

Article

Understanding the Driving Factors for Urban Human Settlement Vitality at Street Level: A Case Study of Dalian, China

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Abstract: Vitality can effectively test the quality of regional space, put forward the concept of urban human settlement vitality, and explore the development status of urban human settlement vitality space, which is of great significance in promoting the high-quality development of urban human settlements. By constructing an evaluation index system of urban human settlement vitality and comprehensively using projection pursuit models, spatial correlation analysis, and spatial measurement models, the spatial pattern and influencing factors of the vitality of urban human settlements in the four districts of Dalian were studied. The results are as follows: (1) The spatial differentiation characteristics of the vitality of urban human settlements in Dalian are remarkable. Overall, it gradually decreased from the city center to the administrative boundary. (2) The spatial dependence of the vitality of urban human settlements among regions is relatively strong, with a more obvious “Matthew effect”. Among them, urban human settlement vitality hot spots were mainly distributed in the southeast of Dalian, showing a concentrated distribution trend, while the cold spots were distributed in the northern fringe area of Dalian, with spatial homogeneity characteristics. (3) Topography, ecological environment, social economy, commercial development, spatial structure, spatial form, regional scale, etc. have different impacts on the vitality of urban human settlements.

Keywords: vitality; human settlements; projection pursuit model; spatial distribution; four districts of Dalian



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1. Introduction

Urban human settlements can effectively reflect the social and economic development and material and cultural living standards of a country and region [1]. At present, the process of urbanization in China is accelerating; the proportion of the urban population has increased from 17.92% in 1978 to 64.72% in 2021, and the proportion of the urban population will continue to grow. With the rapid increase in the number of people in the city center, the urban spatial structure has undergone tremendous changes. Although significant achievements have been made in China's urban construction work, there are still many unbalanced and insufficient problems in the construction and development process, such as urban traffic congestion, housing shortages, environmental pollution, ecological destruction, and a series of human settlement problems. These problems indicate that most cities in China are currently in a sub-healthy state of development [2–5]. Urban human settlements lack vitality. These human settlement problems hinder the development of the growing need for a better life. Building a harmonious and livable city has gradually become a new appeal. Urban vitality can effectively test urban spatial quality and distribution characteristics [6,7], promote the construction of urban human settlements, and strengthen the healthy and stable development of urban society and the economy.

The word “vitality” is derived from biology and is an abstract concept referring to the ability of things to overcome, develop, and sustain [8]. So far, there has not been a widely

accepted concept of the vitality of urban human settlements, and the related concepts are only seen in research reports on urban vitality. Jacobs believed that the degree of spatial agglomeration of borough residents can characterize urban vitality [9]. Montgomery believes that activity, transactions, and diversity constitute urban vitality [10]. Miriam believes that the diversified activities of urban residents and the intersection of social networks make a region vibrant [11]. Although there is no clear conceptual definition of municipal vitality, they all believe that urban vitality has a positive effect on the sustainable development of cities [12].

Early research on urban vitality was primarily based on urban research theories from a sociological perspective [13,14]. Since the 1990s, related research on urban vitality based on the architectural perspective has gradually increased [15,16]. With the vigorous development of big data, many scholars began to analyze urban vitality from multiple angles and dimensions, using POI, Dianping, social media sign-in data, mobile phone signaling, and other data [17–21], using projection pursuit models, fuzzy comprehensive evaluations, spatial analyses, and other methods to measure urban vitality [22,23], and remarkable progress has been made [24]. A large number of studies have proven that the vitality of urban centers is relatively strong, and most of them present a single-center spatial distribution pattern [25,26]. To date, many scholars have explored the vitality of cities [19,27], showing that research content is gradually becoming comprehensive, research methods are gradually diversified, research scales are gradually refined, and research data are gradually diversified. However, there continue to be some deficiencies in research concepts and indicators [28,29]. The main carrier of urban vitality research is the urban environment. Urban residents are the main bodies of cities. Urban vitality mainly originates from a series of residential activities, such as the production, life, leisure, and entertainment of urban residents. Urban residents influence the urban residential environment. Residential activities have the most obvious and profound impact. Therefore, exploring the vitality of urban human settlements has both practical and theoretical significance. At present, few scholars have combined the concepts of urban human settlements and urban vitality to conduct specialized or conceptual research, and they have only mentioned them in related fields. Combining the urban human settlements of urban vitality, understanding and analyzing the vitality of urban human settlements, their spatial pattern, and influencing factors is more helpful for promoting the healthy and sustainable development of the city and providing reference suggestions for the construction of local human settlements.

Streets, on the original meaning, relate to a relatively wide road with houses on both sides. The streets studied in this article are streets in the sense of administrative divisions. The grassroots government organizations of the administrative management system are areas where residents live relatively [30]. The quality of the street's living environment directly influences the quality of life of residents and overall urban human settlements. Therefore, studying the vitality of urban human settlements in neighborhoods has important theoretical and practical significance, whether it enriches the research on urban human settlements or the urban planning and construction of human settlements.

This study aims to answer the following three questions: How do we determine and measure the vitality of urban human settlements? What is the spatial distribution of urban human settlement vitality? What are the factors influencing the vitality of urban human settlements? To solve these three problems, this study proposes the vitality of urban human settlements and the conditions for their production—for example, in Dalian, China, multi-source data such as POI, digital elevation images, night lights, etc. By constructing an evaluation index system for urban human settlement vitality, the projection pursuit model was used to quantitatively analyze it and study the four aspects of Dalian. The spatial distribution of the vitality of urban human settlements in the district explores its spatial differentiation law and influencing factors and proposes relevant optimization strategies to stimulate the vitality of urban human settlements.

2. The Vitality of Urban Human Settlements

2.1. The Concept of Urban Human Settlements Vitality

The most important thing when analyzing the concept and connotation of urban human settlement vitality is to analyze the concept of “vitality”. The term “vitality” refers to vigorous vitality and the ability to develop things. This study combines urban human settlements with urban vitality and operates under the belief that urban human settlement vitality is the endogenous driving force for the development of urban human settlements. It refers mainly to a city that is conducive to the development of human settlements and is closely related to a healthy and sustainable living environment. The ability to develop is a part of a city’s vitality. It is the intensity and state of information flow, material flow, and energy flow exchange between urban residents and urban human settlements. It is a manifestation of the healthy and high-quality operation of urban human settlements and can comprehensively reflect the city, the status quo of the healthy development of human settlements. The vitality of urban human settlements comes from a series of activities of urban residents, which are the result of human settlement activities acting on the human settlements.

The vitality of urban human settlements differs from that of cities and their quality of urban human settlements. The vitality of urban human settlements is subordinate to that of cities. The vitality of urban human settlements is an effective evaluation method to measure the development status of urban human settlements which can effectively test the spatial quality of urban human settlements. This study believes that a city with good living environment vitality should have a sufficient population, a sound basic public service system, and social and economic development in a high-quality and sustainable state.

2.2. Basic Conditions

Urban residents form the core of the vitality of urban human settlements. The series of activities undertaken by urban residents has an impact on the urban space environment. The quality of the urban space environment is an important condition for attracting urban residents. Based on relevant research [12] and concept analysis, this study operates under the belief that the three elements of urban human settlement vitality are urban residents, human activities, and space (Figure 1).

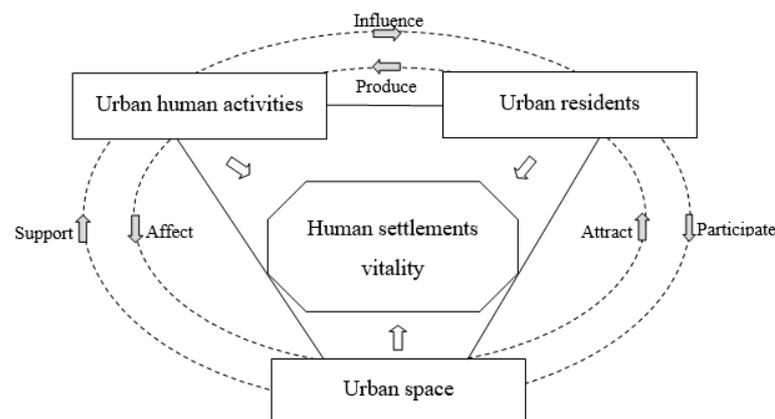


Figure 1. The three elements of urban human settlements vitality.

3. Data and Methods

3.1. Study Area

Dalian City is located at the southern end of Liaodong Peninsula, Liaoning Province (120°58′ E–123°31′ E; 38°43′ N–40°10′ N). It is adjacent to Yingkou City in the north, facing the Shandong Peninsula across the sea, and is adjacent to Japan, South Korea, North Korea, and the Russian Far East. It is the window for opening up the outside world and the largest port city in northeast China. It is also an important economy and trade hub in the eastern coastal areas, ports, industries, and tourist cities (Figure 2). Dalian City includes ten

administrative districts including Zhongshan District, Xigang District, Shahekou District, Ganjingzi District, Lushunkou District, Jinzhou District, Changhai County, Wafangdian City, Pulandian City, and Zhuanghe City. The total area of the city is 12,573.85 km², and the built-up area is 464.4 km². The Statistical Bulletin of Dalian National Economic and Social Development shows that in 2019, the permanent resident population of Dalian was 7,004,000, the GDP regional product was 700.17 billion yuan, and the annual per capita disposable income of urban permanent residents was 46,468 yuan. In 2017, Dalian was praised as “2017 Beautiful Landscape City”.

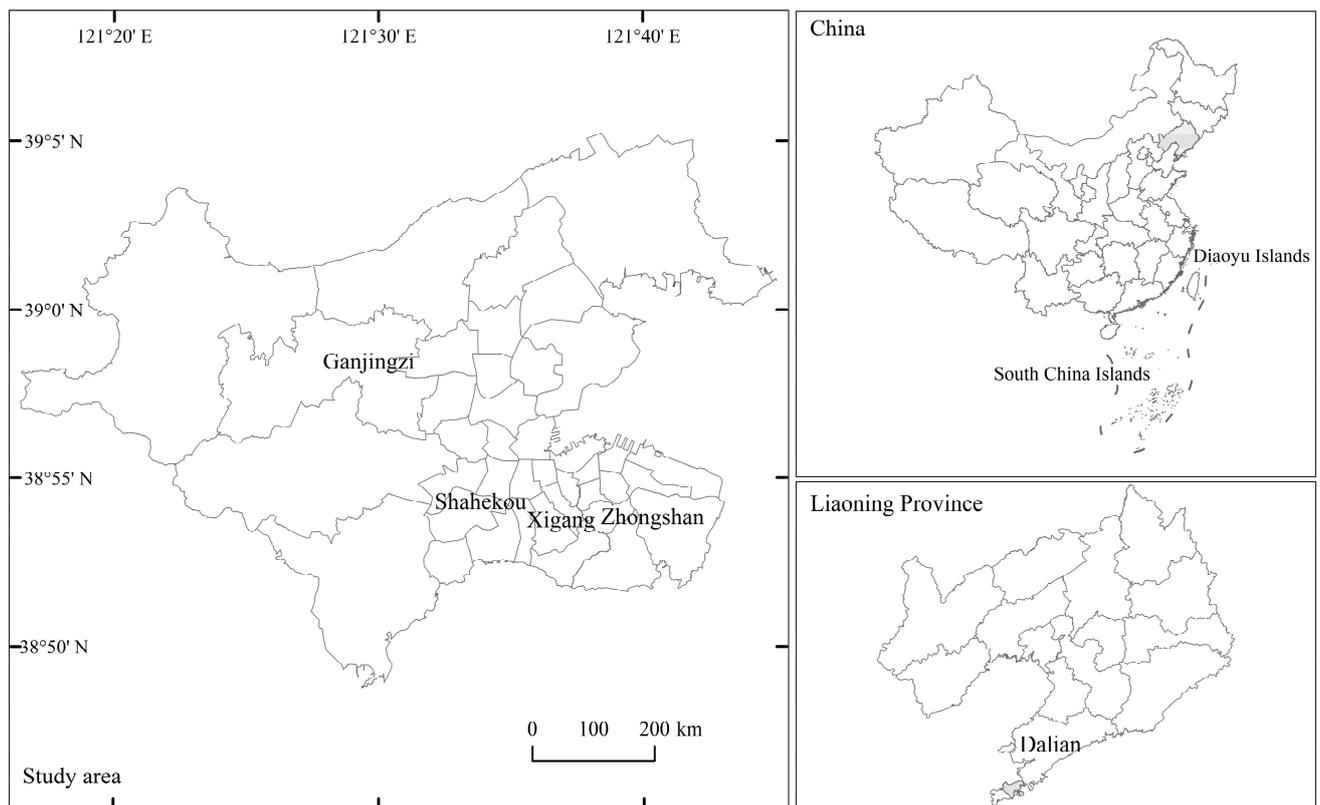


Figure 2. Location of the study area.

As of the end of 2019, the urbanization rate of the registered population in Dalian was 67.59%, and the level of urbanization in Dalian has been constantly improving. It attaches great importance to the healthy and orderly development of urbanization and provides the basic conditions for the vitality of the urban living environment. Zhongshan District is the financial and commercial center of Dalian, Xigang District is the administrative and cultural center, Shahekou District is the center of science and education, and Ganjingzi District plays an important role in the development strategy of Dalian’s westward expansion and northward advancement. Therefore, this study chooses Dalian’s four districts as the main research area.

3.2. Index System

Under the guidance of scientific principles, the systematic characteristics of the index system, the regional characteristics of the research area, and the operability characteristics of the indicators are used to construct an evaluation index system for the vitality of urban human settlements. Jacobs believed that if a city has excellent vitality, the following four conditions should be met: diversified service functions, shortest streets, long history, dense buildings, and sufficient population [31]. Current research on urban vitality is primarily based on two aspects: the urban built environment and urban human settlement activities [17,19]. As China is in a stage of new-type urbanization, the urban population is

gradually increasing, and the interaction and mutual influence between urban residents and the urban environment is more obvious. Therefore, this study divides the vitality of urban human settlements into the urban built environment, urban human settlement activities, and interaction between the three dimensions of the human environment and 13 indicators (Table 1).

Table 1. Evaluation index system of urban human settlements vitality.

| Target Layer | Comprehensive Layer | Index Layer | The Data Shows | Calculation Method | Data Sources | Indicator Attributes |
|---|-------------------------------------|--|--|-------------------------------------|--------------|----------------------|
| The vitality of urban human settlements | Urban built environment | Number of cultural relics protection units | Number of cultural relics protection units in the area | Overlay analysis | a | Positive |
| | | Road length | Average road length between two intersections in the area | Topological method | b | Negative |
| | | Number of intersections | Number of four-way intersections in the area | Topological method | b | Positive |
| | | Building density | The ratio of the area of buildings in the area to the total area of the area | Building area/area area | b | Positive |
| | Urban Habitat Activities | The population density | Population per unit area of land | Total population/area | c | Positive |
| | | POI density | POI point density in the area | Total POI/Regional Area | d | Positive |
| | | POI Mix Index | A total of eight categories of POI mixed index | Entropy index | d | Positive |
| | | Night light index | Average light brightness in the area | Average light brightness index | e | Positive |
| | Human and environmental interaction | Road network density | The ratio of the total mileage of the road network to the area of the area | Road length/area area | b | Positive |
| | | Metro station density | Density of subway stations in the area | Number of subway stations/area area | d | Positive |
| | | Bus station density | Density of bus stops in the area | Number of bus stops/area area | d | Positive |
| | | Road vacuum | Set 50 m and 30 m buffer zones for railways and highways, respectively | Buffer area/regional area | b | Negative |
| | | River vacuum | Establish a 20 m buffer zone for rivers in the area | Buffer area/regional area | b | Negative |

Data sources: (a) National List of Key Cultural Relics Protection Units issued by the State Council (<http://www.gov.cn/>, accessed on 20 September 2019); (b) Open Street Map download platform in 2018 (<https://www.openstreetmap.org/>, accessed on 11 September 2019); (c) 2015 population spatial distribution raster data of the Resource and Environment Science Data Center of the Chinese Academy of Sciences (<http://www.resdc.cn/Default.aspx>, accessed on 1 October 2019); (d) 2018 AutoNavi Map Format POI (<https://www.amap.com/>, accessed on 30 November 2018); (e) Npp Virrs night light data 2018 from the NGDC website (<https://ngdc.noaa.gov/eog/download.html>, accessed on 28 September 2019).

Urban built environments and cultural relic protection units mostly refer to ancient cultural sites, tombs, buildings, cave temples, and stone carvings with historical, artistic, and scientific value. They are the cultural heritage of a region and represent its antique culture. This foundation is of profound significance for attracting residents and visitors and for promoting the development of regional vitality [32]. The length of the road and

the number of intersections can indicate, to a certain extent, the diversified characteristics of the built environment in an area. A shorter road length and number of intersections in an area can indicate that the residents of the area have more activity opportunities [33]. The density of buildings reflects the density and intensity of the living space and working environment of residents in the area and provides basic support for the influx of large numbers of people [34].

Urban human settlement activities and population density are important indicators of urban human settlement activities and the vitality of urban human settlements [27]. A dense population per unit area indicates that sufficient human settlement activities can be obtained. The POI density and POI mixed index can effectively reveal the spatial distribution of basic urban public service facilities. Generally speaking, the greater the density of POI, the greater the density of urban basic public service facilities, and the greater the value of the POI mixing index, the more significant the diversity of urban public service infrastructure [17,18]. The nighttime light index can be used to measure the intensity and breadth of regional human settlement activities, and the average nighttime light index reflects the status of human settlement activities in the region [35].

In human and environmental interactions, the density of a road network is used as an indicator to evaluate urban accessibility [27]. The road network communicates the various components of the city, strengthens the internal connections between cities, and provides support for the travel activities of urban residents. Among them, bus and subway stations are modern transportation methods that can improve residents' travel efficiency and relieve urban traffic pressure. This finding is significant. The vacuum of roads and rivers limits the degree of human settlement activity to a certain extent.

3.3. Impact Factor Selection

The spatial differentiation pattern of urban human settlement vitality is not subject to a single factor but is the result of multiple factors intertwining and influencing each other. Many scholars have explored factors influencing urban vitality and its construction strategies [36,37]. In the process of assessing the spatial pattern of urban vitality in the middle reaches of the Yangtze River, Mao Weisheng explored the impact of university resources, economic density, infrastructure construction, and the degree of informatization on urban vitality [38]. Zhu Ying analyzed the spatial vitality of historical and cultural cities based on five aspects: urban space, economic development, population distribution, ecological environment, and social culture [39]. In addition, some scholars have proven through research that housing prices have a significant effect on the spatial differentiation pattern of urban commercial vitality [40].

In summary, this study selected topography (average altitude and topographic undulation), ecological environment (vegetation coverage), social economy (average housing price), commercial development (density of commercial facilities), spatial structure (space compactness), spatial form (fractal dimension), and regional scale (total population of the region), and eight factors were used as quantitative analysis factors for the vitality of urban human settlements. The selected quantitative analysis factors were tested for multicollinearity, and the results are presented in Table 2.

Table 2. Variance inflation factor (VIF) of each variable.

| Factor | VIF | 1/VIF |
|----------------------------------|------|-------|
| Average altitude | 4.76 | 0.21 |
| Terrain relief | 7.72 | 0.13 |
| Vegetation coverage | 1.71 | 0.58 |
| Average house price | 1.37 | 0.73 |
| Density of commercial facilities | 1.70 | 0.59 |
| Compactness | 6.37 | 0.16 |
| Fractal dimension | 3.36 | 0.30 |
| Regional population | 1.21 | 0.83 |

Among them, the variance expansion factor (VIF) of the topographic undulation degree is greater than 7.5, indicating that there is a multicollinearity relationship between the variables; thus, it is eliminated. The final urban human settlement vitality impact factors are presented in Table 3.

Table 3. Factors affecting the vitality of urban human settlements.

| | Variable Name | Variable Symbol | Variable Description |
|--------------------|----------------------------|-----------------|--|
| Explained variable | Human settlements vitality | V | Projection pursuit model calculation results |
| Explain variable | Topography | X1 | Average altitude |
| | Ecological environment | X2 | Topographic undulation |
| | Social economy | X3 | Average housing price |
| | Business development | X4 | Density of commercial facilities |
| | Spatial structure | X5 | Compactness |
| | Space form | X6 | Fractal dimension |
| | Human capital | X7 | Regional population |

3.4. Research Method

3.4.1. Projection Pursuit Model

The projection pursuit model is a novel statistical method for processing and analyzing high-dimensional data. The basic idea is to project high-dimensional data onto a low-dimensional space and optimize the projection objective function by establishing constraints to find the original high-dimensional data. Find a projection that can reflect the structure or characteristics of the original high-dimensional data and analyze the high-dimensional data in a low-dimensional space [41], which is widely used in scientific research [42–44]. The calculation process is as follows:

(1) First, standardize the original data to eliminate the differences caused by different dimensions.

Positive indicators:

$$x'_{ij} = (x_{ij} - \min x_{ij}) / (\max x_{ij} - \min x_{ij}) \quad (1)$$

Negative indicators:

$$x'_{ij} = (\max x_{ij} - x_{ij}) / (\max x_{ij} - \min x_{ij}) \quad (2)$$

where x'_{ij} is the value after normalization, x_{ij} is the original value, and $\max x_{ij}$ and $\min x_{ij}$ are the maximum and minimum values of the original value, respectively.

(2) The projection index functions are established. The projection direction vector of the urban human settlement vitality evaluation was set, and high-dimensional data were projected into a one-dimensional space for analysis. Let $a = (a_1, a_2, \dots, a_j)$ be the projection direction vector of the m -dimensional data; then, the one-dimensional projection eigenvalue z_i is

$$z_i = \sum_{j=1}^m a_j \times x_{ij}, (0 \leq i \leq n) \quad (3)$$

(3) A projection objective function was established. When optimizing the projection feature value, the projection value z_i is required to have the characteristics of small concentration and large dispersion. Therefore, it is used as the starting point to establish the projection objective function.

$$Q(a) = S_Z D_Z \quad (4)$$

$$S_Z = \sqrt{\frac{\sum_{i=1}^n (z_i - E(z))^2}{n - 1}} \tag{5}$$

$$D_Z = \sum_{i=1}^n \sum_{j=1}^n (R - r(i, j))u(R - r(i, j)) \tag{6}$$

where S_z and D_z are the standard deviation projected to z_i and the local density, respectively; $E(z)$ is the average value of the urban human settlement vitality sequence z_i ($1 \leq I \leq n$); R is the window radius of the local density; $r(i, j)$ represents the distance between samples, where $r(i, j)$ is the absolute value of $z_i - z_j$; the symbolic function $u(R - r(i, j))$ is the unit step function; when $R \geq r(i, j)$, the function value is 1; and when $R < r(i, j)$, the function value is 0.

(4) Optimization of projection objective functions. After the urban human settlement vitality evaluation sample is determined, the change in direction of the projection objective function $Q(a)$ depends on the change in the projection direction vector a . To calculate the optimal projection direction vector, it is necessary to pass the constraints and maximize the solution projection objective function.

Maximize the projection objective function:

$$\max Q(a) = S_z D_z \tag{7}$$

Restrictions:

$$\sum_{j=1}^p a^2(j) = 1 \tag{8}$$

This is a complex nonlinear optimization problem with $a(j) = |j = 1 \sim p$ as the optimization variable, and it is difficult to deal with it using conventional optimization methods. According to the classical genetic algorithm, the quantum genetic algorithm has the characteristics of diversity; therefore, this study used the quantum genetic algorithm to perform high-dimensional global optimization.

(5) The projection evaluation values were divided. Calculate the optimal projection direction vector through constraint conditions and use its value as the weight value of the index. Multiply the index weight value and the standardized value to obtain the evaluation value of each system of urban human settlement activities and the comprehensive evaluation value and sort according to its numerical value.

3.4.2. Spatial Autocorrelation Analysis

Spatial autocorrelation is the degree of interdependence between data on a certain area unit and data on other area units. According to the first law of geography, we know that geographical factors are related to each other in spatial distribution, and there is agglomeration, random, and regular distribution, which shows that geographical factors may be related to each other due to the influence of spatial interaction and spatial diffusion. Therefore, spatial autocorrelation analysis can effectively reveal the agglomeration characteristics of urban human settlement vitality in the spatial distribution. Spatial autocorrelation analysis includes both global and local autocorrelation.

Global spatial autocorrelation measures the overall dependence of observation data. This study mainly used Moran's I index to measure the spatial correlation degree of urban human settlement vitality in the main urban districts of Dalian [45]. The calculation formula is as follows:

$$Moran's\ I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2 \sum_{i=1}^n \sum_{j=1}^n w_{ij}} \tag{9}$$

The value ranges of *Moran's I* are generally between $[-1, 1]$. A negative value indicates that the spatial distribution of urban human settlement vitality is negatively correlated. The

larger the absolute value, the more obvious the spatial differential characteristics; when its value is positive, it indicates that the spatial distribution of urban human settlement vitality is positively correlated. The larger the value, the more noticeable the spatial agglomeration characteristics; when the value is 0, it indicates that urban human settlement vitality is irrelevant in the spatial distribution. n is the number of research areas, x_i and x_j represent the vitality values of the urban human settlements in the i -th street and j -th street, respectively. w_{ij} represents the spatial weight matrix, which is created using the rook method.

The Z value was used to inspect the global autocorrelation results. When $Z > 1.96$, it means that it has a significant positive correlation in the spatial distribution; when $Z < -1.96$, it means that it has a significant negative correlation in the spatial distribution; when $Z = 0$, it means that it has no correlation.

Global autocorrelation can only assess the overall dependency state of geographical objects in the spatial distribution and cannot characterize their agglomeration in the local space. Therefore, local Getis-Ord G^* must be utilized to analyze the spatial agglomeration characteristics of urban human settlement vitality [46,47].

$$G_i^* = \frac{\sum_{i=1}^n w_{ij}(d)x_i}{\sum_{i=1}^n x_i} \quad (10)$$

where n is the number of research areas, x_i represents the value of the vital elements of the i -th street urban human settlement vitality, and w_{ij} represents the spatial weight matrix, which was constructed using the rook method.

3.4.3. Spatial Measurement Model

The vitality of urban human settlements is highly spatially dependent and not spatially independent. In other words, the vitality of a city's human settlements is affected by the vitality of its neighboring areas. Therefore, it is necessary to use a spatial regression model to analyze the spatial spillover effect of the vitality of urban human settlements. There are two common spatial regression models: spatial lag model (SLM) and spatial error model (SEM) [48]. The spatial lag model was mainly used to explore whether there was a spatial spillover effect and spatial error in the spatial distribution of urban human settlement vitality. The model is mainly used to study whether the vitality of urban human settlements is affected by the vitality of the surrounding area and its degree of influence.

The expression of the spatial lag model (SLM) is:

$$Y = \rho W_y + X\beta + \varepsilon \quad (11)$$

The expression of the spatial error model (SEM) is:

$$Y = X\beta + \varepsilon \quad (12)$$

$$\varepsilon = \lambda W\varepsilon + \mu \quad (13)$$

Y is the dependent variable vector, X is the explanatory variable matrix, W is the spatial weight matrix, W_y is the spatial lagging dependent variable, ρ is the spatial regression coefficient, λ is the spatial error coefficient, ε is the random error term vector, and μ is the random error vector of the normal distribution.

4. Result Analysis

4.1. Spatial Distribution Characteristics of Vitality of Urban Human Settlements

Taking the urban human settlements vitality systems and comprehensive scores of the streets in the four districts of Dalian as a data matrix and using the ArcGIS natural breakpoint method to divide the 40 streets in the four districts of Dalian into five levels, the classification results are shown in Figure 3.

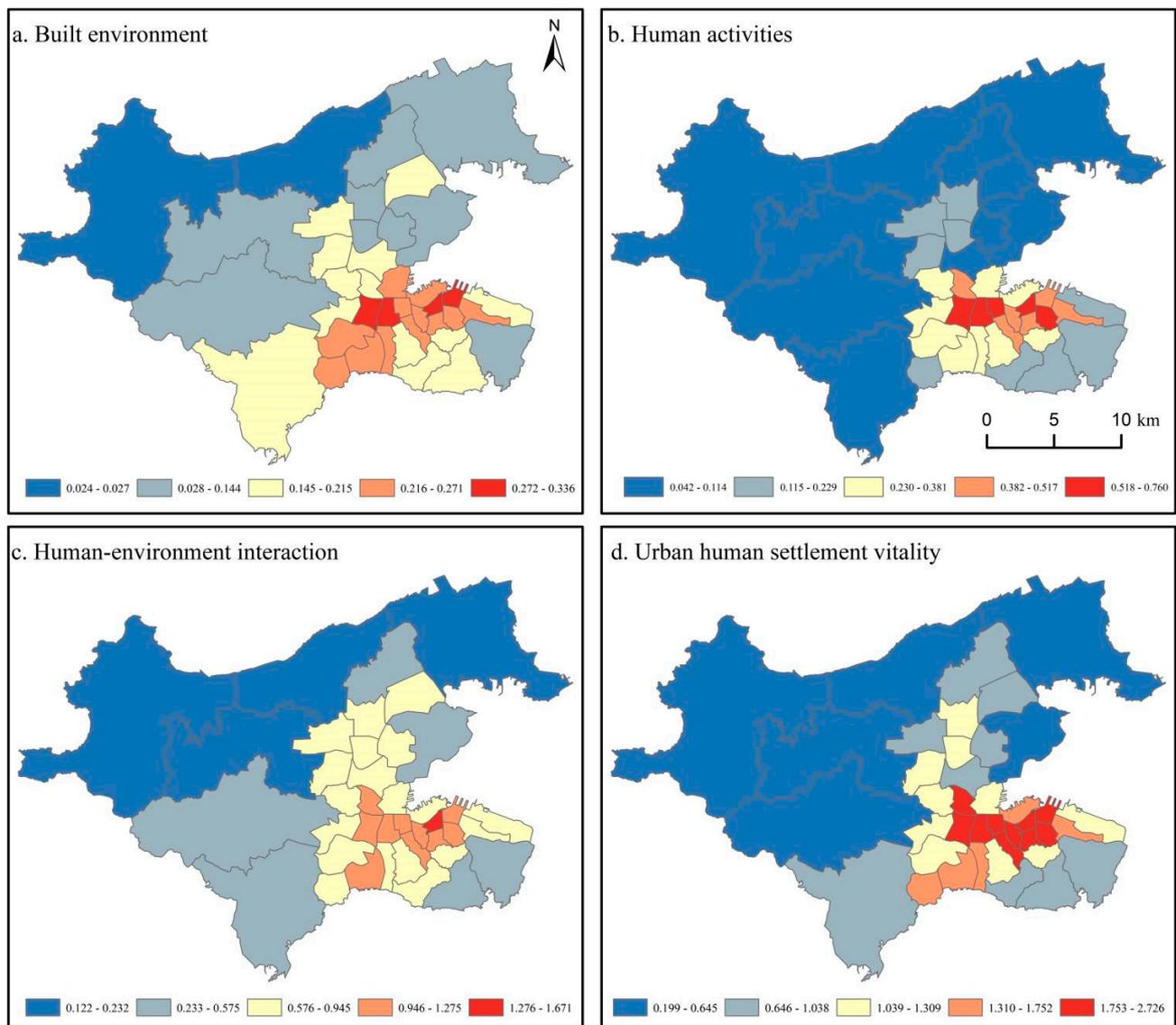


Figure 3. Spatial pattern of urban human settlements vitality.

The high-quality urban built environment areas are mainly distributed on Renmin Road, Qingniwa Bridge, Zhongshan Park, and Xinggong Street, with values ranging from 0.272 to 0.336. Urban built environment vitality presents a dual-core spatial distribution pattern in the spatial distribution. Among them, Renmin Road has a large number of cultural relics protection units, and its building has a long history. Compared with other areas, it has a relatively strong cultural heritage, which can attract locals and foreign tourists to watch and play. The built environments of the Qingniwa Bridge, Zhongshan Park, and Xinggong Street were relatively excellent. First, shorter road length and denser building density provide more convenient conditions and environmental support for urban residents to carry out scheduled activities. The splendid old buildings, as carriers of cultural heritage, attract more visitors, promote an increase in population flow, and thus promote the improvement of street vitality.

The high-quality urban human settlement activity areas are mainly distributed in Qingniwa Bridge and Guilin Street in Zhongshan District, Zhongshan Park and Xinggong Street in Shahekou District, and Beijing Street in Xigang District. The value of urban human settlement activities in high-quality districts ranged from 0.518 to 0.760. In space, the spatial distribution pattern of the dual cores is shown, and it gradually decreases to the

surroundings. Among them, the POI density value of Qingniwaqiao Street has an obvious advantage (ranking first) among the 40 streets in the four districts. The POI mixed index is relatively high, indicating that the basic public service facilities of Qingniwaqiao Street are relatively densely distributed, and there are many types that provide strong support for urban residents to participate in social, economic, political, and cultural activities. The Guilin Sub-district has a relatively abundant population, ranking second in population density, and the intensity of nighttime human settlement activities in the street is also an advantageous position, providing a material basis for the development of regional human settlement activities. The city function index (POI density) and population density of Zhongshan Park Street rank higher (third and second), providing a material basis for the vitality of regional human settlement activities and creating a good development environment. Although the POI density, POI mixing index, population density, and night light index of Xinggong Street were not significant, they also had certain advantages. In addition, due to the radiation effect of its surrounding areas, such as Zhongshan Park Street and Beijing Street, the vitality of urban residential activities in Xinggong Street is relatively high. The vitality of urban human settlement activities in Beijing Street has obvious advantages among the 40 streets in the four districts of Dalian. Among them, the population density of Beijing Street ranks first, the POI density ranks second, and the night light index ranks second. They have the material foundation and the corresponding environmental conditions necessary for the vital development of regional human settlement activities.

The high-quality area for interaction between urban people and the environment is Qingniwaqiao Street, with a value of 1.671, which suggests a single-core spatial distribution structure in terms of spatial distribution. Among them, the density of bus stations and subway stations in Qingniwaqiao Street occupied a clearly dominant position among the 40 streets in the four districts (all ranked first). Although road network density and river vacuum do not have obvious advantages, they are all in the middle and upper levels. It provides great convenience for urban residents to travel and effectively alleviates the phenomenon of regional traffic congestion.

A total of 10 of the 40 streets in the four districts of Dalian have high-quality urban human settlement vitality, including Qingniwa Bridge, Renmin Road, Guilin, and Kunming streets in Zhongshan District; Beijing, Rixin, and People's Square Streets in Xigang District; and Zhongshan Park, Xinggong, and Chunliu Streets in Shahekou District, with values between 1.753 and 2.726. Among them, the vitality value of the urban human settlement vitality in Qingniwaqiao Street was the highest. This is the product of the interaction of the three dimensions of the urban architectural environment, urban human settlement activities, and the interaction between the urban people and the environment. Based on the three dimensions of the urban architectural environment, urban human settlement activities, and the interaction between urban people and the environment, Qingniwaqiao Street has a distinct advantage among the 40 streets in the four districts of Dalian. The vitality value of the urban human settlement environment in Yingchengzi Street is the lowest, mainly because the values of the three comprehensive layers of the urban architectural environment, urban human settlement activities, and the interaction between urban people and the environment in Yingchengzi Street are obvious in the 40 streets in the four districts of Dalian. The urban architectural environment of Yingchengzi Street and the interaction between urban people and the environment ranked last among the 40 streets in the four districts of Dalian.

Based on the various systems and comprehensive scores of urban human settlements vitality in 40 streets in the four districts of Dalian, a three-dimensional scatter plot of urban human settlements vitality is generated through Origin software (Figure 4), where the X-axis represents the urban built environment, the Y-axis represents the urban human settlements activities, and the Z-axis represents the interaction between humans and the environment. As shown in Figure 4, the Qingniwa Bridge, Zhongshan Park, Guilin, and Rixin Street have certain advantages in the three dimensions of the urban built environment, urban human settlement activities, and the interaction between people and the environment.

Dalianwan, Gezhenbao, and Yingchengzi Street are relatively disadvantaged in the three dimensions of urban architectural environment, urban human settlement activities, and the interaction between people and the environment.

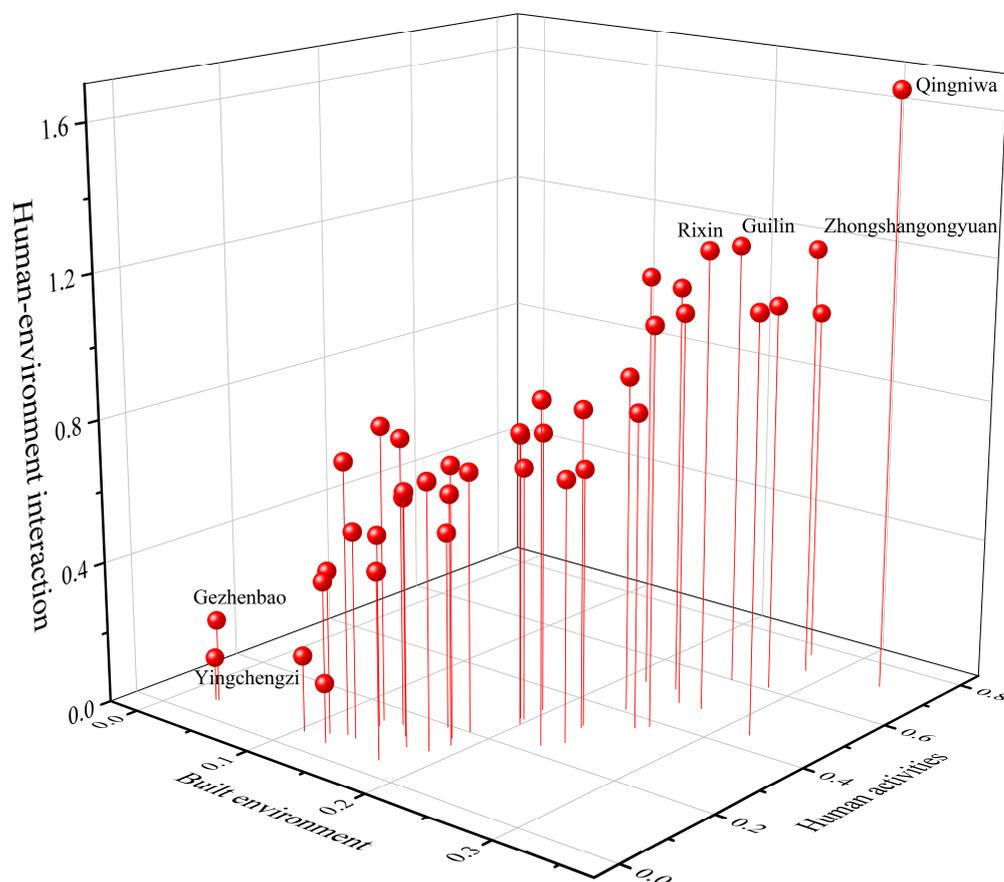


Figure 4. Three-dimensional scatter diagram of urban human settlements vitality.

4.2. Cluster Characteristics of Vitality Space of Urban Human Settlements

The vitality of urban human settlements in the four districts of Dalian has an obvious spatial dependence. The spatial weight matrix was constructed using the Rook method, and the global *Moran's I* value and related values of the vitality of urban human settlements in the four districts of Dalian were calculated using GeoDa software. The global *Moran's I* value was 0.5092, the *p* value was 0.001, and the *z* value was 5.3208, passing the 99.9% confidence test and rejecting the null hypothesis at a significance level of 0.1%, indicating that the urban human settlement vitality in the four districts of Dalian presents a state of uneven development in spatial distribution, and the interdependence between cities is strong, with a more obvious “Matthew effect,” that is, a cluster-like distribution state in spatial distribution.

The Getis-Ord G_i^* spatial correlation index was used to explore the spatial agglomeration status of urban human settlement vitality in the four Dalian districts. The larger the Getis-Ord G_i^* value, the more positive the distribution trend of the research sample, and the higher the level of the surrounding areas. A progressive value, this area is a hotspot for urban human settlement vitality. On the contrary, if this area is surrounded by lower-level areas, it means that this area is a cold spot area of urban human settlement vitality. According to Getis-Ord G_i^* , urban human settlement vitality hotspots are divided into seven categories (Figure 5). From Figure 5, it can be seen that the urban human settlements vitality Getis-Ord G_i^* of the four districts of Dalian City shows that the spatial distribution of Getis-Ord G_i^* deserves to be “southern”. The trend of “high in the north and low in the east and the west” indicates that the trend of decreasing from southeast to northwest

indicates that the vital hot spots of urban human settlements vitality in the four districts of Dalian are mainly located in the southeast of the main urban area of Dalian.

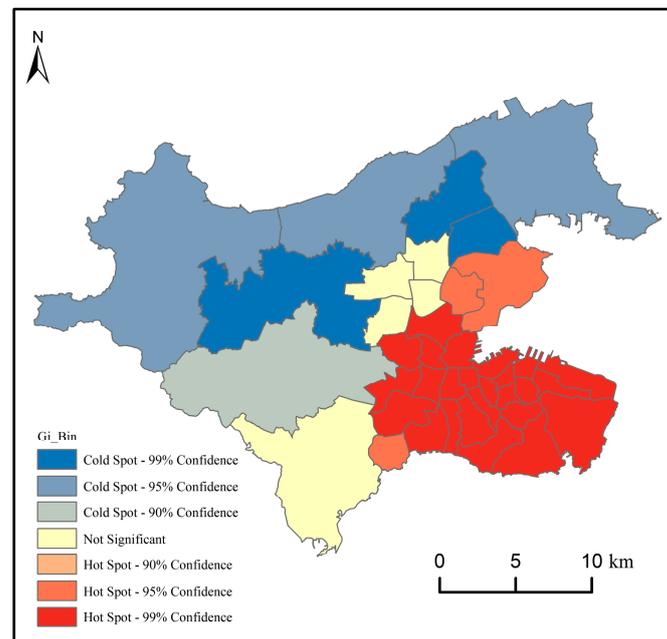


Figure 5. Spatial distribution of vitality of urban human settlements, cold and hot spots.

The vitality hot spots of the urban human settlements in the four districts of Dalian are mainly distributed in Shahekou District, Xigang District, and Zhongshan District, such as Qingniwa Bridge, Kunming, People's Square, Zhongshan Park, and Beijing Street, etc., showing a concentrated distribution pattern in space. The region has a relatively high level of economic development, complete urban basic public service facilities, a relatively abundant population, and a sound foundation for the vitality of urban human settlements. The fringe areas of the four districts of Dalian, namely, Xinzhaizi, Gezhenbao, Paoya, Nanguanling, and Quanshui Street, are regions where the vitality of urban human settlements is cold. The overall level of urban human settlement vitality in this area is weak and in terms of spatial distribution. Homogeneity characteristics exist. The vitality of urban human settlements is lower in all dimensions than that in the surrounding areas. The overall speed of development is relatively slow, and the vitality of the urban human settlements is insufficient.

4.3. A Probe into the Factors Affecting the Vitality of Urban Human Settlements

OLS was used to analyze the factors affecting the vitality of urban human settlements, and the analysis results are shown in Table 4. Among them, commercial development, spatial structure, spatial form, and human capital are significant at the 1% level, and social economy is significant at the 5% level. The topography, landform, and ecological environment have not passed the significance level test; this shows that the above factors are the main factors of the spatial differentiation pattern of urban human settlements vitality in Dalian, which can explain 89.11% of the urban human settlements vitality spatial differentiation pattern. Generally, commercial development, spatial structure, spatial form, human capital, and social economy have a positive impact on the vitality of urban human settlements. The richer the spatial form, the higher the socioeconomic level, and the flatter the terrain, the higher the level of vitality of urban human settlements.

As shown in Table 5, the p values of the Breusch-Pagan and Koenker-Bassett statistics are both greater than 0.05, indicating that the OLS model has heteroscedasticity. The imbalance of factors such as the natural ecological environment, social and economic development, spatial characteristics, and regional population size, as well as the interaction

between regions, together contribute to the spatial distribution pattern of urban human settlement vitality. To further explore the spatial effect of urban human settlement vitality, an appropriate spatial measurement model was selected for analysis. As shown in Tables 4 and 5, the log-likelihood ratios (LogL) of the spatial lag model and the spatial error model are larger than those of the OLS model. In addition, the Akaike information criterion (AIC) and Schwartz guidelines (SC) were smaller than those of the OLS model. To a certain extent, the fitting effect of the spatial measurement model is better. Thus, it is feasible to use a spatial measurement model to explore the vitality of urban human settlements.

Table 4. Regression results of the spatial measurement model.

| Variable | OLS | SLM | SEM |
|----------------------------|------------|------------|------------|
| X1 | −0.0004 | −0.0006 | −0.0004 |
| X2 | −0.3033 | −0.3990 ** | −0.3088 |
| X3 | 0.0032 ** | 0.0054 ** | 0.0049 ** |
| X4 | 0.0403 *** | 0.0628 *** | 0.0399 *** |
| X5 | 4.2607 *** | 3.1152 *** | 4.3145 *** |
| X6 | 2.4138 *** | 1.6011 *** | 2.4412 *** |
| X7 | 0.0051 *** | 0.0073 *** | 0.0023 *** |
| R ² | 0.9107 | 0.9294 | 0.9107 |
| Adjust R ² /ρ/λ | 0.8911 | 0.3011 | −0.0377 |
| LogL | 13.7332 | 17.9762 | 13.7375 |
| AIC | −11.4663 | −17.9524 | −11.4751 |
| SC | 2.0447 | −2.7525 | 2.0360 |

Note: **, *** indicate significance at the 5%, and 1% levels, respectively.

Table 5. Diagnostic test of OLS model estimation results.

| Test Statistics | Statistics | p-Value |
|-----------------|------------|---------|
| Breusch-Pagan | 6.0641 | 0.532 |
| Koenker-Bassett | 9.4137 | 0.224 |
| LMLAG | 7.7274 | 0.005 |
| R-LMLAG | 10.3172 | 0.001 |
| LMERR | 0.0028 | 0.958 |
| R-LMERR | 2.5926 | 0.109 |

Regarding the choice of the spatial measurement model, according to the diagnostic test results of the OLS model (Table 5), it can be seen that the LMLAG passed the significance test, while the LMERR failed the significance level test. R-LMLAG was more robust than R-LMERR. It is more significant. Therefore, the spatial lag model was used to analyze the factors affecting the spatial distribution pattern of the vitality of urban human settlements in Dalian. According to Table 4, the spatial regression coefficient (ρ) of the spatial lag model is 0.3011, which is significant at the 1% level, indicating that the vitality of urban human settlements in Dalian has a significant spatial spillover effect; that is, the vitality of urban human settlements is increased by 1%, and the vitality of urban human settlements in neighboring areas is increased by 0.31%.

In terms of topography, analysis of the spatial lag model showed that the average altitude was negatively related to the vitality of urban human settlements. Generally, the smaller the average altitude, the better the vitality of urban human settlements. The spatial layout of natural elements, such as the topography, forms the basis of the spatial pattern of the urban built environment. Natural environmental elements affect the quantity and quality of regional settlements and affect the spatial differentiation patterns of urban human settlements.

In terms of the ecological environment, the analysis of the spatial lag model shows that there is a negative barrier between regional vegetation coverage and the vitality of urban human settlements. The ecological environment, such as green space and water

systems, limits the intensity and scope of urban human settlement activities to a certain extent, which will affect the vitality of urban human settlements.

In terms of social economy, through analysis, it was found that the social economy has a positive effect on the vitality of urban human settlements, and it has passed the 5% significance level test. In other words, the better the regional socioeconomic development level, the higher the vitality of urban human settlements. The regional social economy provides a source of funds for the construction of the urban built environment and economic support for urban residents to carry out urban human settlement activities, and it promotes the interaction between urban residents and the environment to have a certain degree of impact on changes in the urban environment.

Commercially, it plays an important role in the development of cities. Urban residents conduct shopping, entertainment, and other leisure activities, while commerce carries most of the urban residential activities. The analysis of the spatial lag model verifies that there is a positive correlation between the density of urban commercial facilities and the vitality of urban human settlements, and, passing the 1% significance level test, convenient and diverse commercial service facilities encourage urban residents to consume and entertain to a certain extent a series of human settlement activities such as leisure and leisure activities that have strengthened the exchange of material flow and information flow between regions, thereby enhancing the vitality of urban human settlements.

In terms of spatial structure, whether the regional spatial structure is reasonable will not only affect the production of urban human settlement activities but the “quality” of urban human settlement activities. A reasonable regional spatial structure enhances the comfort of urban residents. This affects the length of time that urban residents stay here, creating conditions for more urban human settlement activities and enhancing the vitality of the regional urban human settlements.

In terms of spatial form, the richer the urban spatial form, the richer the forms and types of urban human settlement activities it carries, thereby promoting an improvement in the vitality of urban human settlements. The estimation result of the spatial lag model shows that the influence of the urban fractal dimension on the vitality of urban human settlements is 0.047, which passes the 5% significance level test. In other words, the more complex the shape of the urban spatial form, the higher the level of vitality of urban human settlements.

In terms of human capital, the “quality” of urban residents is closely linked to the vitality of urban human settlements. Generally speaking, the greater the number of high-quality regional talents, the higher the vitality of urban human settlements. High-quality talent is not just the core factor for improving the level of urban social and economic development but is also the source of vitality for urban human settlements.

5. Discussion

5.1. Findings and Contributions

With the continuous development of China’s urbanization process, the urban population continues to increase, and the urban space continues to expand and restructure. Coupled with the differences in the basis of urban development, the quality of urbanization is uneven, a series of problems in the construction of urban human settlements exists, and the vitality of urban human settlements provides a new research paradigm for solving the problems of urban human settlements. This study uses 40 streets in the four districts of Dalian as the basic research unit. Based on existing theories, this study analyzed the spatial differentiation characteristics of urban human settlements in the core urban area of Dalian and explored the factors affecting the vitality of urban human settlements. The research and application of urban human settlements and urban vitality have certain innovative significance and academic value.

Traditional measures and analyses of regional vitality are usually conducted using statistical data, questionnaire surveys, and expert scoring [49,50]. Although it is convenient to obtain regional vitality related data in this way for calculation and comparison, its

accuracy is limited to some extent, leading to some differences in the research results. With the development of the information age and the application of science and technology such as big data, scholars have begun to use multivariate data to innovate research perspectives and methods [40,51–53]. Based on relevant research, this paper puts forward the concept of innovation of urban human settlement vitality and measures it with multi-source big data. Research suggests that urban residents, urban human settlement activity, and the city space environment are the three elements of urban human settlement vitality. Urban residents, the core of urban human settlement vitality, produce a series of human activities in the urban space environment, and the urban space environment in which residents participate provides support for urban human activities. The three elements of urban human settlement vitality are mutually influential and interactive.

It was found that the factors influencing urban human settlement vitality in Dalian have chain effects, and its spatial pattern is the result of the interaction of many factors. In general, the influencing factors of urban human settlement vitality can be divided into four parts: natural environment factors, socio-economic factors, space form factors, and population scale factors. The natural environment elements include the average altitude and vegetation coverage; the socio-economic elements include the average value of house prices, the density of commercial facilities, government policies, the degree of informatization and industrial structure; the fractal dimension belongs to the elements of spatial form; and the total regional population and human capital are the elements of the population scale (Figure 6). Among them, natural environmental factors, such as the basic elements, play an important role in the urban architectural environment and spatial layout of the product of the interaction between urban residents and the environment. As a supporting element, socio-economic factors provide economic sources for urban residents to carry out a series of residential activities and also provide support for the construction of urban architectural environments. As external elements, spatial form elements provide environmental support for urban human settlement activities. As a material element, the population size factor provides basic support for the vitality of urban human settlements. An appropriate population size is conducive to increasing the intensity of urban human settlement activities to promote the vitality of urban human settlements. The four elements of the natural environment, social economy, spatial form, and population size affect and interact with each other to jointly promote the development of vitality in urban human settlements.

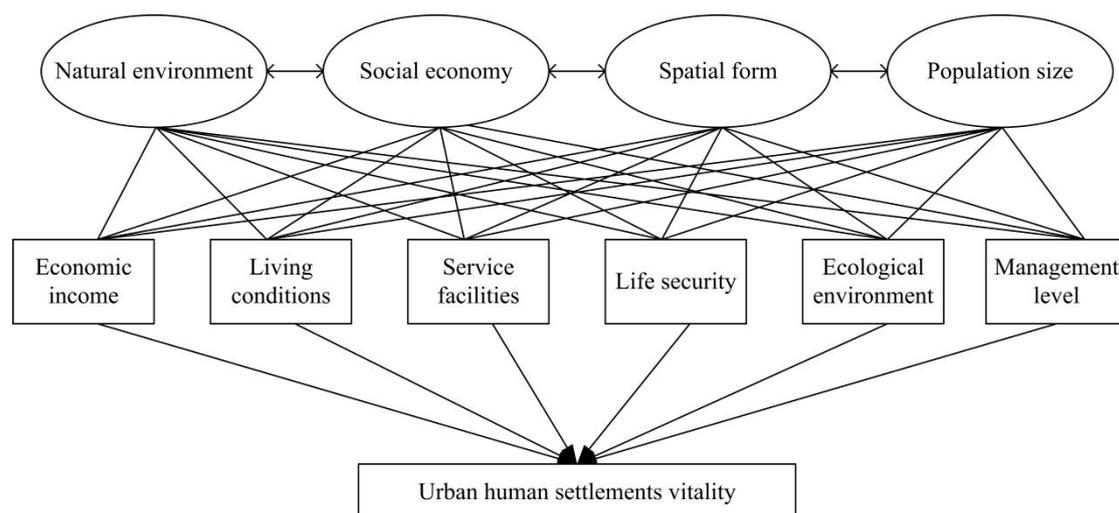


Figure 6. Mechanism of influencing factors of urban human settlements vitality.

5.2. Optimization Measures

Specific suggestions for the vitality development of urban human settlements in the four districts of Dalian are as follows: (1) Create a good city brand. It focuses on creating

a comfortable urban space environment, strengthening the construction of urban management teams, and combining the construction of a hard urban settlement environment with the construction of soft urban settlements. On the other hand, paying attention to regional, historical, and cultural construction gradually forms a regional brand image and enhances regional attractiveness. (2) The vitality of urban human settlements had an obvious positive spatial dependence effect. Each region should strengthen its cooperation with neighboring regions to achieve linkage cooperation. To achieve cross-regional cooperation driven by policies, it is necessary to establish a comprehensive cooperation mechanism, reach consensus on regional cooperation under its guidance, improve the transportation network, build a comprehensive transportation network, and jointly promote infrastructure construction. (3) The three-industry structure of Dalian in 2018 was 6.6:38.1:55.3, indicating that tertiary industry has become the main pillar of Dalian's economic growth. It is essential to accelerate the optimization and upgrading of industrial structures and provide more information for the development of the modern service industry.

5.3. Limitations

This study combines urban human settlements with urban vitality, analyzes the concept and connotation of urban human settlement vitality, and expands the research field of urban human settlements to a certain extent. However, urban human settlements are an open and complex giant system, and their vitality has characteristics such as complexity and chaos, which leads to certain limitations of research. First, this study is limited to the availability of data, the impact of government policies and other indicators are difficult to quantify, and the vitality evaluation index of urban human settlement needs to be further improved. In addition, the vitality of human settlements has evident scale effects, and the vitality of human settlements at different scales has different characteristics. There is an urgent need to conduct research on the vitality of urban human settlements at the scale of a municipality, urban area, block, community, and village or town and to explore the scale effect of the vitality of human settlements at different scales. Because of the limitation of data acquisition means, it is difficult to conduct research at a more micro scale. In the future, we can combine a variety of data means and use big data such as Baidu thermal data [54] to promote the high-quality integration of multi-source data and explore the spatial distribution characteristics and influencing factors of the vitality of urban human settlements at a more micro scale [51]. Finally, the COVID-19 pandemic has had a significant impact on global urban construction, limiting urban residents' travel and other activities, thus affecting the vitality of urban human settlements [55,56]. However, the impact of the COVID-19 pandemic on the vitality of urban human settlements was not considered in this study, because it was before the epidemic. The impact of COVID-19 on the vitality of urban human settlements will be explored further in the future. In view of the above limitations, the vitality of urban human settlements should be studied in the future to provide a reference for urban fine management.

6. Conclusions

In the past, most relevant research on cities has focused on macro-and micro-scales, and there has been no relevant research on the micro scale. As the urban grassroots management organization, the sub-district office explored the current situation regarding the vitality of the entire residential environment in the street, paid attention to the dialectical relationship between the whole and parts, analyzed the spatial differentiation pattern and influencing factors of the vitality of the residential environment in the street, carried out the vitality construction of street residential environments, and used the development of street human settlement vitality to promote the development of urban overall residential vitality.

The city center shows a high vitality of urban human settlements in terms of the urban architectural environment, urban human settlement activities, interaction between people and activities, and comprehensive dimensions. Overall, the vitality of urban human settlements gradually decreases from the city center to the administrative boundary, which

is similar to Sung’s conclusion [25], showing a spatial distribution trend of “high in the east and low in the west, high in the south, and low in the north”. The vitality of urban human settlements presents unbalanced development in space, and the inter-regional interdependence is strong, with a relatively obvious “Matthew effect”. Vitality hotspots of urban human settlements in the main urban area of Dalian are mainly distributed in the southeast. The spatial differentiation pattern of the vitality of urban human settlements is the result of multiple factors intertwining and influencing each other [19]. Commercial development, spatial structure, spatial form, and human capital are significant influencing factors, similar to the conclusions of previous studies [52].

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