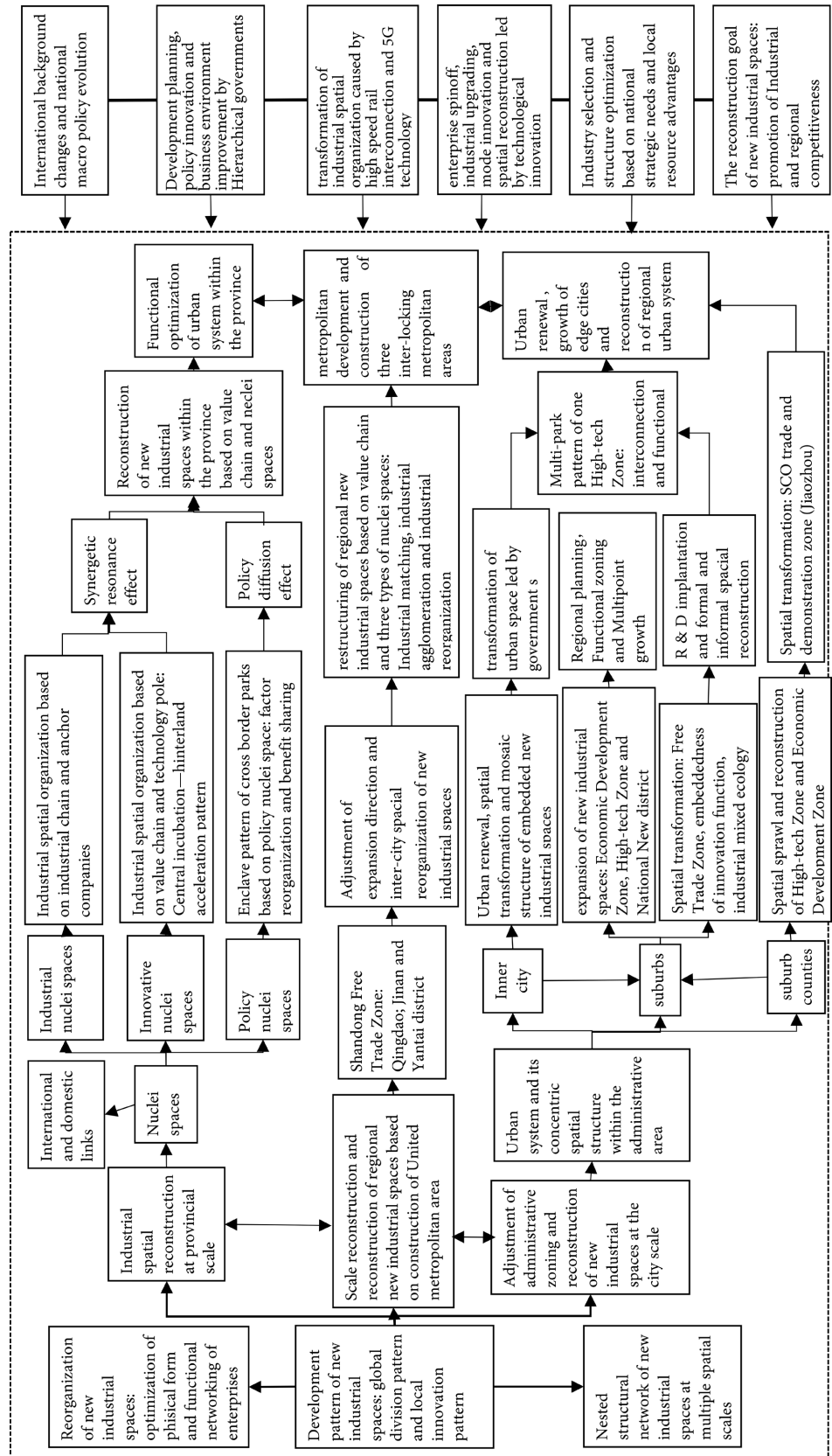
Figure 3. Spatial reconstruction mechanism of new industrial spaces in Shandong Province (source: author's work).

international frontier innovation resources are introduced, including: start-up enterprises, scientific and technological achievements, scientific and technological talents and scientific and technological information, etc. Activate and catalyze the innovation nucleus and industrial nucleus in the province, making it the engine and organization core of Shandong characteristic and advantageous industries. Preferential policies for the development of characteristic and advantageous industries should be introduced, so as to prevent the loss of innovation resources such as scientific and technological achievements and talents. Actively respond to the competition from developed areas such as the Yangtze River Delta and the Pearl River Delta, making Shandong innovation nucleus and industrial nucleus the strategic highlands of similar industries in China.

6.2. Reconstruction of Industrial Spaces at Provincial Scale Based on Value Chain and Nuclei Spaces

The purpose of reconstruction of industrial spaces is to improve the international and domestic competitiveness of Shandong characteristic and advantageous industries. Strengthen the management of various nuclei spaces from the perspective of strategic niche and promote their construction of global niche. Through top-down policy mechanism, promote the local network based on various nuclei spaces to move toward a larger scale regional network (Susura et al., 2019). According to the spatial distribution of Shandong characteristic and advantageous industries and scientific and technological resources, based on Jinan artificial intelligence and information technology, Yantai marine equipment manufacturing and Qingdao Marine biomedical and other characteristic and advantageous industries, innovation actors such as scientific research institutes, transnational companies (R & D institutions) and state-owned enterprises should be focused and introduced so as to strengthen the function of pilot scale test and incubation and foster the innovation nucleus and industrial nucleus. Shandong has many competitive enterprise groups, and they should be encouraged to establish the company's venture capital (CVC). The innovation objectives of exploration or exploitation with CVC should be coordinated through CVC structural autonomy and the CVC operation mechanism (independent or dependent) should be optimized (Leea et al., 2018). Through capturing external technology and dynamic capability and transforming scientific and technological achievements and promoting the growth of start-ups and the expansion of the company's economic scope, the industrial nucleus and innovation nucleus are integrated, and the regional science-technology-business innovation ecology is formed based on the integrated value chain (Xu et al., 2018). The policy nuclei advantages of Qingdao, Yantai and Jinan free trade zones should be fully utilized to promote the import and use of instruments and equipment and free flow of international innovation resources in the province. Focusing on the characteristic and advantageous industrial chains of Shandong, and taking multi-source nuclei spaces as strategic fulcrums, and circling the anchor companies and gazelle enterprises, in-

dustrial matching and industrial acceleration should be carried out in the province scope in order to optimize and reconstruct the resource elements and production enterprises and coordinate the development of featured and advantageous industries in the province. Based on the policy nuclei spaces such as Shandong Free Trade Zone, SCO trade demonstration zone and West Coast new district of Huangdao, and by means of institutional innovation, the accelerators should be built in the hinterland of the province through the development model of enclave parks in order to accelerate the diffusion and transfer of the scientific and technological achievements, start-up enterprises and foreign funded enterprises in the nuclei spaces.

6.3. Scale Reconstruction and Industrial Space Reconstruction Based on Construction of the Interlocking Metropolitan Areas

At present, the metropolitan area linking the world and radiating the hinterland has become the spatial core of the growth of new industrial spaces. Based on the spatial distribution of Shandong cities, three interlocking metropolitan areas, Qingdao-Rizhao, Jinan-Tai'an and Yantai-Weihai, are constructed through zoning adjustment and scale reconstruction, which makes them the key carriers of spatial reorganization and regional agglomeration of Shandong's dominant industries (see Table 4). Strengthen the unified planning of land use and interconnection (inter-city rail) between the cities within the interlocking metropolitan areas, so as to coordinate and promote the integrated utilization of ports, high-speed rail and policy resources. Focusing on the local characteristic industries such as Jinan artificial intelligence and information technology, Yantai marine equipment manufacturing and Qingdao Marine biomedical industry, reorganization of new industrial spaces based on value chain and nuclei spaces will be promoted. Foreign investment and industrial matching are promoted circling the dominant industrial chain in order to form the hike-spoke industrial configuration based on anchor companies. The development pattern of regional linkage between innovation nuclei and hinterland will be formed, with incubation

Table 4. Conception of interlocking metropolis construction based on Industrial and spacial organization in Shandong province (source: author's work).

interlocking metropolis	Land area and population scale	Zoning adjustment
Jinan-Tai'an interlocking metropolis	Including: Jinan City (including Laiwu), Tai'an City, suburb Counties of Qihe and Yucheng in Dezhou City. The total area is 20,406 km²; The total population is 14.268 million.	Qihe County and Yucheng county of Dezhou are under the jurisdiction of Jinan City.
Qingdao-Rizhao interlocking metropolis	Including: Qingdao City, Rizhao City, Zhucheng and Gaomi counties of Weifang City. The total area is 20,335 km²; The total population is 13.083 million.	Zhucheng County and Gaomi county of Weifang are under the jurisdiction of Qingdao City.
Yantai-Weihai interlocking metropolis	Including: Yantai city and Weihai City. The total area is 19,650 km²; The total population is 9.102 million.	Withdraw of Muping county of Yantai and Wendeng county of Weihai into suburb districts make the urban areas of two cities being merged.

focused in the innovation nucleus and acceleration diffused in the peripheries.

6.4. Scale Reconstruction and Reorganization of Industrial Spaces at City Scale

The local governments of cities, districts and counties play an important role in reconstruction of new industrial spaces. The scale reconstruction directly affects restructuring of enterprise location and then affects organization of industrial spaces of urban region through adjustment of financial relations, reform of administrative structure, changes of planning and approval and infrastructure construction (Li et al., 2017). Zoning adjustment based on the theory of center-hinterland is beneficial to industrial spatial organization and formation of regional industrial complex in the city region. Based on the spatial distribution of Shandong new industrial spaces at district and county scale (see Figure 2), besides promotion of zoning adjustment of Qingdao and Jinan city elaborated above, zoning adjustment of Zibo (Zouping county of Binzhou city is under the jurisdiction of Zibo City) and Zaozhuang city (Weishan county of Ji'ning city is under the jurisdiction of Zaozhuang City) are also require promotion. Reconstruction of industrial spaces of different types of cities is promoted Classifically (see Table 5). Industrial transfer and spatial transformation of the inner cities in Qingdao, Jinan, Yantai metropolitan areas will be accelerated to promote the embedded development of new industrial spaces. Informal spacial reconstruction of Economic and Technological Development Zone and embedded development of R & D, creativity and service functions will be propelled targeting function transformation (Ding et al., 2019), so as to promote transition of the economic development zones to the high-tech zone and the free trade zone. Based on network management mode and functional integration of fragmented spaces (Hudalaha et al., 2019), the networking reconstruction of multiple parks within the high-tech zone will be promoted. Focusing on the local characteristic and advantageous industrial chains, industrial matching and agglomeration development will be advanced circling the nuclei spaces to promote the integrating configuration of suburb industries with urban industries. Rizhao, Tai'an, Weihai city which are adjacent to the metropolitan areas will be actively integrated into the industrial allocation of the interlocking metroplis, and supporting industries in these neibouring cities will be developed based on definite industrial chains. In Zibo, Dongying and Zaozhuang cities with multiple urban cores, focusing on characteristic and advantageous industries such as ceramics and new materials, industrial allocation is carried out circling industrial nuclei in the urban area so as to promote modular development of the parks and functional integration of scattered parks in different districts. Weifang, Linyi cities neibouring the coastal metropolis and having weak urban centers and strong suburb counties, should actively accept industrial diffusion from coastal metropolitan areas. Based on the local industrial nuclei and the advantages of port and land resources, supporting industries will be developed in the peripheral suburbs to strengthen the

Table 5. Classification of Shandong prefectures (cities) and restructuring of their new industrial spaces (source: author's work).

City category	City Composition	Regional characteristics and development strategies	Reconstruction of regional industrial spaces
Metropolitan areas	Qingdao, Jinan and Yantai city	Having innovation nuclei, industrial nuclei and policy nuclei. Expansion of Suburbs from suburb counties; rail transit construction; development toward interlocking metroplis.	Interconnection and functional integration of fragmented patches within the High-tech Zone. Functional transformation and upgrading of economic development zone based on informal spacial reconstruction. Integration development of suburbs with urban areas.
Cities circling the metropolitan areas	Rizhao, Tai'an and Weihai city	Adjacent to the metropolitan area. Actively docking with the metropolitan area to promote the integrated use of ports and land. Construction of interlocking metroplis by means of interconnection of cities with neibouring metropolitan area.	Promote the synergy and resonance between local advantageous industries and those of adjacent metropolitan area. Based on the characteristic industrial chains of metropolitan area, accept the industrial diffusion of the metropolitan area and develop related supporting industries.
Cities with scattered-urban centers	Zaozhuang, Dongying and Zibo city	Typical industrial cities. Multi-center development and scattered expansion circling multi urban centers of the city. The reserve land for expansion is sufficient, showing multi-center spatial sprawl.	Promote interconnection and functional integration of industrial parks in different districts. Specialized development of industrial parks based on technology platform. Construction of industrial complex within the city.
Cities with weak urban center and strong suburb counties	Weifang and Linyi city	Better macro location; Strong development of suburban counties. Weak role of urban core in regional industrial organizations. Actively docking with coastal metropolitan areas.	Connect with the coastal metropolitan area and develop supporting industries. Based on the advantages of local agriculture, develop the characteristic industries of suburban counties. specialized configuration of industries within the park.
Cities with weak urban center and weak suburb counties	Ji'ning, Heze, Liaocheng, Dezhou and Binzhou city	Located in the hinterland; The development of both urban area and suburban counties is weak. Obvious advantage of agriculture. Obvious supporting characteristics of processing and manufacturing industries. Relatively loose industrial structure. Enclave park strategy based on local comparative advantages of factors.	Urban expansion and industrial matching based on local industrial nuclei; Based on the advantages of agriculture, develop characteristic industries in suburban counties. Development of enclave parks based on the advantages of land and local labor resources. Based on the mode of external incubation —local acceleration of high-tech enterprises, accept brunch plant of high-tech firms.

characteristic and advantageous industries. The cities with weak urban center and weak counties will focus on promoting the development of enclave parks based on the local comparative advantages of the elements. Based on the mode of external incubation and local acceleration, brunch plants of high-tech enterprises will be introduced actively.

7. Conclusion and Discussion

Compared with traditional industrial zones, new industrial space is a new industrial area dominated by high-tech zones and economic development zones. Based on the long-time series data of high-tech zones and economic development zones in Shandong, this paper analyzes the spatial distribution pattern of new industrial spaces in Shandong. Based on the theories of value chain, flow

space and industrial cluster, this paper explores the spatial pattern and reconstruction mechanism of new industrial spaces in Shandong from multiple spatial scales, and puts forward the strategies and policy measures of spatial restructuring of new industrial spaces in Shandong. Affected by the availability of data, the constructed measurement index system of new industrial spaces needs to be improved, and key indicators such as R & D, technological achievement trading, incubation of high-tech enterprises and industrial connection, need to be included in the analytical framework to reflect the essential characteristics of new industrial spaces. The analysis of reconstruction mechanism and strategies of Shandong new industrial spaces mainly focuses on the reconstruction strategies and policy measures of different types of regional industrial spaces from the perspective of integration of urban space and industrial space. The analysis mainly stays in the conceptual framework at the macro level. The industrial analysis and network analysis based on multi-source data are relatively weak, and the micro empirical research based on cluster theory and enterprise data, will become the focus of future research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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