

## Research Article

# Evolution and Influencing Factors of Township Spatial Form: A Two-Dimensional Perspective

Yanpeng Gao and Wenjun Chen 

*Jiangho School of Architecture, Northeastern University, Shenyang 110169, China*

Correspondence should be addressed to Wenjun Chen; 1901411@stu.neu.edu.cn

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The countryside is the habitat of food, ecology, and culture, and the indispensable basis for human survival and development. Assessing the spatial and temporal evolution of rural settlements contributes to the promotion of rural scientific developments. This study used the fractal theory, center-of-gravity model, and spatial syntax to analyze the spatial and temporal evolution of Shenyang Ciyutuo Subdistrict and its influencing factors based on geospatial data from 2009–2019, from the perspectives of internal characteristics and external morphological changes. In terms of the external characteristics, from 2009–2019, the compactness index increased from 0.414 to 0.454, the expansion rate increased from 1.17% to 3.11%, and the expansion intensity increased from 0.05% to 0.15%. From 2014–2019, the western part of the subdistrict experienced the maximum expansion rate and expansion intensity. The center-of-gravity of the construction land shifted to the west and southwest. The internal characteristics of land use depended on geographical conditions. Clusters of rural settlements were formed in a north-south direction due to the topography and along the riverside in a band-like manner. From 2009–2019, the integration level of the subdistrict improved and the scale and number of integration axis increased, forming a multicore tree-shaped structure. Pearson's correlation analysis showed that urbanization is the main factor affecting the spatial and temporal land-use evolution, with transportation convenience, industrial park, and proximity to the river having little effects. This study provides a theoretical basis for the development of Ciyutuo Subdistrict and provides a reference for the development of similar commercial towns.

## 1. Introduction

Evolution of the form of rural settlements is a process in which the land layout and spatial structure undergo spontaneous or unavoidable changes to adapt to social and economic needs, driven by different influencing factors. The development of rural spatial form plays a key role in the revival of rural settlements and the integration of urban and rural areas. Interdisciplinary research on rural morphology evolution involves geography, ecology, sociology, and urban planning. The research contents are extensive, and the research methods are diverse.

Previous studies have focused on changes in the physical form and social space of rural settlements. Morphological evolution of rural settlements can be analyzed from two perspectives, i.e., the external form and the internal structure. Evolution of the external form of rural settlements is predominantly in two forms: land use [1–8] and landscape

patterns [9–12]. Due to rapid urbanization, rural areas have already undergone land-use conversion to improve the efficiency of land use. The basic uses of land have changed from agricultural to urban and rural construction purposes [3], and urban and rural construction land have continued to expand. Moreover, the land-use structures [6–8] and spatial patterns of rural settlements [4, 5] have been continuously optimized. Simultaneously, the expansion of construction land increases the heterogeneity and fragmentation of the entire landscape pattern [9–12]. The number and area of rural settlement patches are increasing, and patches of cultivated land, forest land, and other ecological land are shrinking and fragmenting. The ecological patterns in rural areas have been destroyed. The evolution of the internal structural characteristics of rural settlements is predominantly affected by changes in the geographical environment and road network. The geographical environment affects the evolution of the spatial form of villages. Presently, most of

the research in this area is concentrated in areas with unique landforms, such as Jiangxi [13], Shanxi [6], Guizhou [7], and Guangdong [14]. However, there is insufficient research on the northern plains of China. At the same time, rural settlements usually develop along transportation lines and expand radially. Accessibility to the road network plays a key role in driving the changes of rural spatial patterns [15, 16]. Road-based accessibility to central cities and towns of different ranks has different effects on the distributions of rural settlements. Road accessibility to townships has the greatest impact on the spatial distributions of rural settlements, whereas access to prefecture-level cities has a smaller influence on the distribution of rural settlements.

The research methods for land use in rural settlements are becoming increasingly diverse. These methods include the typing theory [17], the spatial autocorrelation and spatial variability map measurement model [18], GIS-based comprehensive analysis [19, 20], fractal theory and land use and land cover (LULC), and the cellular automaton artificial neural network (CA-ANN) model [21–24]. The research method has been greatly developed, which is conducive to a more comprehensive understanding of the spatial and temporal evolution of land use in rural settlements.

There exists close relationship between the internal and external factors of rural spatial morphology. Transportation networks and natural conditions affect the distribution of land use. Similarly, land-use changes can lead to improvements in transportation systems and better adaptations to the natural environment [25]. Although the spatial patterns of rural settlements have been analyzed from different angles, previous studies have provided unilateral perspective on the rural development model, rarely analyzing it using the two dimensions of external form and internal structure. The purpose of this study was to examine the spatiotemporal patterns of rural settlements and their corresponding influencing factors from the aforementioned two-dimensional perspective. Several research methods such as fractal theory, the gravitational model, and spatial syntax were used on cities and towns to characterize the spatial and temporal evolution of rural settlements from both internal and external perspectives. The results of this study provide a theoretical basis for the development in Ciyutuo Subdistrict for promoting economic development, strengthening regional connectivity, and supporting urban-rural integration, as well as to provide a reference for the development of similar commercial towns.

## 2. Research Data and Methods

**2.1. Study Area.** Ciyutuo Subdistrict (41°28′30″–41°35′00″N, 122°48′45″–122°58′54″E) is located in the southeast of Liaozhong District of Shenyang City (Figure 1). It is bordered by Sifangtai Town to the north, Changtan Town to the northeast, Wuxing Town of Dengta City to the southeast, Xiaozhaimen Town to the south, and Panjiabao Town to the northwest. The subdistrict stretches 12.8 km from north to south and 13.7 km from east to west, with a total area of 103.9 km<sup>2</sup>. Ciyutuo was transformed into a town in 1984, and Shenyang Municipal Government revoked the

Ciyutuo Subdistrict and established the Ciyutuo Subdistrict Office in 2017.

**2.2. Data Sources and Processing.** The data used in this study mainly included geospatial data and township statistical data (Table 1).

After manual vectorization in ArcGIS, satellite data were combined with existing geospatial and administrative data of Ciyutuo Subdistrict to produce the land-use maps from 2009–2019. Subsequently, the computational geometry function in ArcMap was used to calculate the area of construction land in different periods as well as the compactness index, expansion rate, and expansion intensity of land use in the study area. In addition, Depthmap software was used to analyze the spatial topology of the road network in 2009, 2014, and 2019.

After identifying the factors influencing land-use changes, the Pearson correlation analysis was conducted on the comprehensive dynamic degree of changes in the construction land area using SPSS 24.0. Pearson correlation coefficients and the significance levels between different influencing factors and comprehensive dynamic degrees in different regions were determined.

## 2.3. Research Method

### 2.3.1. Fractal Theory

- (1) The compactness index of BCI, which was first proposed by Batty [26], reflects the changes in the external outline of an urban built-up area and can be calculated as follows:

$$BCI = \frac{2\sqrt{\pi A}}{P}, \quad (1)$$

where BCI is the compactness index,  $A$  is the urban built-up area, and  $P$  is the perimeter of the built-up area. The BCI value ranges from 0 to 1; a larger BCI indicates that the built-up area is more compact and has a nearly circular shape (note that the BCI of a circle is 1) and a smaller BCI indicates a greater degree of dispersion.

- (2) The expansion rate index,  $M$ , and expansion intensity index,  $I$ , can be used to analyze the dynamic degree of land areas and land-use expansions, respectively, of towns and villages [27, 28]. The expansion rate and expansion intensity can be obtained as follows:

$$M = \frac{\Delta U_i}{\Delta t \times ULA} \times 100\%, \quad (2)$$

$$I = \frac{\Delta U_i}{\Delta t \times TLA} \times 100\%,$$

where  $\Delta U_i$  is the change in the built-up area of a town within a certain period,  $\Delta t$  is the time span, ULA is the built-up land area at the beginning of period, and TLA is the total land area in the study area.



FIGURE 1: Location of the study area.

TABLE 1: Summary of data and sources used in this study.

	Data	Data sources
Geospatial data	Satellite remote sensing data of Ciyutuo subdistrict	Satellite remote sensing data of Landsat5 (2005) and Landsat8 (2015) obtained through the NASA landsat
	Google earth satellite map	Google earth
	Vectorgraph of Ciyutuo subdistrict administrative division	Liaoning urban and rural construction planning and design institute co., ltd.
	Vectorgraph of administrative divisions of various towns	Liaoning urban and rural construction planning and design institute co., ltd.
Township statistics	Industrial economy, population structure, and urbanization data of Ciyutuo subdistrict from 2009 to 2019	Liaozhong district government work report 2009–2019, master plan of Ciyutuo subdistrict of Liaozhong district, Shenyang city (2018)

2.3.2. *Center-of-Gravity Model.* The physical concept of “center-of-gravity” was first introduced into the studies on population problems by F. Walker, an American scholar, in 1874. The center-of-gravity model calculates the spatial moving direction and geometric distance of the center-of-gravity of different indicators to show the spatial evolution of geographic units, thereby determining the evolution model of the spatial position of each element [29]:

$$X = \frac{\sum_{i=1}^n m_i x_i}{\sum_{i=1}^n m_i}, \quad (3)$$

$$Y = \frac{\sum_{i=1}^n m_i y_i}{\sum_{i=1}^n m_i}.$$

The moving direction of the center-of-gravity is calculated as follows:

$$\theta = \theta_{t+1} - \theta_t = \left[ \frac{k\pi}{2} + \arctan\left(\frac{\bar{y}_{t+1} - \bar{y}_t}{\bar{x}_{t+1} - \bar{x}_t}\right) \right] \times \frac{180^\circ}{\pi}, \quad (4)$$

where  $k = 0, 1, \text{ or } 2$ ;  $\theta \in (-180^\circ, 180^\circ)$ ; east is set at  $0^\circ$  and the counterclockwise rotation is positive.  $\theta$  indicates the

moving direction of the center-of-gravity from year  $t$  to year  $t + 1$ .

2.3.3. *Space Syntax.* In the 1970s, Bill Hillier of the Bartlett College, London University, proposed that integration, or closeness, can measure the sum of distances from spatial elements such as axes and pixels to all other spatial elements and can be expressed as the reciprocal of the total depth [30].

(1) Integration equation:

$$I_i = \frac{m[\log_2((m+2-1)/3) + 1]}{(m-1)|\bar{D}-1|}, \quad (5)$$

where  $I_i$  is the integration value,  $\bar{D}$  is the mean depth value, and  $m$  is the number of connections from a certain space to other spaces.

(2) Integration core: in the axial model, the axes with high integration capability dominating in the model space are called the global integration core, which represents the most central region [31]. It can be

used to express the evolution pattern of the internal morphology of a region and provide a reference for determining the direction of regional development.

**3.3.4. Correlation Analysis.** The Pearson correlation coefficient is a statistical measure of the dependency or correlation between random variables and provides information about the direction and degree of correlation of specific interdependent variables.

The Pearson correlation coefficient is calculated using equation (6) as follows:

$$\begin{aligned} \rho_{x,y} &= \frac{\text{cov}(X,Y)}{\sigma_x\sigma_y} = \frac{\sum((X-\mu_x)(Y-\mu_y))}{\sigma_x\sigma_y} \\ &= \frac{\sum(XY) - \sum(X)\sum(Y)}{\sqrt{\sum(X^2) - \sum^2(X)}\sqrt{\sum(Y^2) - \sum^2(Y)}}. \end{aligned} \quad (6)$$

### 3. Results and Discussion

#### 3.1. External Driving Factors: Evolution of External Morphology of Townships

**3.1.1. Scalability of Morphological Changes.** Based on the manual vectorization of Google Earth satellite images of Ciyutuo Subdistrict in 2009, 2014, and 2019 using ArcGIS, the construction land area was calculated for each year (Table 2). Analysis of the temporal changes in the area showed an overall increasing trend in the construction land area, whereas the growth rate of rural residential areas lagged behind that of urban areas.

(1) *Land-use Compactness Index.* From 2009–2019 (Table 3), the BCI of the construction land of Ciyutuo Subdistrict increased continuously, indicating that the compactness of the land-use form increased annually. The changes in compactness in the last five years of the study period were significantly faster than those in the first five years, thereby indicating the intensification of land use in the subdistrict in recent years.

(2) *Expansion Rate and Expansion Intensity.* From 2009–2014, the overall change in construction land was 127.27 ha; the expansion rate was 1.17%, and the expansion intensity was 0.05%. From 2014–2019, the total change in construction land was 133.66 ha; the expansion rate was 3.11%, and the expansion intensity was 0.15%.

From 2009–2019 (Table 4), the construction land area in Ciyutuo Subdistrict showed continuous growth. The expansion rate and the expansion intensity in the second five year period increased by 1.94% and 0.1%, respectively, as compared with those in the first five years. This indicated that the external expansion of the construction land was most evident from 2014–2019.

The expansion rate and expansion intensity of different land-use units were calculated to comprehensively assess the expansion condition of the study area (Table 5). The

expansion intensity was not separately analyzed due to relatively small values and minor changes.

From 2009–2014, 18 land-use units exhibited accelerated expansion. The maximum expansion rate (14.22%) was in Huanglatuocun, whereas the minimum expansion rate (−3.44%) was in Houlingcun. From 2014–2019, there were 16 land-use units with accelerated expansion, with the maximum expansion rate (6.13%) in the downtown area and the minimum expansion rate (−2.99%) in Wangjiawopeng. The maximum comprehensive expansion rate among all the units of Ciyutuo Subdistrict from 2009–2019 was 15.42% (Lijiayao), whereas the minimum was −2.22% (Houlingcun). Overall, a development trend was observed.

**3.1.2. Directionality of Morphological Changes.** Based on the construction land conditions of Ciyutuo Subdistrict from 2009–2019, the directional change in the external spatial morphology of the study area was explored by analyzing the direction of the construction land expansion and the shift of the center-of-gravity.

(1) *Expansion Direction.* The intersection of Provincial Highway 102 and Shengli Road was selected as the origin. An appropriate radius was selected to divide the study area into eight equivalent sections by clockwise rotation starting from the north (Figure 2).

Subsequently, the expansion rate and expansion intensity were calculated for each section, revealing the direction of construction land expansion (Table 6).

(2) *Center-of-Gravity Shift.* The spatial center-of-gravity model was used to calculate the changes in the latitude and longitude of the center-of-gravity of Ciyutuo Subdistrict (Figure 3). In 2009, the center-of-gravity of the construction land of Ciyutuo Subdistrict was located near Qianwai-biancun. In 2014, it progressed southwest towards Jiancai Subdistrict on the north side of the downtown area. In 2019, the center-of-gravity continued to develop southeast, shifting near to the junction of Jiancai Subdistrict and Chunxiao Road.

In summary, from 2009–2019, the western part of Ciyutuo Subdistrict experienced the maximum expansion rate and expansion intensity. The center-of-gravity of the construction land shifted to the west and southwest, with greater shift in the longitude than that in the latitude. During the study period, the center-of-gravity of Ciyutuo Subdistrict shifted to the west, as reflected by the development trend towards the west.

#### 3.2. Internal Structure: Evolution of Internal Morphology of Townships

**3.2.1. Geographical Environment Constraints.** Based on the geomorphological characteristics of Ciyutuo Subdistrict, four representative land-use units were selected to analyze the spatial features of the study area and reveal its internal morphological characteristics (Table 7).

TABLE 2: Summary of changes in the construction land area of Ciyutuo Subdistrict.

	Urban construction land area (hm <sup>2</sup> )	Annual growth rate of urban construction land area	Rural residential land area (hm <sup>2</sup> )	Annual growth rate of rural residential land area	Total area (hm <sup>2</sup> )	Annual growth rate of total area
2009	187.02	—	294.71	—	481.73	—
2014	206.17	0.10	303.67	0.03	509.84	0.06
2019	273.71	0.46	315.47	0.07	589.18	0.22

Note: the base year of the growth rate was 2009.

TABLE 3: Land-use compactness index of Ciyutuo Subdistrict.

	Perimeter of built-up area (m)	The compactness index (BCI)
2009	41,248.31	0.414
2014	43,580.32	0.415
2019	46,033.89	0.454

TABLE 4: Changes in construction land of Ciyutuo Subdistrict from 2009–2019.

	Urban construction land area (hm <sup>2</sup> )	Rural residential land area (hm <sup>2</sup> )	Total (hm <sup>2</sup> )
Newly added land use from 2009–2014	48.48	29.21	77.69
Reduced land use from 2009–2014	13.98	35.60	49.58
Newly added land use from 2014–2019	53.73	52.77	106.50
Reduced land use from 2014–2019	7.89	19.27	27.16

The geographical environment shapes the internal spatial form of an area. Ciyutuo Subdistrict is located in the central part of the Liaohe Graben. Thus, its geomorphological landscape belongs to the alluvial plain of the lower Liaohe River and its spatial form is affected by the river and topography. Typical villages in this region are compact clusters developed along the borders with a north-south orientation. The spatial form of villages located along the river follows the shape of the river, often forming a band-like pattern.

**3.2.2. Road Network Promotion.** The change in the spatial form is closely related to the ease of the transportation network. In this study, the space syntax method was used to analyze the topological relationship of the road network in Ciyutuo Subdistrict in 2009, 2014, and 2019.

**(1) Global Integration.** The space syntax method was used to determine the global integration values of Ciyutuo Subdistrict in 2009, 2014, and 2019 (Figure 4). In 2009, the whole integration value ( $Rn$ ) of the subdistrict ranged from 0.21 to 0.88, with an average of 0.55. The axis of Huatai Road had the maximum integration value (0.88), followed by Shenfu

Highway (0.83). The areas with high global integration in the subdistrict were more concentrated only in the downtown area. During this period, the spatial morphology of Ciyutuo Subdistrict had an evident interconnection, and the spatial accessibility of the surrounding villages was poor.

In 2014, the  $Rn$  of Ciyutuo Subdistrict ranged from 0.29 to 0.91, with a mean of 0.60. The comprehensive integration value witnessed a slight increase, and Huatai Road remained the axis with the maximum integration value (0.92). Simultaneously, the distribution extent of high global integration areas increased, exhibiting a westward trend along Dandong Avenue with an improvement in road accessibility.

In 2019, the  $Rn$  of Ciyutuo Subdistrict ranged from 0.32 to 0.96, with a mean of 0.64. Together with the improvement in the whole integration value, Huatai Road (0.96) remained the axis with the maximum integration value in the subdistrict. Moreover, road connectivity and accessibility in the subdistrict were enhanced.

**(2) Dynamic Shift of Integration Core.** In 2009, the scale and number of the integration axes of Ciyutuo Subdistrict were relatively small. Moreover, they were concentrated primarily in the downtown area near the intersection of Huatai Road and Shenfu Highway; this formed a cross-shaped integration core, thereby maintaining single-core development at that time. In 2014, the number of integration axes increased. Furthermore, the scale extended, breaking through the constraints of the downtown area. Expansion along Dandong Avenue to the west and southwest strengthened the link with the Southwest Industrial Park and formed a tree-like integrated core. In 2019, the number and scale of integration axes remained unchanged, and the core continued to show a development trend towards west, with more branches added to the tree-like pattern.

**3.3. Analysis of Influencing Factors.** The influencing factors that may affect the internal and external morphology of construction land use were selected and analyzed (Table 8):

- (1) Urbanization is an important external driving force of the evolution and development of rural settlements. According to the statistical data of Ciyutuo Subdistrict, by the end of 2009, the total population was 53,826, and the resident population living in the town area was 28,000; thus, the urbanization rate of the resident population was 51.9%. By 2018, the total population was increased to 85,000, the resident population of the downtown area reached 56,000, and the urbanization rate of the resident population



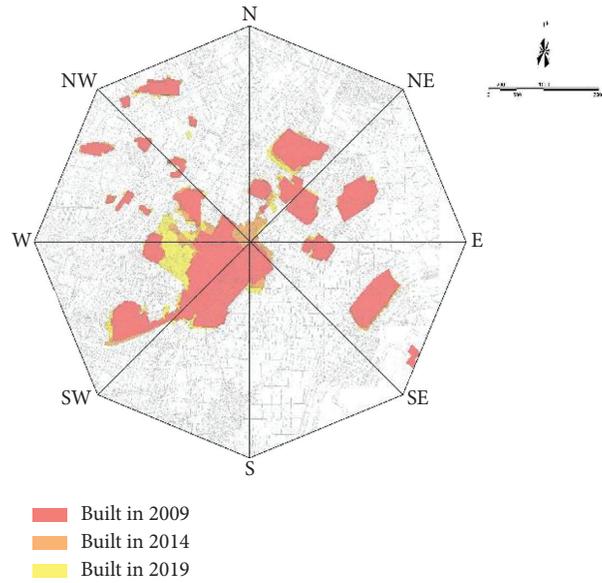


FIGURE 2: Radar chart of town construction land expansion from 2009–2019.

TABLE 6: Directions of construction land expansion in Ciyutuo Subdistrict from 2009–2019.

	2009–2014	2014–2019
	<p>Chart title</p>	<p>Chart title</p>
Expansion direction	SE, W	W
The maximum expansion rate (direction)	12.42% (W)	10.01% (W)
The minimum expansion rate (direction)	-3.67% (NE)	-5.09% (SE)
The maximum expansion (direction)	11.27% (SE)	7.03% (W)
The minimum expansion intensity (direction)	-4.5% (NE)	-3.81% (SE)

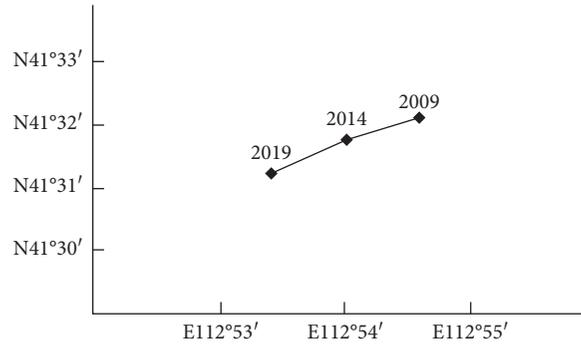
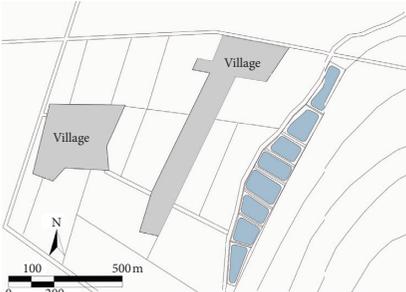
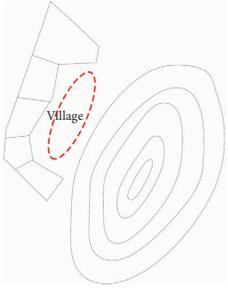


FIGURE 3: Moving map of the center-of-gravity of town construction land from 2009–2019.

TABLE 7: Spatial morphological characteristics of villages in Ciyutuo Subdistrict in 2019.

	Satellite pictures	Village shape	Spatial schema
Pianbaozicun			
Huangnancun/ Huangbeicun			
Shijiawopeng			

TABLE 7: Continued.

	Satellite pictures	Village shape	Spatial schema
Koujiabaocun			

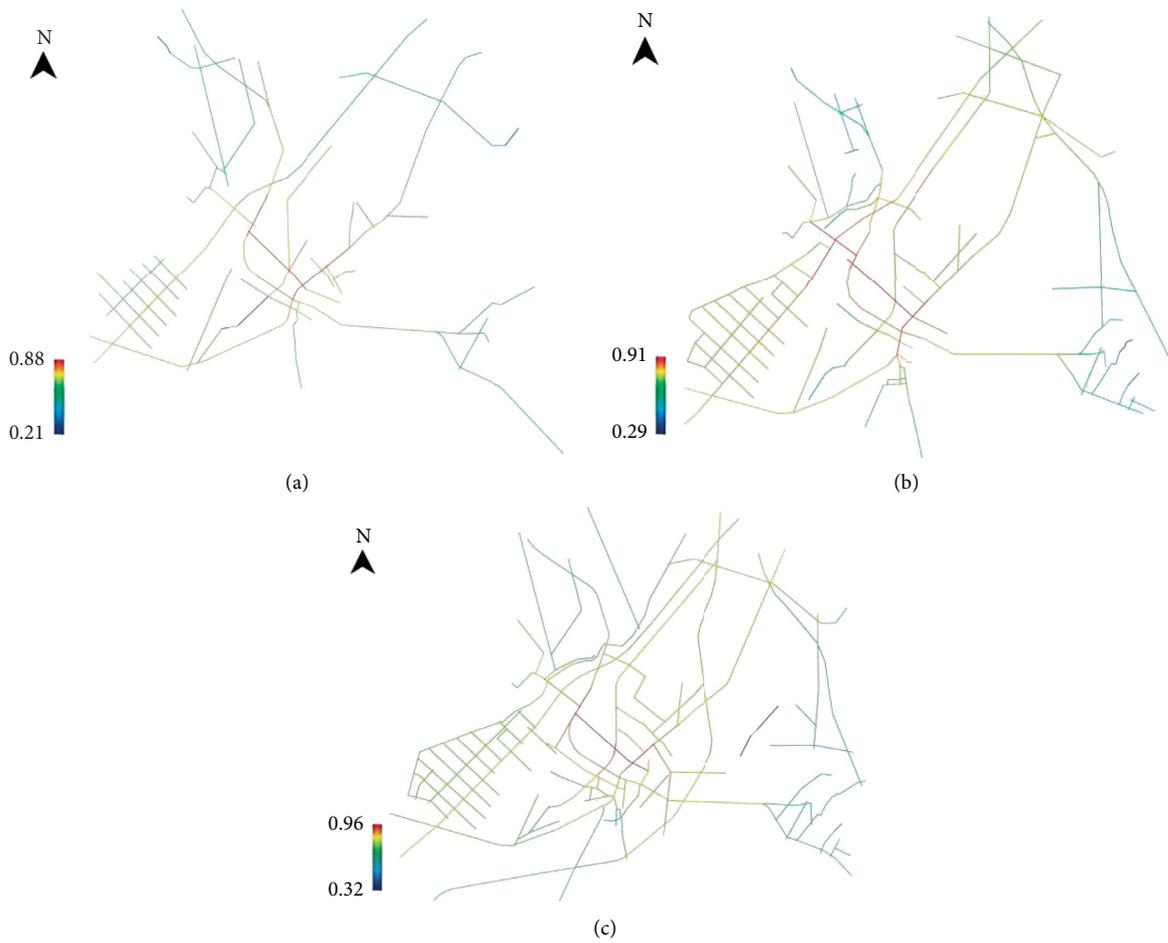


FIGURE 4: Global integration axis. (a) 2009. (b) 2014. (c) 2019.

TABLE 8: Factors and indicators of spatial and temporal land-use evolution in Ciyutuo Subdistrict.

Direction of influence	Factor	Index selection
External factors	Urbanization process	Distance from downtown
	Traffic conditions	Distance from Liaozhong District Distance from main road
Internal factors	Natural resources	Distance from river system
	Industry development priorities	Distance from industrial park

Note: the distance is the length from the center of area A to the center of area B.

TABLE 9: Correlation analyses of land-use change from 2009–2019 in Ciyutuo Subdistrict.

Index selection		2009	2014	2019
External factors	Distance from downtown	−0.602**	−0.614**	−0.625**
	Distance from Liaozhong District	0.061	0.043	0.014
	Distance from main road	−0.23	−0.226	−0.224
Internal factors	Distance from industrial park	−0.062	−0.08	−0.106
	Distance from river	0.302	0.283	0.254

Note: \*\* at the 0.01 level (two-tailed), the correlation is significant; \* at the 0.05 level (two-tailed), the correlation is significant.

was 65.9%. The high urbanization rate had a profound effect. Distance from the downtown area of the subdistrict and from the downtown area of Liaozhong District were identified as the influencing factors.

- (2) The road network is the essential condition for the flow of production materials between different regions. Ciyutuo Subdistrict has evident geographical advantages as it is located in the suburbs of the Shenyang metropolitan area and has a convenient transportation network. In the area where the main road passes, private businesses commenced early and developed rapidly, which drove the overall economic development. With further economic development, industrial enterprises began to concentrate on both sides of Kaifa Avenue (which runs on the western side of the downtown area), eventually forming clustered industrial parks. The influence of road traffic is evident, and the nearest distance from the main road was selected as the influencing factor.
- (3) Geographical factors played a key role in land-use form evolution. In 2009, 2014, and 2019, the morphological changes of land-use units in Ciyutuo Subdistrict were peripheral expansions and reductions on the original sites, with evident influences of topography and hydrology. The overall topography of Ciyutuo Subdistrict was flat and had a low impact on the evolution of rural settlements. The closest distance to the river was selected as the influencing factor.
- (4) Economic development was a direct driving force for the expansion of township land use. The economy in Ciyutuo Subdistrict is dominated by secondary and tertiary industries. In 2018, an industrial park was established on the western side of the downtown area, enabling various enterprises to cluster and boost the economy. As a result, the allocation of land use within the subdistrict was continuously optimized. The distance from the industrial park was selected as the influencing factor.

Pearson's correlation analysis (Table 9) showed that the distance from the downtown area was statistically significant in 2009, 2014, and 2019 at  $P = 0.01$ , which means that this factor affected the evolution of construction land use. Other factors, including the distances from the downtown area of Liaozhong District, the arterial road, the industrial park, and the river did not pass the test at the predetermined significance level, thereby showing that these factors did not

influence the evolution of rural construction land in the subdistrict.

The correlation analysis showed that the ease of transportation had a minor impact on the evolution of construction land in Ciyutuo Subdistrict from 2009–2019 and that the influence of the industrial park to the west of the subdistrict was weak because the park was under development. In addition, although the river had a certain impact on the location of village sites, its effect was not significant when there was a sufficient water supply.

#### 4. Conclusions

- (1) Evolution of external morphology of townships: from 2009–2019, the scale of land use continued to expand. The development rate in the downtown area was significantly higher than that in rural residential areas. The compactness index of land use increased from 0.414 to 0.454, and land use intensified throughout the study period. The overall expansion rate and expansion intensity continued to increase during the study period, whereby the expansion rate increased from 1.17% to 3.11%, and the intensity increased from 0.05% to 0.15%. The land-use units showed an overall trend of accelerated growth, with the western part showing maximum growth and the northern rural settlements showing negative growth. The expansion rate and expansion intensity of the spatial land-use form in the west were greater than those in other directions, and westward expansion of the subdistrict was evident. The center-of-gravity of the subdistrict shifted to the southwest, with the longitudinal shift exceeding the latitudinal shift.
- (2) Evolution of internal morphology of townships: the river and topography restricted the forms of land use in the subdistrict, with the majority of land-use areas developing from north to south along the borders or in a band-like pattern along the river. The road network affected land-use morphology in the subdistrict. The scale and number of axial lines of the integration core increased gradually, with the integration core slowly changing from a cross-shaped single-core to a multicore tree-like structure.
- (3) Urbanization: the main factor affecting changes in construction land use. Urbanization was caused by the nearest downtown area of Ciyutuo Subdistrict. Transportation convenience had a minor impact on the construction land evolution over the past ten

years. Because the industrial park on the west side had not been completely developed at the time of the analysis, its effect on construction land morphology was also relatively small. Finally, the river had no significant impact on land-use change in areas with sufficient water resources.

**4.1. Innovation Potential.** The evolution characteristics of rural settlements at different levels vary greatly. However, majority of previous studies were conducted at the regional and village levels [32]. This study demonstrated that the land-use scale, compactness, and expansion rate of the study area showed an overall growth trend at the subdistrict level. Growth was directional and was driven by urbanization. The urbanization of the nearest urban area was the main factor influencing the evolution of urban land use in this area. The impact of road network accessibility was not significant, which is inconsistent with previous studies, where the evolution of rural settlements was highly dependent on road network conditions [32–34].

Rural areas are multidimensional and complex systems [35]; regional village forms and the geographical environment are dependent [36]. However, majority of studies have only considered the external shape or internal characteristics. In this study, internal and external factors were used as evaluation criteria to explore the spatial morphology evolution mode of Ciyutuo Subdistrict. The change in the external morphology was characterized by expansibility and directionality and that the change in the internal morphology was restricted by geographical conditions, presenting a multicore tree-like development.

**4.2. Study Limitations.** In this study, the results can be used as a reference for optimizing land-use layout and improving its spatial structure. However, this study has the following limitations: (1) resolutions of the satellite remote sensing images and the administrative division maps used were not uniform; thus, there may be slight discrepancies between the land-use boundaries obtained from the statistical data and the actual conditions, and (2) only spatial factors were selected as the influencing factors of the rural settlements; however, other multidimensional factors such as cultural and social factors should be considered.

### Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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