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A New Approach to Evaluate the Integrated Development of City and Industry: The Cases of Shanghai and the Kangqiao Industrial Park

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Abstract: The integration of population, industry, transportation, and land is the objective requirement of the coordinated development of industrialization and urbanization. However, previous research has not appreciated long-time series of city–industry integration from the multi-scale perspective, and there is an over-reliance on statistical data, which limits the spatial perspective in evaluation systems. The purposes of the research are (1) understanding the connotations and essence of the integrated development of city and industry from different spatial scales, (2) introducing a spatial perspective into the evaluation system, with multi-source geospatial data, and (3) evaluating it dynamically. Results showed that (1) at the city scale, the degree of city–industry integration in Shanghai has an upward trend over the 20 years, with volatile changes. (2) At the scale of the industrial park, functional, social, and spatial integration show an increase. The contributions of city development change were ranked high to low as follows: functional integration, spatial integration, and social integration. (3) Multi-source geospatial data improve data availability for the research in this field. The multi-source data fusion fixes the lack or abnormalities of the data in traditional research, which enriches the evaluation perspective. The contributions of this article include (1) this study established the city-population, industry, and transportation interaction system (C-PIT) to describe the integrated development of city and industry at city and industrial park scales; (2) this study introduced the spatial perspective to construct a new evaluation approach, which is based on the coupling coordination degree, the entropy method, and multi-source data; and (3) this study conducted a long-time series analysis of two cases, Shanghai and Kangqiao industrial park.

Keywords: city–industry integrated development; city scale; industrial park scale; evaluation index system; coupling effects

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1. Introduction

The coordinated development of industry, city, and population has always been the goal of urban planners. How do we understand the connotations and essence of the integrated development of city and industry from different spatial scales? How do we evaluate the level of the integrated development of city and industry dynamically? These are two core problems in the study of the integrated development of city and industry.

The city is the organism of system integration, including population concentration, industrial agglomeration, infrastructure allocation, and public service supply. The process of urbanization is an interactive development process involving the population structure, industrial structure, residential structure, and land-use structure under certain time and space conditions. The planning and construction of early garden cities, satellite cities, and industrial suburbs aimed to achieve the integration of urban and rural space development [1–3]; although spatially separated from the metropolitan built-up areas, its strong economic and social self-sufficiency is still emphasized. Later, as a specific area in the expansion of the central city, new towns or new cities began to be planned and constructed [4–8], which was also aimed to relieve the over-dense population and employment of the central city, and led to the rise of greenbelt cities, edge cities, and technical suburbs [9,10]. Citizens exist within a complete living environment that integrates work, life, and entertainment, so the layout of the factory must take into account the relationship between the factory and the residential area [11]. In addition to industrial suburbs, residential suburbs, commercial suburbs, and information suburbs have also emerged. Whether it is "modern urbanism" advocating for urban concentration, increasing green space areas, and optimizing the transportation network, or "new urbanism" advocating for the mixed-use of land and space, both involve city–industry integration or urban–rural integration to a certain extent [12,13]. This evidence suggests that the scope of city–industry integration has gradually expanded from new towns or technical suburbs to the urban scale. Unfortunately, these new towns or technical suburbs are far less attractive to industries and talent than the central cities. As a result, there is a job–housing imbalance or uncoordinated industrial and urban development between the central city and the suburbs.

On the whole, academic research on city–industry integration mainly involves the following aspects:

(1) Research on the connotations and essence of city–industry integration. In developed western countries, there is no explicit concept of city–industry integration development. However, there are studies in the field of urbanization and industrialization related to the concept of city–industry integration [14], including a causal relationship between industrialization and urbanization [15], a positive effect of urban development on industrial-scale returns, and the promotional effect of industrial agglomeration on urban development [16,17]. The upgrading of the industrial structure and industrial diversification are the main drivers of the sustainable development of urbanization [18]. City–industry integration refers to the interactive evolutionary relationship between industrialization and urbanization, which may exist in three forms: over-urbanization (i.e., urbanization leads while industrialization lags, also known as the "city before production" model), under-urbanization (i.e., industrialization leads while urbanization lags, also known as the "production before city" model), and simultaneous urbanization (i.e., coordinated development of industrialization and urbanization or integrated development of city–industry) [19–26]. However, it should be noted that industrialization and urbanization not only have significant spatial differences but also have distinct stage differences. In the initial stage of economic development, it may be reasonable that the level of industrialization is higher than that of urbanization; in the post-industrialization period, it is normal that the level of urbanization is higher than that of industrialization. In other words, industrialization and urbanization are not always synchronized at different stages of economic development.

In China, city–industry integration refers to the degree of alignment between the industrial structure and urban functions in new urban areas or industrial parks, and dissonance between the two is reflected in the separation of city and industry [27–29]. Along with the expansion of the study area, the focus of city–industry integration has gradually moved from a pure city–industry relationship to further encompass the development of the main body of the city—the people themselves, i.e., the integrated development of industry, city, and people [14,30,31]. At the same time, the development of urban rail transport has also led to a focus on transport and accessibility [7]. In a broad sense, city–industry integration covers economic integration, social integration, cultural integration, industrial integration, ecological integration, functional integration, and spatial integration. The essence of city–industry integration is the integration of residence and employment and the integration of urban communities and industrial parks.

(2) Research on the characteristics and driving mechanisms of the city–industry integration. "Industry" includes manufacturing, the service industry, and various related industrial forms; "city" refers to the urban agglomeration of various functions, such as regulation, production, coordination, and services [32]. Moreover, the ideal city–industry

integration has the characteristics of a symbiosis between urban function and industrial layout, the coexistence of life and employment, the interaction between the manufacturing and service industry, and harmony between economy and environment. Its driving forces include economic, institutional, socio-cultural, technological, and biophysical drivers. The evolution of city–industry interaction is an inherent mechanism for the high-quality development of new urban areas. An increase in the degree of city–industry integration can significantly promote regional innovation development; compared to the path of "industry before city", the path of "city before industry" has a more pronounced role in promoting regional innovation [33]. The underlying mechanism for the coordinated development of industries and cities depends on the people and services that connect them [34,35]. Overseas scholars pay more attention to the environmental effects of industrialization and urbanization [8,36] or the planning and construction of eco-industrial parks [37,38]. It should be pointed out that peri-urbanization [39–42] is a necessary stage of urban expansion, which is caused to a greater extent by institutional or government policies, especially in developing countries. Additionally, urban shrinkage is the result of deindustrialization, suburbanization, industrial transformation, and changes in the population structure [43–46]. The essence of shrinking cities is the weakening of growth drivers, the loss of jobs, and a decrease in the financial revenue of cities, caused by the decline of their traditional leading industries. The main reason for the decline of traditional leading industries lies in the lag in the shift from old to new drivers and the transformation from scale expansion to quality and efficiency improvement. In a sense, this is also a consequence of the serious imbalance between cities and industries.

(3) Measurement method for the degree of city–industry integration. With the depth of research, the study of city–industry integration has gradually developed from qualitative analysis to quantitative research. Scholars tend to consider city–industry integration as a state or process of urban development and choose different indicators for evaluation, specifically using methods such as factor cluster analysis, fuzzy hierarchical analysis, principal component analysis, grey correlation analysis, and the entropy method [29,32,47–50]. However, most of these studies focus on a certain point in time and are strongly dependent on statistical data. Recently, based on the urban population–industry system, some scholars have used the coupling coordination degree to quantitatively evaluate the level of city–industry integration and identify its spatial-temporal pattern and the key impacting factors [51,52]. This provides a reference for research on the multi-temporal development of city–industry integration. However, due to the lack of a profound understanding of the internal mechanism of city–industry integration, the evaluation indicators that are selected are either too numerous or too arbitrary, or there is an excessive reliance on statistical data, which contain statistical bias caused by subjective feelings and sample selection. Moreover, statistical units are often of a large regional scope, which makes it difficult to obtain data of fine scope, etc. Because the integrated development of city and industry is the result of the interaction between population and industry in space, some important data related to space often cannot be obtained directly and need to be obtained indirectly by means of geo-computing methods. At the overall level of the city, the statistical data are relatively rich; however, at the level of industrial parks and even plots, statistical data are relatively scarce, and need to be supplemented by spatial data. Some indicators that are readily available are often unimportant, while those that are important are often difficult to obtain.

(4) Research on the modes and paths of city–industry integration. Researchers have regarded city–industry integration as a policy tool, or a means and a goal of healthy urban development, and focused on practical problems such as the imbalance between urbanization and industrialization, the mismatch between urban function and industrial layout, and the imperfect government function and operation mechanism. They have proposed the development modes, paths, and tactics of new city or new town construction [53–57], including structure optimization, function upgrading, industrial upgrading, transportation organization, supporting facilities, urban landscape construction, low-carbon development, etc. However, some studies have ignored the organic combination of new-town

construction and old-city renewal or the interactive development between industrial parks, university campuses, and urban communities [30]. The living needs of migrant workers and the rationality of land use in industrial parks have not received enough attention.

In summary, the following problems are noted in the existing studies: (1) the concept of city–industry integration is vague and diverse, and its internal mechanism is not fully understood; (2) the multi-scale nature of city–industry integration is not appreciated; (3) there is a lack of evaluation of long time-series of city–industry integration; and (4) there is an over-reliance on statistical data, which has led to a lack of spatial and population mobility perspective in the existing evaluation system.

Therefore, aimed at the above problems, the purposes of this study are: (1) to understand the connotations and essence of the integrated development of city and industry from different spatial scales, (2) to introduce the spatial perspective into the evaluation system, with multi-source geospatial data, and (3) to evaluate it dynamically.

The contributions of this paper are as follows: (1) a theoretical framework (C-PIT model) is constructed to analyze city–industry integrated development; (2) three dimensions (functional integration, social integration, and spatial integration) and their index systems are proposed to measure the level of city–industry integration at the industrial park scale; (3) a multi-temporal dynamic evaluation of city–industry integration is conducted. The proposed methodology of this paper can be used as a reference for similar research in developing large cities with advanced industrialization and lagging urbanization.

The remainder of this paper is organized as follows. Section 2 introduces methodology of this research, including: (i) Definition of city–industry integration on the city scale and the industrial park scale; (ii) C-PIT theoretical model; (iii) Evaluation index system of city–industry integrated development; and (iv) Case study approach. Section 3 is an empirical analysis of Shanghai and an industrial park in Shanghai. Section 4 discusses the results of the case study, including a comparative discussion of the results from other studies. Section 5 reports on the main conclusions.

2. Methodology

2.1. Definitions of City–Industry Integrated Development and Spatial Scale Choice

The city is a multi-scale space. From the perspective of the city–industry integrated development, it includes the city scale, urban sub-regional scale, and community scale. Urban areas are the main scale at which people conduct their lives [58]. Urban sub-regions are the key development regions of the urban industrial economy (such as development zones in China) and the key functional areas. The city–industry integrated development at the community level mainly refers to the arrangement of a certain proportion of pollution-free industry around the community or the reservation of an appropriate amount of clean industry land within the community (such as hawker centers and the night-time economy in Singapore) [59].

The urbanization process depends on various unique combinations formed by the interaction of various urban individuals. Whether cities can produce unique goods and provide unique services depends on the amount of "productive knowledge" in the economy. All types of development zones represent productive knowledge blocks in cities, which not only produce various types of new products but also produce various types of patents, standards, brands, and other knowledge assets. If cities can effectively connect different productive knowledge blocks distributed in different locations, their productive potential will be expanded, their adaptability will be improved, and their ability to cope with complexity and future uncertainty will be further enhanced. For the convenience of management, each development zone has its clear boundary. However, each development zone cannot cope with all the complex problems independently. It also needs to maintain close contact with the whole city and share the information, knowledge system, and experience of the whole city system [60–63]. This is why it is of great significance to combine the urban scale with the development zone scale to discuss city–industry integration development. Therefore, this paper focuses on two spatial scales: city and community (or industrial park).

At different spatial scales, the objectives and emphases of city–industry integrated development are different. Focusing on the city scale helps to provide a more comprehensive insight into the relationship between urbanization and industrialization, and better address the challenges of the complexity of urban systems and the uncertainty of the future. The main function of an industrial park is production, but one cannot completely ignore its closely related life functions. Otherwise, it could result in longer commutes and higher commuting costs for employees, increased traffic congestion, energy consumption, and carbon emissions. It is undeniable that industrial parks are also an important part of cities, and employment, residence, recreation, and travel are the main functions of cities, which should be reasonably matched in space. In this sense, it is necessary to examine the functional matching and spatial reconstruction of industrial parks from the perspective of the city–industry integrated development [33,35,63,64].

Therefore, city–industry integrated development at the city scale is defined as the coordination of urbanization and industrialization; at the industrial park scale, it is defined as the adaptation of the production and life functions within an industrial park, which includes the three dimensions of functional integration, social integration, and spatial integration. Integrated development at the level of the industrial park depends on the policy guidance at the level of the city.

2.2. Theoretical Framework

The theoretical framework of city–industry integration development is illustrated in Figure 1.

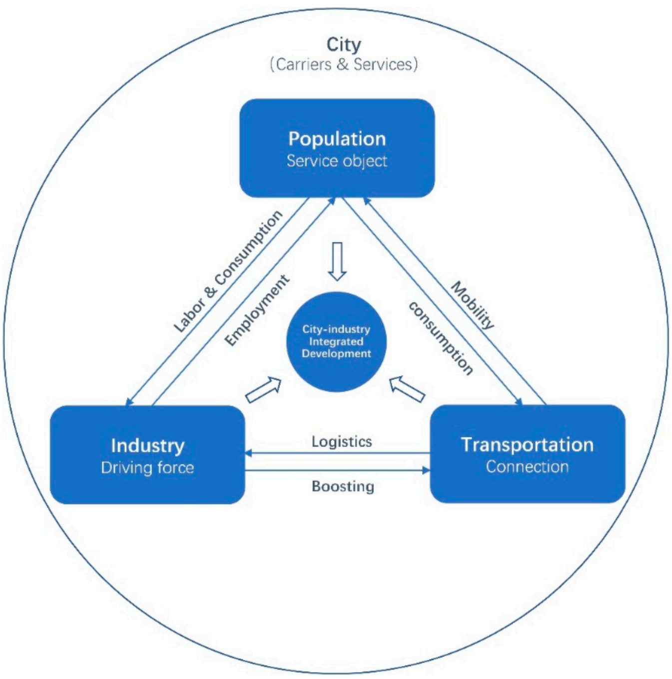

Figure 1. The theoretical framework of city–industry integration development.

A city is a huge, open, and complex system mainly composed of a population subsystem, industrial subsystem, infrastructure subsystem, and public service subsystem. It provides both spatial carriers (e.g., land) and public services (e.g., transportation) for human activities and economic development. Industrial allocation is one of the basic drivers of urban development, especially regarding manufacturing and service industries. The scale economy effect, external economy effect, and information transfer effect generated by the spatial agglomeration and diffusion of industrial elements promote changes in urban size, employment structure, and land-use structure [30,60,61]. These fully demonstrate the role of industrial development in promoting the rise and expansion of the city. Cities are the spatial carriers of industrial development, population residence and mobility, infrastructure, and social public services, supporting and maintaining the interests of the industrial operation, the well-being of residents, and social and ecological security. The interactions of population, industry, transportation, market, institution, and other agents form various urban network systems. In a sense, city–industry integrated development can also be understood as an innovative network system formed by the interaction of "population, industry, transportation, and the city" on a specific spatial scale.

Based on this concept, this paper constructs the city and population, industry, and transportation interaction system (C-PIT) as a theoretical basis for the evaluation of city–industry integration. In this system, population (P), industry (I), and transportation (T) are the three key elements of the urban system. As shown in Figure 1, the population is the main body and service object of the urban system, which provides the labor force and consumption for other subsystems. The industry is the driving force of city development, which is the engine that keeps communities growing and provides employment opportunities for the population. Transportation is the connection between citizen mobility and industrial logistics. The agglomeration of resources and the expansion of industries also require smooth transportation conditions. The city–industry integrated development is the result of the interaction between the city and population, industry, and transportation (C-PIT).

2.3. Evaluation Index System of City–Industry Integrated Development

Based on the C-PIT system, the paper constructs two valuation index systems that provide an overview of the city–industry integrated development on two spatial scales (Table 1).

Table 1. An analytical framework of the two spatial scales for city–industry integration evaluation.

Conception	Spatial Scale	Dimension	Indexes	Direction	Index Reference Sources
City–industry integrated development	City	Population	Population urbanization rate	+	[51]
			Job–housing separation	−	[65]
		Industry	Industrial urbanization rate	+	[52] *
			New jobs created	+	[33]
		Land	Land urbanization rate	+	[66]
			The matching degree of residential land and non-residential land	−	[67]
	Industrial park	Function integration	The concentration of leading industries	+	[51] *
			The rationality for the proportion of residential land	−	[68]
			Average commute distance	−	[69]
		Social integration	The proportion of migrant workers	+	[70–73] *
			Housing supply diversity	+	[70–73] *
		Spatial integration	Land-use diversity	+	[52] *
			Accessibility to basic life demands	+	[52] *

Note: The indicators, whose "Index reference sources" with "*" are based on the content of the relevant references or else are from the reference sources.

2.3.1. Evaluation Index System at a City Scale

Step 1: Constructing an Evaluation Index System Based on the C-PIT

City–industry integrated development at a city scale generally refers to the overall situation of the coordinated development of industrialization and urbanization. Coordinated development is the interactive adjustment and optimization process of the industrial structure, population structure, employment structure, land-use structure, or spatial structure; in other words, it is a process of integrated development involving industry, housing, transportation, and the environment. The development goal of the comprehensive city is to pursue a competitive economy, an amiable society, and a more livable environment. The realization of this goal depends on the formation of a reasonable industrial structure, employment structure, land-use structure, and urban and rural spatial structure.

City–industry integration necessitates the coordinated growth of land, population, industry, and transportation because they are associated with one another [74–76]. Traffic plays a connecting role among various elements and is difficult to be separated independently. Therefore, traffic indicators are added to other relevant elements. The coupling coordination degree model is used to evaluate the coupling effects [52,77]. The degree of coupled coordination takes into account both the amount of system coordination and the stage of coordinated development.

Therefore, six indicators from three dimensions are selected to construct an index system. The details of the six indicators are shown in Table 2.

Table 2. The dimensions, key elements, and index system for evaluating the level of development of city–industry integration at the city scale.

Dimensions	Indexes	Key Elements	Data Method
Population	Population urbanization rate	Population	Field survey
	Job–housing separation	Population, land, and transportation	Ratio of daytime to nighttime population and Gini coefficient
Industry	Industrial urbanization rate	Industry	Field survey
	New jobs created	Industry	Field survey
Land	Land urbanization rate	Land	Field survey
	The matching degree of residential land and non-residential land	Land and transportation	Gini coefficient

Based on the C-PIT model, the population urbanization rate and job–housing separation show the development of the population in the process of city–industry integration. The population urbanization rate reflects the trend of population urbanization by the proportion of the urban population in the resident population. Job–housing separation calculates the space Lorentz curve and Gini coefficient based on the ratio of employed population to resident population in each district. The Gini coefficient or index is calculated by the area between a graph of the cumulative income share against the cumulative share of recipients (the Lorenz curve) and the line of perfect equality. It is a statistic used to describe in summary form the degree of inequality in distributions. The Gini coefficient is widely used in the study of separation in cities, such as industrial agglomeration, the spatial pattern of residential segregation by race [67], and the geographic dispersal of visitors [65]. The population was assigned to administrative districts based on the relationship between industry and land use type. Due to the lack of daytime and nighttime population statistics, we use the employment and residential population survey data as an indirect substitute. The daytime and nighttime population distribution reflects the separation of work and residence, and commuting status within urban districts [78].

The industrial urbanization rate is calculated by the proportion of the employee population in the secondary and tertiary industries in the total employee population of Shanghai. New jobs created shows the government's ability to provide jobs and employment services, which is an important basis for evaluating the development level of city–industry integration.

Land urbanization rate is expressed as the ratio of built-up area to the total urban area, which reflects the planning direction of urban land use. The matching degree of residential land and non-residential land is calculated by the Gini coefficient of the ratio of residential land to non-residential land by district, which shows the distribution of residential and non-residential functions in the city in terms of land-use structure and commuting.

Step 2: Calculation Method for the Coupling Coordination Degree

In the evaluation of city–industry integration at the city scale, there are interactive effects among various indicators, and it is necessary to conduct a unified evaluation of the multidimensional coordinated development of industry, population, land, and transportation. The Fisher Discriminant was passed by the coupling coordination degree model used to compute the coupling effect [52]. Therefore, the calculation of the coupling coordination degree of population urbanization, industrial urbanization, and land urbanization was used as the basis for judging the degree of city–industry integrated development on the city scale. The method for determining the weights of the evaluation indicators in each dimension is the entropy weight method (see Section 2.3.2 Step 2).

(1) Coupling model. The coupling degree calculation model used here is as follows:

$$C = \left[\frac{u_1 u_2 u_3}{\left(\frac{u_1 + u_2 + u_3}{3} \right)^3} \right]^{\frac{1}{3}} \quad (1)$$

where C is the coupling degree, which has a value between 0 and 1. The larger the C value is, the higher the coupling degree between systems and the closer the relationship between systems is [79]. u_1, u_2, and u_3 are the population urbanization rate, industrial urbanization rate, and land urbanization rate. Because the dimensions of the three factors are consistent, there is no need to standardize.

(2) Coupling coordination model. The coupling function can describe the degree of coordination of the development of multiple systems, but it is impossible to determine whether the degree of coordination between systems is at a higher level or a lower level. Therefore, the coupling coordination function was introduced [80]. The coupling coordination function can not only reflect the degree of coordination between the systems but also reflect the stage of the coordinated development level. Its calculation formula is as follows:

$$R = (C \times T)^{\frac{1}{3}} \quad (2)$$

where R is the coupling coordination degree. The larger the R value is, the higher the coordination level between the systems is. T is the comprehensive evaluation index, and its calculation formula is as follows:

$$T = \alpha \times u_1 + \beta \times u_2 + \gamma \times u_3 \quad (3)$$

where $\alpha = \beta = \gamma = 1/3$.

(3) Division of city–industry integration stages. According to previous research results, only when the coupling coordination degree was greater than 0.5 could it be judged as the city–industry integration stage [79]. According to the value of the coupling coordination degree, we divided the city–industry integrated development on the city scale into four stages (Table 3).

Table 3. The classification of coupling coordination degree.

Calculation Results	Classification
0.00–0.50	Discordance
0.51–0.70	Basic coordination
0.71–0.80	Good coordination
0.81–1.00	Excellent coordination

2.3.2. Evaluation Index System on an Industrial Park Scale

Step 1: Constructing an Evaluation Index System Based on the C-PIT

The industry is the foundation of urban development, and cities are the spatial carriers of industrial development. Living and working happily are two basic needs in the sustainable development of urban residents. City–industry integrated development on the industrial park scale is essentially the coordination of the development process among the industrial production function, the employment function of the residents, and the city life functions (residential, transportation, consumption, leisure, etc.). Therefore, seven indices from three dimensions (functional integration, social integration, and spatial integration) are selected to establish an index system for evaluating the level of development of city–industry integration at the industrial park scale (Table 4).

Table 4. The dimensions and index system for evaluating the level of development of city–industry integration at the industrial park scale.

Dimension	Index	Data Method
Function integration	Concentration of leading industries	Field survey
	The rationality for the proportion of residential land	Reclassification and spatial statistics
	Average commute distance	Spatial statistics
Social integration	Proportion of migrant workers	Field survey
	Housing supply diversity	Reclassification, spatial statistics, and Shannon Index
Spatial integration	Land use diversity	Reclassification, spatial statistics, and Shannon Index
	Accessibility to basic life demands	Buffering and shortest path (network) algorithms

The integration of urban functions involves the coordination and cooperation of urban multi-functions. The purpose of functional integration is to meet the employment, residence, travel, and leisure needs of different levels of urban residents using land balance, employment balance, commercial infrastructure balance, and living balance. Three indicators, i.e., the concentration of leading industries, the rationality for the proportion of residential land, and the average commute distance, were selected to measure the functional integration level.

To a large extent, the acquisition of urban functions comes from services and manufacturing. In particular, the leading industry usually adopts advanced technology and has a high growth rate and is strongly correlated with other industries. As a result, it has a strong leading effect on other industries and the economic development and employment growth of the entire region. In an industrial park, the leading industry determines its output, employment, and development potential. The rise and fall of an industrial park depends to a large extent on the rise and fall of its leading industry. The output performance of the leading industry is closely related to its degree of agglomeration. The weak foundation of leading industries and the scattered distribution of enterprises are the main problems associated with industrial parks in China. Hence, the concentration of leading industries is selected as an indicator for industrial development. The calculation formula for the concentration of leading industries is as follows:

$$\begin{aligned} The\ concentration\ of\ leading\ industries\ =\ (the\ output\ value\ of\ the\ leading\ industry)/ \\ (the\ total\ output\ value\ of\ the\ park) \end{aligned} \quad (4)$$

The rationality for the proportion of residential land is an important index reflecting the matching degree of the residential function (living function) and non-residential function (production function) in an industrial park. The degree of coordination between them affects the sustainable and healthy development of an industrial park. The rational ratio differs in different countries or even cities due to the social and natural conditions [81].

As Shanghai is the study area, the rational ratio is between 25.0% and 40.0%, according to the urban land-use classification and planning and construction land-use standards (GB 50137-2011) of China [68]. The calculation formula of the rationality for the proportion of residential land is as follows:

$$\begin{array}{l} The\ rationality\ for\ the\ proportion\ of\ residential\ land = \\ \begin{cases} 0, the\ ratio\ of\ residential\ land\ to\ construction\ land\ within\ the\ reasonable\ ratio \\ Abs\ (the\ ratio\ of\ residential\ land\ to\ construction\ land - the\ reasonable\ ratio), \mid else \end{cases} \end{array} \quad (5)$$

The residential land area and the construction land area in this case are obtained through GIS by reclassification and spatial statistics of the land-use parcel data.

The average commute distance is a common index to reflect the spatial separation of work and residence. It should be pointed out that in Japan, the most well-known indicator reflecting the separation of employment and residence is the ratio of the day and night populations [82]. If the day-to-night population balance, i.e., the day-to-night population ratio, tends towards 1, the total amount of urban traffic can be reduced and the contradiction between the capacity of transportation facilities and demand can be alleviated [69]. In other words, the closer the day-to-night population ratio is to 1, the better the city–industry integrated development. However, in Shanghai or other large cities in China, very few employees of enterprises live in the industrial park at night, so the accuracy this index for measurement is not ideal. Therefore, we select the average commute distance to measure the separation of employment and residence.

Social integration means that members of society can widely share social experiences and actively participate in them, all citizens enjoy extensive equality of opportunity and life opportunities, and all citizens have basic social welfare [70–73]. The purpose of social integration is to meet the diverse needs of residents of different races, different origins (residents and migrant populations), and different income classes. Employment and dwelling space are two major issues concerning people's livelihoods, and their inclusiveness and diversity are core indicators of social integration. The increase in population mobility and the diversification of the housing supply pose new challenges to the sustainable development of industrial parks. In China's industrial parks, the migrant labor force is huge, and their housing problems are prominent. Therefore, based on the availability of data, two indicators, i.e., the proportion of migrant workers and housing supply diversity, are selected to measure the social integration level. The Shannon index of the land area for different residential types serves as the measurement of the housing supply diversity.

Spatial integration here refers to the coordinated layout, overall development, division of labor and cooperation, and coexistence and co-prosperity of different functional areas in an industrial park. The purpose of spatial integration is to control the scale of land use, the land-use structure, and the functional layout of each region to ensure that residents can enjoy the services of neighborhood businesses, to shorten commuting distances, and to improve spatial performance. Spatial performance is reflected by the diversity of the land-use structure and the convenience of public services. Thus, two indicators, i.e., land-use diversity and accessibility to basic life demands, are selected to measure the spatial integration level.

Land-use diversity is not only an important indicator of urban efficiency and vitality but also an important embodiment of urban resilience and spatial integration. This index is calculated using the Shannon index of area for different land-use types.

The accessibility to basic public services, such as medical care and elementary education, as well as the convenience of shopping and consumption, leisure, and entertainment, is the objective requirement of the city–industry integrated development, which not only affects the quality of life of urban residents but also is closely related to their subjective well-being. Moreover, the lack of business, education, and medical services in industrial development is one of the most common problems existing in the urbanization mode of "production before city". Therefore, to provide more and better education, healthcare, shopping, culture, and sports services for the working population and resident population in the industrial park and its surrounding areas is one of the policy goals of the park management authorities and local governments. The accessibility to basic public services is calculated by the percentage of residential land that meets the 15-min living circle standard, which is obtained through geospatial analysis via the buffering and shortest path (network) algorithms.

Step 2: Method for Determining the Weights of the Evaluation Indicators

The entropy method is a commonly used method for objective weight determination [83,84]. To eliminate the influence of different dimensional indicators on the evaluation results, it is necessary to standardize the various evaluation indicators. Generally, an index with a larger value that has positive effects on city–industry integration is called a positive effect index, and an index with a smaller value that is more favorable to city–industry integration is called a negative effect index.

The standardized formula for positive effect indices is as follows:

$$r_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad (6)$$

The standardized formula for negative effect indices is as follows:

$$r_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} \quad (7)$$

where r_{ij} is the standardized index value; x_{ij} is the original value of the index; max (x_{ij}) and min (x_{ij}) are the maximum and minimum values of each index, respectively.

Based on the entropy method, the weight results of seven indices on the Kangqiao industrial park scale are shown in Table 5.

Table 5. The weight results of the Kangqiao industrial park.

Dimension	Index	Measurement Influence Direction	Weight
Function integration	Concentration of leading industries	+	0.144
	The rationality of the proportion of residential land	−	0.144
Social integration	Average commute distance	−	0.144
	Proportion of migrant workers	+	0.144
	Housing supply diversity	+	0.142
Spatial integration	Land-use diversity	+	0.141
	Accessibility of basic life demands	+	0.141

2.4. Case Study Approach

The case study approach is widely used in management studies and the social sciences more generally [66]. We used Shanghai as the city scale subject of the case study and the Kangqiao industrial park in Shanghai as the industrial park scale subject.

The main reasons for choosing Shanghai are as follows: (1) Shanghai is the leader of urbanization in China. Its process and experience of industrialization and urbanization development are representative. As the economic center of China, it is the city with the most industrial categories and the highest level of urbanization among inland cities in China. (2) Shanghai is one of the rising global cities. It is an important model of sustainable urbanization within the world. Over the past three decades, Shanghai has provided its massive urban immigrant population with a quality of life and extensive infrastructure that no other megalopolis can offer.

The main reasons for choosing the Kangqiao industrial park are as follows: (1) The Pudong New Area is not only the pioneer of Shanghai's reform and opening up but also the pioneer of innovative development and the leader of the development of the Yangtze River Delta. The status of the Pudong New Area in Shanghai continues to rise. The Kangqiao industrial park is located in the Pudong New Area. As one of Shanghai's 23 municipal-level development zones, its gross industrial output value accounts for approximately 20.1% of Shanghai's municipal-level development zones. Several indicators of the Kangqiao industrial park among Shanghai's 23 municipal-level development zones were the highest. (2) The Kangqiao industrial park is a typical example of the urbanization model of "production before city". The industrial development, population living, urban infrastructure construction, and public service provision of the Kangqiao industrial park have certain representativeness.

3. Case Study

3.1. Study Area

Shanghai is not only the birthplace of modern Chinese industry but also the most mature city in Chinese industrial development at present. In 2017, the permanent resident population of Shanghai reached 24.18 million, with a GDP of 3063.299 billion yuan.

The Kangqiao industrial park is adjacent to Shanghai Disneyland in the east, Shanghai World Expo Park in the west, and the Shanghai free trade zone in the north (Figure 2). It is dominated by the electronic information industry and automobile parts manufacturing industry. It is a typical example of the urbanization model of "production before city".

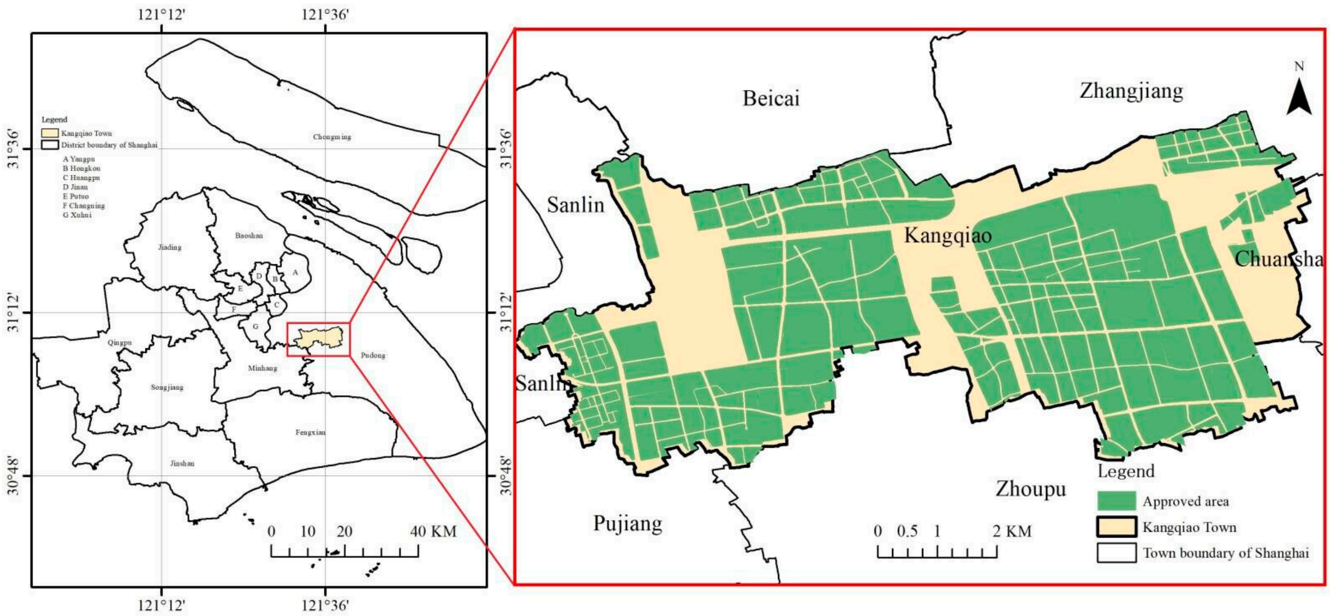

Figure 2. The location of the Kangqiao industrial park in Shanghai.

3.2. Data Sources

The main data type and data sources of indices are shown in Table 6. All data are integrated into a geospatial database for spatial matching and spatial statistics and analysis. The data processing method and calculation formulas for indices are described in Section 2.3.

Table 6. Data type and sources of the index system of city–industry integrated development.

Indexes	Data Type	Data Sources
Population urbanization rate	Statistical data	Shanghai Statistical Yearbook
Job–housing separation	Statistical data and Land-use parcel data	Shanghai Statistical Yearbook and National Geographic Survey Cloud Platform
Industrial urbanization rate	Statistical data	Shanghai Statistical Yearbook
New jobs created	Statistical data	Shanghai Statistical Yearbook
Land urbanization rate	Land-use parcel data	National Geographic Survey Cloud Platform
The matching degree of residential land and non-residential land	Statistical data and Land use parcel data	Shanghai Statistical Yearbook and National Geographic Survey Cloud Platform
Concentration of leading industries	Statistical data	Shanghai Pudong New Area Statistical Yearbooks
The rationality for the proportion of residential land	Land-use parcel data	Shanghai Institute of Geological Surveys
Average commute distance	Mobile signaling data (GPS)	Ji Smart Platform (http:daas.smartsteps.com (accessed on 9 October 2020))
Proportion of migrant workers	Statistical data	Kangqiao Town Government
Housing supply diversity	Land-use parcel data	Shanghai Institute of Geological Surveys, Kangqiao Town Government
Land-use diversity	Land-use parcel data	Shanghai Institute of Geological Surveys
Accessibility of basic life demands	Land-use parcel data and POI data	Shanghai Institute of Geological Surveys, web crawler

3.3. Results

3.3.1. The City–Industry Integration Degree on the City Scale

The evaluation index data of the city–industry integrated development of Shanghai are shown in Table 7. Table 8 displays the classification of the coupling coordination degree. Using SPSSAU (version 22.0) (The SPSSAU project, 2022. Retrieved from https://www.spssau.com (accessed on 3 August 2022)), the calculation results were produced. The city–industry integration degree of Shanghai has been constantly improved in the period 2000–2019, from discordance in 2000 to basic coordination in 2005, good coordination in 2010, and excellent coordination in 2015 and 2019 (Figure 3).

Table 7. Evaluation index data for the city–industry integrated development of Shanghai.

Dimensions	Indexes	2000	2005	2010	2015	2019
Population	Population urbanization rate (%)	77.58	82.11	86.72	89.23	100.00
	Job–housing separation	0.26	0.28	0.23	0.13	0.13
Industry	Industrial urbanization rate (%)	89.23	92.93	96.60	96.62	97.04
	New jobs created (10,000 units)	46.20	65.10	63.15	59.66	57.04
Land	Land urbanization rate (%)	22.74	28.85	36.50	40.48	43.91
	The matching degree of residential land and non-residential land	0.22	0.18	0.19	0.17	0.16

Table 8. Evaluation results for the city–industry integrated development of Shanghai.

Dimension	2000	2005	2010	2015	2019
Population	0.083	0.094	0.383	0.768	1.000
Industry	0.000	0.729	0.921	0.833	0.793
Land	0.000	0.477	0.554	0.808	1.000
The coupling coordination degree (D)	0	0.565	0.762	0.896	0.962
City–industry integration classification	Discordance	Basic coordination	Good coordination	Excellent coordination	Excellent coordination

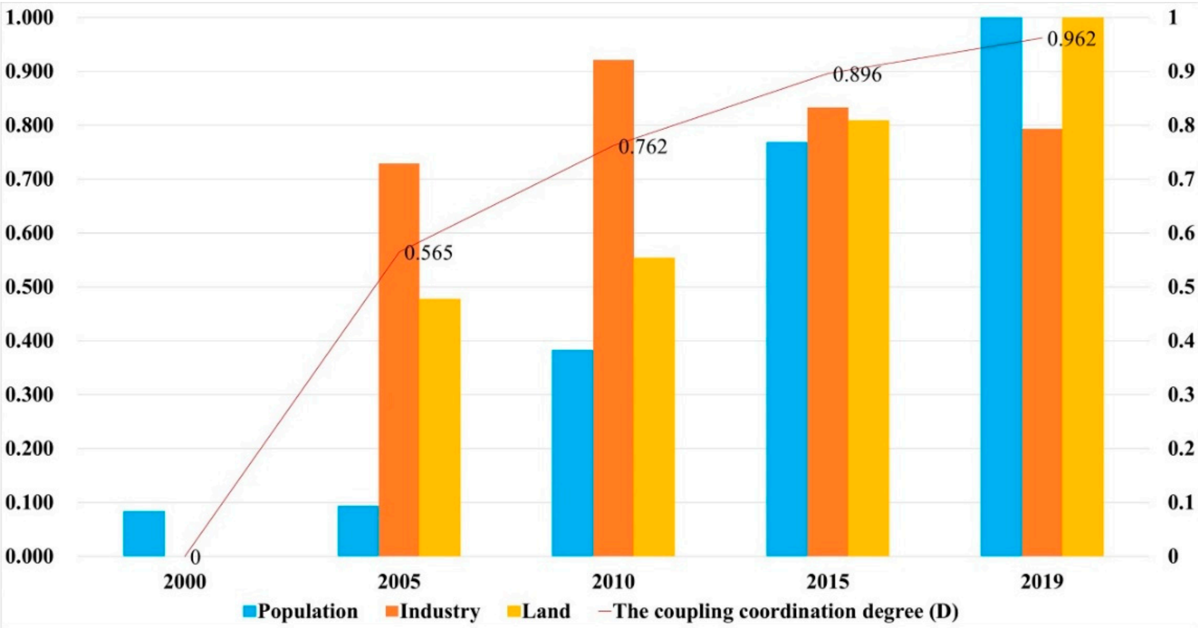

Figure 3. The city–industry integrated development in Shanghai from 2000 to 2019.

3.3.2. The City–Industry Integration Degree on the Industrial Park Scale

The evaluation index data of the city–industry integrated development of the Kangqiao industrial park are shown in Table 9; the evaluation results are shown in Table 10 and Figure 4. Overall, the degree of city–industry integration within the park constantly improved during the study period.

Table 9. Evaluation index data for the city–industry integrated development of the Kangqiao industrial park.

Dimension	Index	2011	2013	2016	2019
Function integration	Concentration of leading industries	81.28%	85.61%	85.78%	87.36%
	The rationality of the proportion of residential land	0.16	0.08	0.00	0.03
Social integration	Average commute distance	11.93	9.84	9.04	8.34
	Proportion of migrant workers	59.16%	58.17%	60.96%	59.37%
	Housing supply diversity	0.96	0.98	1.00	1.10
Spatial integration	Land-use diversity	1.69	1.70	1.75	1.98
	Accessibility of basic life demands	67.99%	74.51%	95.78%	94.34%

Table 10. Evaluation results for the city–industry integrated development of the Kangqiao industrial park.

Dimension	2011	2013	2016	2019
Function integration	0.000	0.253	0.366	0.400
Social integration	0.051	0.018	0.186	0.204
Spatial integration	0.000	0.040	0.171	0.275
City–industry integration	0.051	0.312	0.724	0.879

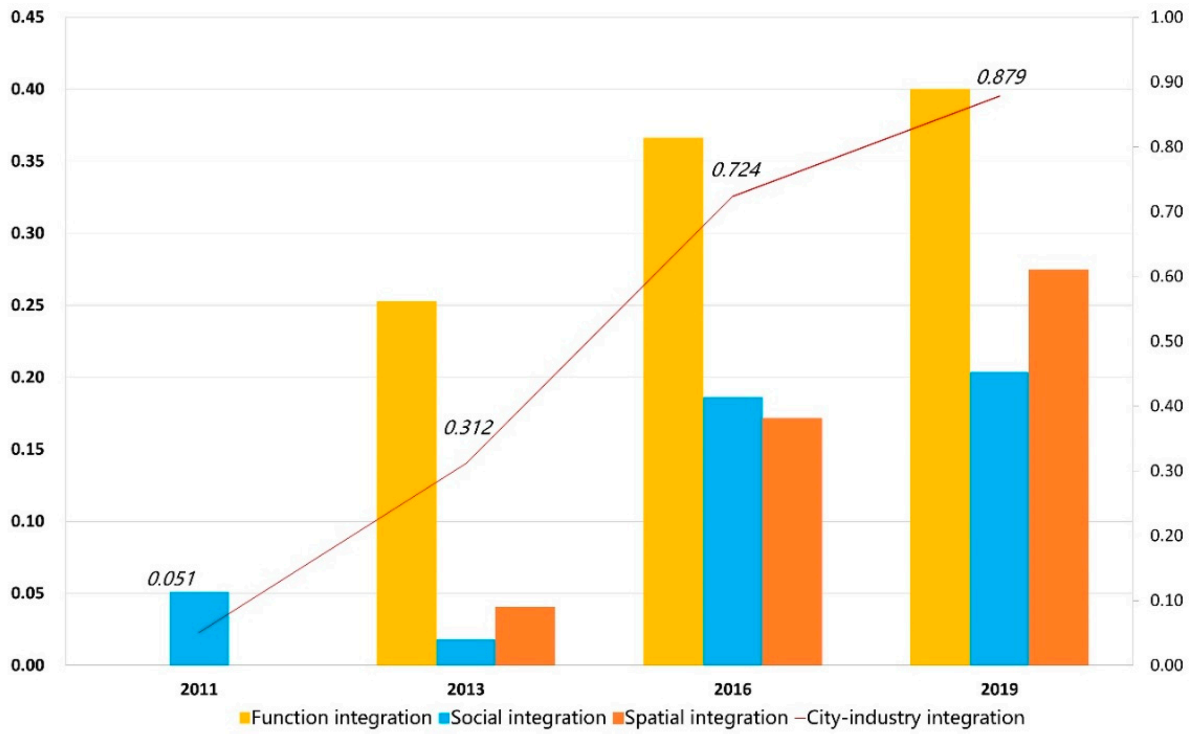

Figure 4. The city–industry integrated development in the Kangqiao industrial park from 2011 to 2019.

As mentioned above, to perform time-series comparison and subsequent calculations, the index values at the scale of the industrial park are standardized. The value is relative rather than absolute. It only represents the level of integration among the selected four years and does not represent the evaluation result in a broad sense. Therefore, the result that the degree of fusion is 0 only indicates that the degree of fusion is the weakest relative to the four-year calculation results and does not mean that it has no fusion in the corresponding dimension.

From 2011 to 2019, the degree of functional integration of the Kangqiao industrial park gradually improved (Table 10). The concentration of the leading industries increased year by year, which guaranteed the ability of the park to increase its output and efficiency, attract talent, introduce foreign investments, and improve the infrastructure and public services within the park. The residential function and non-residential function were gradually balanced. With the continuous improvements in the subway and other public transportation conditions, the average commuting time of workers was shortened year by year, and the separation between working and living space was alleviated.

The degree of social integration in the Kangqiao industrial park gradually improved during the same period (Table 10). Because the Kangqiao town was merged with the Pudong New Area in 2009, a large number of migrant workers obtained new opportunities and moved into the Kangqiao town, causing a sharp increase in the employed population; in the next few years, with their own development, non-labor populations, such as children and parents, were brought to the Kangqiao town, resulting in an increase in the resident population. Real estate development sped up, and housing supply diversification began to occur. However, the construction of some high-end villas may be insufficient to meet the needs of migrant workers in the Kangqiao industrial park.

The proportion of industrial land in the Kangqiao industrial park was the highest, followed by residential land, which together accounted for 69.5% of the total area of the park. In 2013, a batch of new industrial land and residential land was put into use, and the amount of commercial land did not change significantly, resulting in a change in the land-use diversity index that was not obvious in 2013. In 2016, the commercial land in the park was put into use, and the land-use diversification index was significantly improved. In 2016, the Shanghai International Tourism Resort opened for business near the Kangqiao town, and the commercial service environment inside and outside the Kangqiao industrial park was significantly improved.

4. Discussion

Based on the evaluation system of the C-PIT model, this research demonstrates the development patterns of city–industry integration in the two cases of Shanghai and the Kangqiao Industrial Park. Compared with existing studies, this study adds a spatial perspective to the evaluation system. This section will discuss the reliability and innovation points of this study by comparing the findings with previous studies. The reliability of the data processing methods, the limitations of this study, and policy recommendations will also be discussed in this chapter.

4.1. Comparative Analysis

At the city level, the results of this study also show that the degree of city–industry integration in Shanghai has generally shown an upward trend over the past 20 years. Previous studies also found that, since 2000, the level of city–industry integration development in Shanghai has consistently occupied a leading position within China [63,85]. However, unlike the increasing trend of integration exhibited by population and land, the degree of industrial integration shows fluctuations in this study. The change in the industrial integration degree in Shanghai is consistent with previous research findings and can be traced practically.

Gan et al. [52] conducted an empirical analysis of panel data of 18 cities in Sichuan Province from 2000 to 2016 to analyze the development process. They found that the key constraint was the development level of the industry subsystem. Other research also reveals the fact that the degree of city–industry integration will not remain unchanged after reaching a certain level. Liu et al. [33] conducted a study on 285 prefecture-level cities in China and found that city–industry integration has an inter-industrial difference in shaping the industrial structure, with a neutral effect on the secondary industry and an encouraging effect on the tertiary industry. If the promotional effect of city–industry integration on the secondary industry fails, it will inevitably bring about the adjustment of the industrial structure. This inevitable obstacle in the urban transition period will cause the city to experience the fluctuation phenomenon in the degree of city–industry integration.

Practically, since China joined the WTO in 2001 and established Shanghai's "Four Centres" development strategy in 2009, Shanghai's industrial structure has undergone great changes, and a single industrial hub was transformed into a diversified economic hub. Although Shanghai is still one of the most important manufacturing centers in China, the service economy has taken up a dominant position in Shanghai's economy. In 2019, Shanghai's service industry accounted for 72.7% of the GDP, and industrial output accounted for 27% of the GDP.

At the industrial park level, most studies are qualitative and lack a quantitative evaluation system for industrial parks. Therefore, the correlation between the results of the coupling coordination degree calculation and the evaluation results of the industrial park's city–industry integration were tested, and the correlation coefficient value between the two was 0.992, showing a significance level of 0.01, thus, indicating a significant positive correlation between the two. Both evaluation results show that the development level of city–industry integration in Kangqiao industrial park has a positive development trend (Table 11). When the coupling coordination degree is greater than 0.5, the evaluation results of this paper show higher values; when the coupling coordination degree is less than 0.5, the evaluation results of this paper show lower values. In the future, with more data samples, it can be further explored whether this method has the advantage of expanding the variability of the stages of city–industry integration.

Table 11. Coupling coordination degree and classification results in the Kangqiao industrial park.

Year	City–Industry Integration	The Coupling Coordination Degree (D)	Classification
2011	0.051	0.27	Discordance
2013	0.312	0.43	Discordance
2016	0.724	0.59	Basic coordination
2019	0.879	0.72	Good coordination

4.2. Data Validity

In addition to the relevant economic indicators, the spatial distribution characteristics of the industrial land-use structure also show corresponding changes. We compare the ratio of residential land to industrial land in each administrative district of Shanghai from 2000 to 2019 and calculate its Gini coefficient (Table 12). The results show that the ratio of residential land to industrial land has increased significantly in the central urban areas and shown a decreasing trend in the suburban areas during the past 20 years, and the uneven distribution within the city has increased. The industrial land in Shanghai shows a clear trend of shifting from urban to suburban areas. The overall industrial structure of Shanghai is adjusting from the secondary industry, which is mainly manufacturing, to the tertiary industry, which is mainly financial, scientific, and creative services. This development trend is consistent with the stable state after the completion of industrial restructuring, as reflected in the industrial perspective of this paper.

Table 12. The Gini coefficient of the ratio of residential land to industrial land in Shanghai (2000–2019).

Year	Gini Coefficient
2000	0.306
2005	0.325
2010	0.348
2015	0.431
2019	0.443

Due to the access limitations of statistical data, this paper uses the resident population to represent the nighttime population and the employed population (secondary industry and tertiary industry) to represent the daytime population. Based on the correspondence between industries and related land use, the number of employees in each industry in each district is assigned to each area according to the type of land use. The results of this paper are compared with the available statistics on the number of employees in the administrative districts (2000, 2005, 2010, and 2015), and the relative errors are calculated for verification (Figure 5).

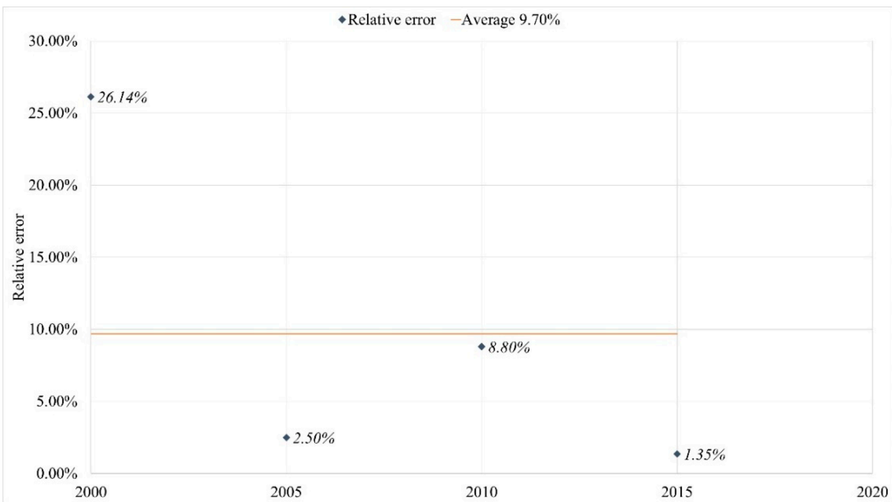

Figure 5. Relative errors of the estimated number of employees in the Pudong New Area.

Figure 5 shows that the average error of population estimation for the four specific years is 9.70%, among which the errors of estimation for three years are less than the average error, and the error of estimation for 2000 is higher than the average error, with a maximum error of 26.14%. The year with the largest error in population estimation is 2000, which is probably since the land allocation for the early industries in the Pudong New Area preceded the population inflow.

4.3. Limitations

The limitations of this paper are as follows. (1) On the city scale, the characteristics and paths of city–industry integration will be different for cities with different natures and functions. As a comprehensive metropolis, the evaluation ideas and methods of city–industry integration in Shanghai may be different from those of small- and medium-sized specialized cities, which need to be further studied. (2) On the industrial park scale, the comparative study of different types of industrial parks needs to be further strengthened. In China, there are various industrial parks, economic and technological development zones, high-tech development zones, and export processing zones. Although their common characteristics include obvious industrial advantages and a single function, especially a weak social service function, there are still some differences among them. (3) There is no empirical study on the development mode of new cities or new towns (i.e., "city before production" mode), such as Songjiang New City and Anting New Town in Shanghai, and there is no comparative analysis between the "production before city" mode and the "city before production" mode. This paper mainly focuses on the "production before city" mode, and it neglects the "city before production" mode. At present, Shanghai is carrying out the planning and construction of "five new cities" (Songjiang, Jiading, Qingpu, Fengxian, and Nanhui New Cities) [86], and the model of "city before production" exhibits great research potential, which also shows that the theory of city–industry integration development has broad application prospects. Improving the theoretical system and methodology of the city–industry integrated development through more empirical studies is an important academic goal for the future.

4.4. Policy Recommendations

At the city scale, the policy focus of city–industry integrated development is (1) integrating high-quality housing, leisure, and recreational facilities into the commercial centers and sub-centers; (2) building more office space, shopping space, and leisure and entertainment space close to homes along major traffic routes to reduce the need for transportation. Simply increasing the density can render cities more efficient, but it cannot make them livable. By fully paying attention to the internal relationship between scale, size, density, distance, land, and industry, and better-integrating happiness into work, life, travel, and leisure and entertainment services, a livable city with the integrated development of industry, city, and people will be achieved.

At the industrial park level, attention should be paid to the coordinated allocation of land for public service facilities. The investigation and analysis show that the shortages of commercial land, educational facilities land, and public open space are the main restricting factors for the city–industry integrated development in Kangqiao industrial park. Excellent public open space can improve residents' psychological or spiritual well-being. Strong social networks are associated not only with residents' trust and life satisfaction but also with their sense of belonging. In future planning, the scale of these three types of land needs to be appropriately increased, but the construction of high-end villas should be controlled. Of course, to give full play to the utility of supporting facilities, mixed land use should be rationally planned. The increase in single-use land makes it difficult to increase the degree of the regional city–industry integration. Only by coordinating the allocation of various supporting facilities can the degree of the regional city–industry integrated development be effectively improved.

In addition, to deepen the city–industry integrated development, more attention should be paid to social integration. Social integration is not only an integral part of the city–industry integrated development but also an inevitable requirement for the construction of a happy city. Cities are aggregates of different races and social classes. Integrating family integration, ethnic integration, social class integration, and community integration into the city–industry integrated development is conducive to promoting the integrated development of residential communities, industrial parks, public activity areas, and urban areas.

It is worth noting that Marne Lavalle, a suburban new town in Paris, France, is the most successful of the five new towns in Paris. In its planning and construction process, in addition to fully considering the integration of housing, employment, and service functions, it also benefits from the healthy development of Discat Science City and Disneyland. Kangqiao town is now a part of Zhangjiang Science City and is adjacent to Shanghai Disneyland, which brings new opportunities to the Kangqiao industrial park. The Kangqiao industrial park can learn from the experience of Marne Lavalle so as to better exploit this special development opportunity, strengthen its ties with Zhangjiang Science City and Shanghai Disneyland, further improve the level of the city–industry integrated development, and promote the transformation of the Kangqiao industrial park into a new science and technology city.

5. Conclusions

This study constructs the C-PIT model to form an evaluation system at two spatial scales to analyze the integrated city–industry development. Combining the coupling coordination degree and the entropy method, Shanghai and the Kangqiao Industrial Park are used as examples to evaluate their long-time series city–industry integration development.

The main conclusions of this paper are as follows: (1) at the city scale, the degree of city–industry integration in Shanghai had an upward trend over the last 20 years, with volatile changes. (2) At the scale of the industrial park, functional, social, and spatial integration show an increase. The contributions of city development change were ranked high to low as follows: functional integration, spatial integration, and social integration. (3) Multi-source geospatial data improve data availability for the research in this field. The multi-source data fusion fixes the lack or abnormalities of data in traditional research, which enriches the evaluation perspective.

More empirical studies are required to explore the practicability of this theoretical system and methodology in different types of cities and industrial parks.

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