Distribution Characteristics and Spatial Reciprocity Between an Industrial Park and Vocational Education Park in a City Center

Qiushi Hao*, Benchen Fu and Liying Wang

1 Ph.D., Department of Architecture, Harbin Institute of Technology, China
2 Professor, Department of Architecture, Harbin Institute of Technology, China
3 Professor, Department of Architecture, Changchun Institute of Technology, China

Abstract
This study aims to explore the spatial distribution characteristics and spatial reciprocity between industrial parks (IPs) and vocational education parks (VEPs): agglomeration density, functional matching, spatial organization efficiency, as well as space intensive utility. To achieve this objective, IPs and VEPs in urban centers of Jiangsu Province are selected as the objects of the study. First, spatial analysis of thermodynamic diagrams is employed in this study to qualitatively analyze the evolutionary characteristics of the spatial distribution of IPs and VEPs to explore the spatial aggregation characteristics of their clustering, integration, and comprehensive crossover. Second, a horizontal comparison of the data and indexes concerned reveals that areas with high agglomeration and functional matching exhibit a sound spatial reciprocity. Third, this study crystallizes the four structural prototype paradigms formed during the reciprocity evolution between IPs and VEPs; it compares spatial organization efficiency with the agglomeration–core structure ranking first, followed by the circle–core structure. Finally, SPSS is used to analyze the space intensive utility to verify the results of qualitative analysis. The findings can comprehensively explain the regularities of the spatial distribution and reciprocity between IPs and VEPs. The findings can also elucidate the design of regional industrial development and educational programs.

Keywords: industrial parks (IPs); vocational education parks (VEPs); distribution characteristics; space reciprocity

1. Introduction

1.1 Background
The development of vocational education parks (VEPs) in China is constantly increasing. By May 2015, the number of colleges in China reached 2845, among which 1334 are higher vocational schools, comprising 46.9% of the total. More than 80% of large- and medium-sized enterprises are estimated to participate in vocational education by 2020 (Ministry of Education, 2014). The professional features and pedagogical methods of vocational education determine its inseparable relationship with industrial development. Therefore, a major goal in recent China is to optimize the resources of industrial parks (IPs) and vocational education parks (VEPs) to obtain mutual benefits and induce progress by integrating their functions and spatial systems (Hao et al., 2017). As a key notion, reciprocity highlights the holistic or multiplier effect resulting from the cooperation and interaction of various spatial factors in the system, which is exhibited by the quantity of functional aggregation, as well as the organizational efficiency of the whole space and cost constraint for coordinating its various parts — that is, agglomeration density, functional matching, spatial organization efficiency, and space intensive utility (Kang, 2012).

1.2 Literature Review
In the past decade, the issue of reciprocity between industries and colleges was a highly debated topic in economics and education research. First, in terms of the spatial distribution and agglomeration density of IPs and VEPs, the result shows that enterprises adjacent to a university town accumulate profit with relative ease (Liang, 2009). Meanwhile, technology-intensive enterprises gain large profits from the university community and exert a far-reaching impact on the regional economic development in cities (Felsenstein, 1996). Studies on the internal function allocation of VEPs have been conducted by several researchers in urban planning and architecture; by contrast, the external connection

*Contact Author: Qiushi Hao, Ph.D., Department of Architecture, Harbin Institute of Technology, No. 73, Huanghe Road, Nangang District, Harbin, Heilongjiang Province, 150000, China Tel: +8618345159503 Fax: +0451-86289323 E-mail: haoqiushi@hit.edu.cn
(Received April 4, 2017; accepted March 6, 2018)
DOI http://doi.org/10.3130/jaabe.17.321
with regional industry organizations has rarely been investigated. (Zhang et al., 2010) — that is, whether an interactional relationship exists between industries and schools in terms of spatial distribution. In addition, issues concerning the relationship between their respective spatial patterns, configuration evolution, and consequent development trends, among others, are rarely studied and insufficiently supported by theoretical evidence.

Second, with regard to the functional match between the industry and education — that is, the study of the match between the industry and related disciplines in VEPs and how to make them function effectively is key to the spatial reciprocity problem (Dewancker et al., 2002). Previous studies are more often than not based on solving the educational problems in vocational educational models with stakeholder participation (Liu, 2012). These findings cannot sufficiently verify the effective interaction between IPs and VEPs in one area, owing to the lack of verification concerning pertinence and rationality.

Third, studies in spatial organization efficiency have been conducted. Reports have indicated that in the evolution of urban spatial configuration, monocentric cities tend to form a spatial configuration with high density and tight clusters (Parr, 2004). Among the related studies in China, the pole-axis proposed by Dalu Dao is the most effective regional development paradigm in Chinese social economic organization (Lu, 2001). Therefore, studies on spatial organization efficiency can be effectively reduced by exploring the spatial distribution characteristics and generalizing the agglomeration density of prototypical spatial structure paradigms; it can also shed light on our study. Whether a rule underlies the various configurations of the IPs and VEPs distribution and whether any mutual structure prototypes exist between them needs to be determined. How can spatial distribution and spatial agglomeration achieve a profitable effect, and how can their interaction improve space intensive utility? These issues await further study.

1.3 Purpose

The methods employed in most of the aforementioned studies focus on the qualitative aspect of proposing a set of methodology systems (Kim and Ha, 2015, Wen, 2015). In response to such limitations, Lu et al. employed SPSS, a canonical correlation analysis in multivariate statistics to examine the interaction between industry agglomeration and urbanization. For the first time, quantitative analysis is conducted to improve the significant interaction or relationship between industry agglomeration and urbanization by analyzing the typical variables between them (al, 2011). Simultaneously, after suitable exploration, treatment, and spatial analysis of thermodynamic diagrams, a method for urban space study based on space use intensity can be used to provide a more dynamic perspective and method for urban space study. In the present study, quantitative verification combined with qualitative evidence by spatial analysis of thermodynamic diagrams and correlation analysis in SPSS are adopted to overcome the limitation in the previous study. Efforts are directed toward the following aspects: 1) Qualitative study in spatial distribution and form evolution of IPs and VEPs to analyze the agglomeration density; 2) Matching between industry types and programs provided in the local VEPs; 3) Characterization of the common features of various structures categorizing four spatial prototypes and spatial organization efficiency analysis; 4) Verification of the space intensive utility of the four spatial prototypes with quantitative analysis.

2. Methodology

2.1 Research Subjects

In this study, typical case studies are conducted in Jiangsu Province. The reasons are as follows: (i) Jiangsu Province, one of the industry-intensive areas, ranks first with its vocational colleges (6% of the total, which is 1334); (2) Jiangsu consists of a large number of small- and medium-sized enterprise clusters, and VEPs under the dominance of industry clusters grow well; and (3) Suzhou, Wuxi, Najing, and Changzhou are the top four typical cities proud of their advanced vocational education. Therefore, IPs and VEPs in 27 urban central districts in the four cities are chosen as samples. The following reasons support our sampling: (1) Four city centers are chosen in this study without taking other areas into consideration; (2) The IPs chosen are similar in radiation scope, are on a certain scale and can serve as representatives; and (3) All VEPs chosen are similar in orientation and on a certain scale (more than 5000 pupils). This method increases the analytical accuracy and potential because some park samples double or triple in number with the college rebuilding.

2.2 Sampling, Data Collection, and Analysis

All data come from educational institutes, municipal departments, land planning agencies, and other related sectors in pursuit of rigor and precision in this study.

1. With 652 geographical coordinates, urban spatial configuration in thermodynamic diagram analysis is employed to generalize the spatial evolution rules and phase distribution characteristics in central districts at different times, as well as to analyze the space agglomeration density.

2. After the data collection and categorization, functional matching between IPs and VEPs in the same area is analyzed.

3. By field investigation, together with vector map data, cooperative collection study, and other methods, spatial configuration prototype paradigms are generalized, and spatial organization efficiencies are compared horizontally.

4. Correlation analysis is conducted in SPSS to verify the organizational efficiency of the spatial structure prototype paradigm of IPs and VEPs, as well as space intensive utility.
3. Results and Analysis
3.1 Spatial Distribution Rules and Agglomeration Density Analysis of IPs and VEPs

In this study, spatial analysis of thermodynamic diagrams is employed. Spatial distribution samples of IPs and VEPs during three periods (1960–1980, 1980–2000, 2000–2016) are selected in Suzhou, Wuxi, Nanjing, and Changzhou (construction of VEPs started in 1960). The spatial agglomeration density of the geographical coordinates of IPs are indexed with special high brightness, and the geographic coordinate distribution in the VEPs are indexed with red spots. Software is used for coupling analysis, with different intensities of color indicating the agglomeration density. The deeper the color, the higher the agglomeration density (Table 1.).

As seen in the distribution map, in the past 56 years, IPs and VEPs in Suzhou City have simultaneously expanded eastward from Wuzhong District toward Eastern Suzhou IPs and then agglomerated in the central districts of Gusu and Huqiu. Meanwhile, IPs and VEPs drew nearer geographically, exhibiting fragment distribution.

In Wuxi, the development of IPs generally underwent three stages: expansion along the riverside, homogenous clustering expansion, and layer-circle spreading. From 1960 to 1980, IPs were distributed homogeneously in the inner city, with clustered buildings of similar scales, whereas VEPs were mainly distributed on the riverside. From 1981 to 2000, IPs were spread homogenously in an open style, with multicenters and VEPs developed at a slow pace. In the decade that followed (2001–2010), Wuxi witnessed large-scale development and construction, and the building groups mainly consisted of large industrial buildings, spread in Hushan District and Binhu District. VEPs developed rapidly year after year, forming fragment clustering with IPs. Notably, these areas fall well within the peak point range of urban development intensity analysis.

In Nanjing, from the 1980s, the trajectory of building key IPs formed a ring-like shape, meanwhile the development emphasis of VEPs moved from a sporadic distribution toward the IP areas. On the whole, during the mid-1980s to 2000, IPs expanded in patterns of concentric circles from Xuanwu District to Jianye and Qixia Districts; fragmental expansion occurred merely in the northeastern areas. VEPs developed slowly, without close correlation with the expansion of IPs. Immediately after 2000, both underwent a rapid development, and the built-up area increased by more than 40 km$^2$ annually. VEPs are adjacent to IPs, particularly in Jiangning District, Qixia District, and Jianye District, thus featuring a planar distribution. In 56 years, the expansion orientations in the three stages were quite uneven, however, a marked trend in agglomeration was observed in the geographic distribution between IPs and VEPs.

From 1960 to 1980, IPs in Changzhou were generally scattered in an east–west belt, slightly connected to VEPs. After 1990, IPs clustered in the city centered areas and evolved in the form of ring and radiation type to proceed with urban structure development. VEPs were mainly centered in Wujin District in southern Changzhou; in 2010, they moved northward to Xinbei District. The spatial configuration of the two reflected disperse clustering.

---

Table 1. Spatial Distribution Rules between Industrial Parks and Vocational Education Parks

| City    | Spatial Distribution Rules                               | Example |
|---------|----------------------------------------------------------|---------|
| Suzhou  | Agglomerated in the central districts of Gusu and Huqiu  | ![Suzhou](image) |
| Wuxi    | VEPs forming fragment clustering with IPs                 | ![Wuxi](image) |
| Nanjing | Northeast–southeast–southwest evolution process           | ![Nanjing](image) |
| Changzhou | The spatial configuration of the VEPs and IPs reflected disperse clustering | ![Changzhou](image) |

---

As seen in the distribution map, in the past 56 years, IPs and VEPs in Suzhou City have simultaneously expanded eastward from Wuzhong District toward Eastern Suzhou IPs and then agglomerated in the central districts of Gusu and Huqiu. Meanwhile, IPs and VEPs drew nearer geographically, exhibiting fragment distribution.

In Wuxi, the development of IPs generally underwent three stages: expansion along the riverside, homogenous clustering expansion, and layer-circle spreading. From 1960 to 1980, IPs were distributed homogeneously in the inner city, with clustered buildings of similar scales, whereas VEPs were mainly distributed on the riverside. From 1981 to 2000, IPs were spread homogenously in an open style, with multicenters and VEPs developed at a slow pace. In the decade that followed (2001–2010), Wuxi witnessed large-scale development and construction, and the building groups mainly consisted of large industrial buildings, spread in Hushan District and Binhu District. VEPs developed rapidly year after year, forming fragment clustering with IPs. Notably, these areas fall well within the peak point range of urban development intensity analysis.

In Nanjing, from the 1980s, the trajectory of building key IPs formed a ring-like shape, meanwhile the development emphasis of VEPs moved from a sporadic distribution toward the IP areas. On the whole, during the mid-1980s to 2000, IPs expanded in patterns of concentric circles from Xuanwu District to Jianye and Qixia Districts; fragmental expansion occurred merely in the northeastern areas. VEPs developed slowly, without close correlation with the expansion of IPs. Immediately after 2000, both underwent a rapid development, and the built-up area increased by more than 40 km$^2$ annually. VEPs are adjacent to IPs, particularly in Jiangning District, Qixia District, and Jianye District, thus featuring a planar distribution. In 56 years, the expansion orientations in the three stages were quite uneven, however, a marked trend in agglomeration was observed in the geographic distribution between IPs and VEPs.

From 1960 to 1980, IPs in Changzhou were generally scattered in an east–west belt, slightly connected to VEPs. After 1990, IPs clustered in the city centered areas and evolved in the form of ring and radiation type to proceed with urban structure development. VEPs were mainly centered in Wujin District in southern Changzhou; in 2010, they moved northward to Xinbei District. The spatial configuration of the two reflected disperse clustering.
The spatial distribution and the evolutionary trajectory of IPs and VEPs in the four cities indicate that their distributional orientation and layer–circle distribution are consistent to a certain extent; the two types of land use manifest a medium spatial configuration in terms of a patch structure relationship and adhesive strength. From the perspective of urban scale, the distributional orientation of IPs and VEPs underwent a separation–merging–integration process, and the agglomeration moved from the spotted, cloddy type through planar to networked spatial distribution. Therefore, geographical adjacency — that is, high density of spatial agglomeration — is the primary condition for spatial reciprocity of IPs and VEPs (Table 2).

### Table 2. Evolution of IPs and VEPs Spatial Distribution

| Development | Separation | Indifference | Merging | Integration |
|-------------|------------|--------------|---------|-------------|
| Process     | Partial Connection | Loose Interaction | Increasing Connection with Radiation Effects | Regional Integration |
| Function Structure | IPS & VEPs | Comprehensive IPs Dominated by Industry | Compound IP/VEP | New Urban Districts |

3.2 Functional Matching Between IPs and VEPs

In this section, functional matching is explored in areas with high spatial agglomeration by comparing horizontally the matching between industry types and programs provided in the local VEPs — that is, the ratio of programs offered by vocational colleges matching the regional industry development. Among the 18 VEPs in Suzhou, Huqiu District ranks first in functional matching (80%), followed by Gusu District (75%), Suzhou IP (66%), and Wuzhong District (40%). The reason is that Huqiu District, as a central district, is the seat of industries, Suzhou IP located in the eastern Suzhou urban area ranks second in terms of functional matching.

This fact verifies the general picture of the spatial distribution and evolution of IPs and VEPs in Suzhou: moving forward from west to east. The overall spatial agglomeration density in Suzhou is positively correlated with its functional matching.

In Wuxi City, the two areas with high functional matching are Huishan District and Binhu District (55% and 50%, respectively); this finding is consistent with the results of the aforementioned spatial agglomeration analysis (Fig.2.).

Among the 30 VEP samples in Nanjing, 5 are located in Qixia District, 12 in Jiangning District (both have a functional matching rate of 75%), 2 in Gulou District, and 2 in Wuxi District.

---

**Fig.1.** The Functional Matching in Suzhou
District, 1 in Jianye District, and 2 in Luhe District; their functional matching rate is 50% (Fig.3.). The small number of VEPs with relatively high functional matching rates in Gulou, Jianye, and Luhe districts indicates the higher matching efficiency rate between IPs and VEPs than that in Qixia and Jiangning districts. In Lishui District, no corresponding matching relationship is determined, and IPs and VEPs are dispersed.

In Wujin District Changzhou City, all of the 6 VEPs are densely clustered in the same area. The functional matching rate is 63%, with IPs adjacent to VEPs. These results are highly consistent with the previous findings: high spatial agglomeration corresponds to good functional matching, and vice versa (Fig.4.)

Therefore, the study shows that functional matching values are high in Suzhou Outang VEP, Xianlin VEP in Qixia District, Nanjing City, VEPs in Wujin District, Changzhou City.

The fieldwork survey suggests great success in their actual industry–college unification. The reasons are as follows: a high reciprocity mechanism is formed between IPs and VEPs, adjacent or integral with each other. This observation suggests that through geographical accessibility and business contact between industries and colleges, efficient division and cooperation are exhibited between various professional enterprises and disciplines, thereby benefiting innovation, technical progress, and knowledge transmission. In this manner, a complex interdependent network is formed to increase their competitiveness (Sohn, Kim, Lee, & Kim, 2010).

### 3.3 Spatial Organization Efficiency Analysis of IPs and VEPs

The spatial distribution and evolution characteristics of IPs and VEPs pose challenges to the study of spatial organization efficiency, hence the difficulty in spatial reciprocity analysis via common features. This study determines the common structural prototypes

**Table 3. Spatial Organization Efficiency Analysis**

| Category          | Spatial Structural Prototype Patterns | Example                                      |
|-------------------|--------------------------------------|----------------------------------------------|
| Monocentric Structure | ![Monocentric Structure](image)        | Jiangning District, Nanjing                  |
|                   | ![Monocentric Structure](image)        | Qinhuai District, Nanjing                    |
|                   | ![Monocentric Structure](image)        | Binhu, Wuxi                                  |
| Axis-core Structure | ![Axis-core Structure](image)          | Gulou District, Nanjing                      |
|                   | ![Axis-core Structure](image)          | Huishan District, Wuxi                       |
| Circle-core Structure | ![Circle-core Structure](image)        | Jianye District, Nanjing                     |
|                   | ![Circle-core Structure](image)        | Qixia District, Nanjing                      |
|                   | ![Circle-core Structure](image)        | Liuhe District, Nanjing                      |
| Agglomeration-core Structure | ![Agglomeration-core Structure](image) | Wuzhong District, Suzhou                     |
|                   | ![Agglomeration-core Structure](image) | Wujin District, Changzhou                    |
underlying the phenomenon to significantly simplify the analysis of spatial organization efficiency.

As shown in the figure, four spatial structural prototype patterns are proposed after analyzing the spatial evolution and spatial configurations of the 565 IPs and 57 VEPs in Jiangsu Province, namely, monocentric structure, axis–core structure, circle–core structure, and agglomeration structure. IPs and VEPs in Jiangning District, Qinhua District in Nanjing City, and Binhu District in Wuxi are correspondingly located in the same section. The agglomeration density decreases gradually from the central area to the periphery — referred to as the monocentric structure — an initial stage and a necessary basis for a more complex structure (Table 3.).

When industry–college aggregation reaches the stage with increasing dispersion — e.g., VEPs in Gulou District, Nanjing City as well as VEPs in Huishan District and Wuxi City, as the core, VEPs are connected to the IPs on both sides, forming an axis–core structure.

Industrial aggregation and connection continues with increasing dispersion, and similar types of industry accrue in number. These IPs match and aggregate with VEPs of the same type and distribute around, which enables sharing of the short-distance resources, thus achieving good spatial organizational efficiency. As shown in the figure, the circle–core structure is well exhibited in the IP–VEP structure of Jianye District, Qixia District, Luhe District in Nanjing, and Huqu District in Suzhou.

The agglomeration–core structure, which is huge in scale and highly efficient in the spatial organization rate, is the ideal stage of spatial structure. A strong cohesion exists between IPs and VEPs. As a whole, they form a cubic networked configuration with multi-clusters, connected with each other as a patch to optimize sharing of training and production, thereby interweaving the urban space with the service system. VEPs in Changzhou and the Outang District of Suzhou City also well represent this structure, where factories are introduced into VEPs, integrating communities, IPs, and VEPs to optimize social and economic benefits.

The qualitative analysis above shows that spatial structure prototypes with high organizational efficiency are favorable for the formation and development of spatial reciprocity. Among the four types of structural prototype diagrams, the agglomeration–core structure exhibits the highest spatial organization efficiency, followed by the circle–core structure, the axis–core structure, and the monocentric structure.

### 3.4 Space Intensive Utility of IPs and VEPs

This study indicates that three conditions shall be met to serve as an industry–college space with sound reciprocity: high spatial agglomeration, high functional matching, and efficient inner spatial organization. Space intensive utility is the most important evaluation index, and the ultimate goal of reciprocity is to enhance the benefits.

First, the total profit of the construction investment of a per-land IP and VEP (referred to as the output benefit per area; that is, it is the ratio of the difference of total annual profit produced by the cooperation of industry and school and the total investment cost of construction to total area) is selected as the measurement index of the quantitative expression of space intensive utility. The output benefit per area shows that the IP and VEP mutually coordinate and interact to save land and reduce the construction cost and economic investment. The output benefit per area is affected by the distance between the industrial and vocational space, frequency of use, allocation of space resources, and degree of economic agglomeration. This feature can be directly reflected by overlay analysis and quantitative expression of space elements. The factors that influence space intensive utility are identified by Pearson correlation analysis in SPSS. Finally, space intensive utility is comprehensively evaluated for several typical VEPs by obtaining the standard deviation of each index.

This article is cited from the calculation method of the intensive evaluation index system of urban construction land on the basis of the compilation perspective of urban and rural planning. Correlation assessment was conducted on the 13 indexes, including the total building area of the IP–VEP, total number of people, industrial and vocational space with co-construction, number of facilities, per capita building area, frequency of space utilization, and output benefit per area (Wang, 2012).

Results indicate that the correlation coefficient between the output benefit per area and the frequency of space use, the rate of space reconstruction in VEP, rate of space reconstruction in IP, and disposal rate of idle land is greater than 0.6. The level of significance is less than 0.01. It shows the significance correlation. The correlations are -0.746, 0.661, 0.561, 0.593, and 0.63, respectively (Table 4.).

Results indicate that the correlation coefficient between the output benefit per area and the frequency of space use, the rate of space reconstruction in VEP, rate of space reconstruction in IP, and disposal rate of idle land is greater than 0.6. The level of significance is less than 0.01. The correlations are -0.746, 0.661, 0.561, 0.593, and 0.63, respectively (Table 4.). This shows that the output benefit per area has a certain correlation with the aforementioned factors and passes the significance test, which exhibits a strong positive correlation. That is, with an improvement in the factors, the output benefit per area exhibits an increasing trend. Meanwhile, the output benefit per area exhibits a negative correlation with the distance between VEP and IP. This result shows that with decreasing investment and reduction of distance, the output benefit per area increases. However, the output benefit per area
exhibits a certain correlation with the space number of VEP and IP co-construction, area, per capita building area, and allocation ratio of training base, which fails to pass the significance test. The result shows that the degree of dependence of the output benefit per area on the factor is relatively weaker.

Table 4. Correlation Analysis

| Dependent variable | Factors | Pearson | SIG (P) |
|--------------------|---------|---------|---------|
| Output benefit per area | Investment profit by VEP and IP co-construction | -0.386 | 0.092 |
|                     | The space number of VEP and IP co-construction | 0.622* | 0.012 |
|                     | Building area of VEP and IP co-construction | 0.899* | 0.016 |
|                     | Construction area per capita of VEP and IP co-construction | 0.465* | 0.024 |
|                     | Allocation ratio of training base co-constructed by VEP and IP | 0.639* | 0.031 |
|                     | Distance between VEP and IP | -0.746** | 0.000 |
|                     | The frequency of space use (%) | 0.661** | 0.000 |
|                     | Rate of space reconstruction in the VEP (%) | 0.561** | 0.000 |
|                     | Rate of space reconstruction in the IP (%) | 0.593** | 0.002 |
|                     | Disposal rate of idle land (%) | 0.633** | 0.003 |
|                     | Population in the IPs and VEPs | -0.353 | 0.206 |
|                     | Area of the IPs and VEPs | 0.222 | 0.103 |

Notes—dependent variable: spatial organization efficiency; *p<0.05; **p<0.01

First, the weight of each influencing factor is determined. This measurement is conducted to score by the multiple assessments of experts. The weight of the index of space intensive utility is finally determined. Second, the evaluation index is standardized as follows: When \( L_i \) has a negative correlation, it is expressed as \( L_i = (a_i - x_i) / (a_i - b_i) \). When \( L_i \) has a positive correlation, it is expressed as \( L_i = (x_i - b_i) / (a_i - b_i) \).

Where \( L_i \) \((i=1, 2, 3, ..., n)\) is the standardization value of the evaluation index of the IP and VEP space intensive utility \( x_i \) \((i=1, 2, 3, ..., n)\) is the variable value of the evaluation index, \( a_i \) and \( b_i \) are the upper and lower limits of the indexes, respectively. Thus, the space intensive utility \( C \) is expressed in the equation \( C = \sum L_i W_i \).

The characteristic of the space intensive utility of four kinds of space structure prototypes is intuitively reflected in the calculation. That is, a larger standard deviation indicates that the space intensive utility of a research object is superior. The assessment values are 0.78 for Changzhou, 0.51 for Suzhou, 0.45 for Wuxi, and 0.42 for Nanjing (Table 5.).

The aforementioned qualitative analysis can be verified from the values. That is, the polar nucleus has the highest space mutual feedback ability, followed by the circular nucleus. Second, the space intensive utility reflects efficiency of land utilization, potential, and development ability. For example, the Changzhou and Suzhou VEPs exhibit high efficiency of space utilization, whereas the Wuxi and Nanjing VEPs show low efficiency of space utilization. However, it has a greater development potential. The reason is that the area of the VEP is greatly increased by rapid construction. In addition, the increase in the amplitude of college enrollment has slowed down and showed a declining trend in recent years. Consequently, the relevant indexes are decreased. These changes lead to an improvement in the frequency of use by the

Table 5. Standard Deviation Analysis

| Case       | Nanjing VEP | Wuxi VEP | Suzhou VEP | Changzhou VEP | W_i |
|------------|-------------|----------|------------|---------------|-----|
| Space structure prototype | Circle-core | Circle-core | Agglomeration-core | Agglomeration-core | -   |
| Output benefit per area | 7 | 6 | 10 | 8 | 0.2 |
| Distance between VEP and IP | 8.3 | 8.8 | 2.5 | 2 | 0.21 |
| The frequency of space use (%) | 27.13 | 23.9 | 18.2 | 30.77 | 0.15 |
| Rate of space reconstruction in the VEP (%) | 21.8 | 18.8 | 14.2 | 24.1 | 0.11 |
| Rate of space reconstruction in the IP (%) | 30.8 | 25.8 | 10.6 | 22.5 | 0.17 |
| Disposal rate of idle land (%) | 0.02 | 0.07 | 0.05 | 0.06 | 0.16 |
| Standard deviation | 0.42 | 0.45 | 0.51 | 0.78 | - |

3.4.1 Typical VEPs Evaluation by Space Intensive Utility Measurement

This evaluation selects the spatial agglomeration density for four cities, which have a typical space structure prototype and the space intensive utility measurement is conducted between it and the mutual feedback space of the IP.

reconstruction utilization of the space in the VEP or IP. To achieve the economy and intensification utilization of the industrial and vocational space, the following are promoted: reconstruction of IPs and VEPs is guided, the reconstruction of original low-density buildings, and the combination of the tapping of synergistic potential and appropriate expansion of extension.
4. Conclusion and Discussion

Conclusions can be drawn based on the findings of this study.

(1) In terms of urban spatial development, spatial distribution and evolution of IPs and VEPs move in a more aggregate and comprehensively interwoven manner, exhibiting a reciprocal trend. IPs are built on industry agglomeration theory, thus attracting talents in various fields and the flow of goods, where the labor force can be ensured both in quantity and quality. VEPs tend to aggregate with IPs, which is essentially the reason for the spatial agglomeration pattern of the two.

(2) Spatial reciprocity can be improved by raising the functional matching of areas with high agglomeration. Industrial structure will affect the scale, level, and disciplinary structure of vocational education, guiding its direction of development. This guidance is expected to upgrade, adjust, and optimize the industrial structure.

(3) Four spatial structure prototype diagrams are proposed: monocentric structure, axis–core structure, circle–core structure, and agglomeration–core structure, with ascending spatial organization efficiency.

(4) The space intensive utility is affected by different elements, such as the frequency of space use, space reconstruction rate of the VEP, industrial and vocational distance, etc. It also has the tendency of preference element from the aspect of industrial and vocational space reconstruction. That is, the existing space is reconstructed by alteration to improve the frequency of space use, fulfilling the purpose of functional agglomeration and space intensification. Simultaneously, the proportion of industrial and vocational co-construction is enhanced. The unidirectional investment cost is reduced. The division requirement of industrial and vocational high-efficiency is satisfied. Therefore, it is necessary to control special stock regulation from increment. The variable use of the existing space is actively guided and shared, which is significant for mutual feedback utilization and layout of industrial and vocational space under the guidance of various functions in the future.

(5) Industrial and vocational space with excellent space mutual feedback need to satisfy four conditions: high agglomeration of space, matching functional type, high-efficiency organization of overall space, and space intensive utility. Their synergistic effect should be fully used to rationally allocate their functions, reduce low-efficient allocation or ineffective supply, improve accessibility, and obtain reasonable estimates based on market demand and development trend.

The 2016 statistical report of education is used for the evaluation in this study. By the time the study is submitted, many changes in education will have occurred. The result does not represent the current situation of land utilization in each place. However, the index data can be updated to form a dynamic evaluation, providing the basis for mutual feedback between industrial space and vocational space and the allocation of rational resources.

Acknowledgment

This study was funded by the National Natural Science Foundation of China (Grant No. 51578174).

References

1) EDUCATION, M. O. (2014) Construction planning of modern vocational education system (years 2014-2020). Vocational and technical education, 18, pp.50-59.
2) HAO, Q., FU, B. & FEI, T. (2017) A study of space syntax and sustainable design in Chinese vocational education parks: three case studies. Mediterranean Green Buildings & Renewable Energy. Springer.
3) KANG, H. (2012) The reciprocity between urban infrastructure and space evolution in Harbin: Harbin Institute of Technology.
4) LIANG, H. (2009) The study on synergetics development and design of Guangdong vocational and technical college. Guangzhou: South China University of Technology Press.
5) FELENSTEIN, D. (1996) High technology firms and metropolitan locational choice in Israel; a look at the determinants. Geografiska Annaler. Series B. Human Geography, pp.43-58.
6) ZHANG, H., Uwasu, M., HARA, K. & YABAR, H. (2010) Land use change patterns and sustainable urban development in China. Journal of Asian Architecture and Building Engineering, 9, pp.131-138.
7) DEWANCKER, B., FUKUDA, H. & OJIMA, T. (2002) A study on the land use change in Kurokasi and proposal of an urban biotope network. Journal of Asian Architecture and Building Engineering, 1, 2, 123-129.
8) LIU, X. (2012) Research on higher vocational school-running model reform: from the perspectives of stakeholder theory East China Normal University, pp.39-43.
9) PARR, J. (2004) The polycentric urban region: a closer inspection. Regional studies, 38, pp.231-240.
10) LU, D. (2001) An analysis of spatial structure and optimal regional development. ACTA Geographica Sinica, pp.127-135.
11) KIM, J. & HA, M. (2015) A study of the environmental elements affecting campus images. Journal of Asian Architecture and Building Engineering, 14, pp.1-8.
12) WEN, D. X. C. (2015) Research on the space structure performance of Shenyang city center and its optimization methods. URBANISM AND ARCHITECTURE, 22, 023.
13) AL, G. L. E. (2011) Research on relevance between industrial cluster and urbanization based on canonical analysis. China soft science, pp.101-109.
14) Sohn, S.-H., Kim, T.-H., Lee, J.-S., & Kim, H.-K. (2010). Spatial analysis of urban structure changes in Korean mega-cities. Journal of Asian Architecture and Building Engineering, 9(1), pp.201-206.
15) WANG, Z. T. X. (2012) A research on the evaluation of urban development land-use intensity- a views from planning and management. Urban Planning Forum, 4, 015.