

Article

Composite Characteristic and Mechanism Analysis of Human Settlements in Jinan City Based on Demand Hierarchy Theory

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Abstract: The composition of human settlements is important to resolving urban issues, such as land shortage, and to rationally distributing human settlements and social resources. Based on the demand hierarchy theory, this paper comprehensively used the methods of location entropy, information entropy, and geographic detector to analyze the characteristics and driving mechanism of the specialization, composition, and compatibility of human settlements at all levels. (1) The composite characteristics of human settlements were influential; that is, clear concentration differences were found among various types of human settlements, with the specialization of primary human settlements having the highest concentration. The specialization of human settlements was characterized as center–periphery; that is, the centrality of basic and high-level human settlements was obvious and the discreteness of primary human settlements was obvious. (2) The spatial differences in the north–central–south compositions of human settlements were also influential. These spatial differences showed that the composite characteristics of the basic high-level and intermediate high-level human settlements were similar, and the composite features were weakly affected by the scale of the elements. (3) Furthermore, single human settlements were dominant, and the multi-level human settlements that were compatible with the comprehensive composite form were the primary form of expression. The interactions between the primary and other human settlements were relatively high. Finally, (4) the high-level human settlement elements and regional economic vitality were the dominant factors of the composite characteristic heterogeneity of human settlements. Residential self and social attributes have an impact on the diversity of their needs, and they interact with human settlements through human settlement elements. The results of the study are of great significance to the rational allocation of human settlements and the promotion of the composition of human settlements.

Keywords: demand hierarchy theory; human settlements; composite feature; driving mechanism; Jinan (Shandong Province)



Citation: Gao, J.; Cao, F.; Sun, D.; Bai, Z.; Lang, Z. Composite Characteristic and Mechanism Analysis of Human Settlements in Jinan City Based on Demand Hierarchy Theory. *Buildings* **2023**, *13*, 1624. <https://doi.org/10.3390/buildings13071624>

Academic Editors: Linchuan Yang, Bao-Jie He and Junqing Tang

Received: 13 January 2023

Revised: 23 February 2023

Accepted: 10 March 2023

Published: 27 June 2023



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1. Introduction

The composition of human settlements refers to the existence of multiple human settlement elements within a specific urban space, giving it functional composite characteristics. Information technology has been redefined [1] and fundamentally changed [2] since the 1990s, making traditional urban spaces more flexible in location selection and regional layout [3].

Human settlements are living spaces closely related to human behavior and are a combination of the physical environment and its activity facilities [4]. It lays more importance on artificial space and focuses on providing comfortable residences and facilities for inhabitants [5]. According to Maslow’s demand hierarchy theory, the continuous satisfaction of demands leads to more complex demands [6]. The rapid development of

the national economy in China has led to the diversification and composition of residential needs. The “composition of human settlements” has been applied to meet the diversification of these demands.

Western scholars pay more attention to public facilities and residential spaces to meet the basic needs of residents, which exhibit heterogeneity due to the needs of the subject [7], and their distribution and evolution are affected by various socioeconomic factors, such as land use [8] and urban expansion [9]. The layout of public facilities can be affected by the supply [10] and demand of public facility resources [11], the difference in the availability of different facilities [12], the matching degree between the supply and service capacity of public facilities [13], and the allocation of facility resources [14]. Human settlements in China are researched on microscale and macroscale, with microscale research mostly focusing on single human settlements and having attributes of both physical and social spaces [15,16]. Additionally, with the diversification of residential demands, microscale human settlements, such as commercial spaces for consumption [17] and shopping behavior [18], public service spaces supported by public facilities [19], and recreation space meeting the leisure needs of residents [20], tend to be refined. The research on the macroscale characteristics of human settlements considers regions or urban agglomerations as units to evaluate their formation, evolution [21,22], spatial expansion [23], and connection [24]. Human settlements are generated from the continuous development of demand, and the gradual change of demand has promoted the change of the composite characteristics of human settlements. Maslow’s hierarchy demand believes that human needs are pyramid-shaped by the needs of physiology, security, emotion and belonging, respect, and self-realization, and it believes that human needs are a gradual process from low-level needs to high-level needs. Only when the low-level needs are met can they be turned to the higher-level ones. At present, there are still few relevant research on human settlements based on Maslow’s hierarchy of needs theory, mainly focusing on improving the hard and soft environment of human settlements through the change of needs, and the quality of human settlements for specific groups based on the hierarchy of needs theory.

According to domestic and foreign research, scholars at home and abroad have mostly focused on single human settlements, with few studies having been based on the demand perspective and the research on the composition of human settlements being relatively lacking.

Information technology developments have made profound changes in the composite characteristics of human settlements in Jinan while the adjustment of administrative divisions and the advancement of the “Sponge” Project have identified the composition of human settlements as an important trend of spatial development in Jinan; however, Jinan still faces the problems associated with single urban structures and disordered spaces. This study uses demand theory to combine an empirical study of “New Jinan” and reveals the composite characteristics and driving mechanism of human settlements to enrich human settlement research and provide a reference for the layout of human settlements in Jinan and its overall economic development. The overall framework of this paper is as follows: the first part is the introduction, the second part is the methods and data, the third part is the empirical research, namely, the composite characteristics of human settlements in Jinan, the fourth part is the mechanism construction, and the fifth part is the conclusion and discussion.

2. Methods and Data

2.1. Study Area and Data Sources

On 9 January 2019, Laiwu City became a part of the Jinan City jurisdiction, and this administrative change has complicated and unoptimized urban spaces. Research on the composition of human settlements has been mostly characterized by urban land use, but its application is limited because the data are difficult to obtain and have low accuracy. The rapid development of the internet has made big data a new data source, among which POI data are widely used for urban space research because of its accessibility [25,26] (Table 1), and also become the main data of this study. Since the research scale is city and the research

unit is street, it is difficult to obtain the multi-source data that meet the requirements and have time consistency. This paper only selects the corresponding data of the year to conduct a rough study on the composite mechanism of human settlements in Jinan.

Table 1. Data types and sources.

Data Types	Data Sources
POI	Gaode Map (captured in March 2019, https://lbs.amap.com/ , accessed on 12 January 2023)
Road network	Openstreet (captured in 2019, http://www.openstreetmap.org/ , accessed on 12 January 2023)
Night light	NOAA (2018)
Land use	Resource environment data cloud platform (2015, https://www.resdc.cn/ , accessed on 12 January 2023)
Population	The Sixth National Population Census (2010, http://www.stats.gov.cn/sj/pcsj/rkpc/dlcrkpcsj/ , accessed on 12 January 2023)

Using Maslow’s demand theory [27], combined with facilities and resources, this study defined living and eating as the primary needs of residents in basic human settlements and residential safety and environmental quality as their secondary needs, with the safety provided by the government being divided into primary human settlements. Social interaction is the tertiary demand of residents, with the elements of social attributes divided into intermediate human settlements. Finally, self-actualization is the highest level of demand, with the non-essential elements divided into high-level human settlements (Table 2). The data were preprocessed by de-duplication, with 398,067 data obtained and streets used as the research unit.

Table 2. Human settlements categories, number of elements, and proportion.

Human Settlements Categories	Maslow’s Demand	Elements	Number	Proportion %
Basic human settlements	Basic living	Catering and housing	80,588	20.2
Primary human settlements	Living safety	Medical, science and education, public facilities, transportation, government organizations, and banks	67,400	16.9
Intermediate human settlements	Social behavior	Shopping, life services, enterprises, companies, and insurance	234,276	58.9
High-level human settlements	Self-actualization	Leisure and entertainment, sports venues, hotels, and scenic spots	15,803	4.0

2.2. Methods

2.2.1. Location Quotient

The location quotient is often used to measure the concentration level of an industry in a region, with higher values correlating to higher specialization rates [28]. It is used to analyze the degree of concentration of each level of human settlements to indicate the specialization of human settlements, and its meaning is shown in Table 3.

$$LQ = e_{k-a} / e_k \quad (1)$$

where LQ is the location entropy, e_{k-a} is the ratio of human settlement elements at level a in street k to all human settlement elements at level a in the study area, and e_k refers to the ratio of total human settlement elements in street k to all human settlement elements in the study area.

Table 3. Location entropy value range.

LQ Value Range	Connotation
$LQ < 1$	The human settlement concentration of the street is less than the average concentration of the study area
$LQ = 1$	The human settlement concentration of the street is equal to the average concentration of the study area
$1 < LQ < 1.5$	The human settlement concentration of the street is higher than the average concentration of the study area
$LQ > 1.5$	The human settlement concentration of the street is significant

2.2.2. Entropy Index

The entropy index was introduced into composition of human settlement calculations, with the proportion of human settlement elements at each level replacing the proportion of land use [29], as follows:

$$EI_i = \frac{-\sum_{k=1}^k (p_{ki}) \ln(p_{ki})}{\ln(k, i)} \quad (2)$$

$$p_{ki} = \frac{x_k}{\sum_{k=1}^k x_k} \quad (3)$$

where EI_i refers to the composition of human settlements, k refers to the number of human settlements levels, and P_{ki} is the proportion of k human settlements in street i . x_k refers to the quantity of the k -type of human settlement elements. The data deviation was standardized to eliminate dimension-induced errors. The larger the E_i , the higher the composition of human settlements.

2.2.3. GeoDetector

GeoDetector is a statistical method used to reveal spatial differentiation and driving factors that can express similarities within a unified region and differences between different regions [30,31]. It is calculated as follows:

$$q = 1 - \frac{1}{n\sigma^2} \sum_{n=1}^l n_h \sigma_h^2 \quad (4)$$

where q is the explanatory power of the influencing factor, with a range of $[0, 1]$, with the larger q values correlating to a greater effect that the dependent variable has on the spatial differentiation; n is the number of samples in the study area; σ^2 is the dispersion variance of the Y value in the whole study area; h is the partition of variable or factor; and l is the number of partitions.

3. Composite Characteristics of Human Settlements in Jinan

The composite characteristics of human settlements are characterized by the degree of specialization, complexity, and compatibility of human settlements. Among them, the degree of specialization is characterized by location entropy. The balanced distribution of human settlements indicates the composite characteristics of human settlements. The composite type further reflects the compatibility of human settlements in Jinan. Taking the street as the research unit, with the help of ArcGIS, the human settlement elements at all levels are obtained and characterized by location entropy and information entropy.

3.1. Specialization of Human Settlements

The quantitative grade and location entropy distribution of human settlements on each street (Figure 1) showed that each street in Jinan City contained different levels of human settlement elements, indicating that it had significant composite characteristics. The concentration of these elements showed that the location entropy of most streets was less than 1; however, differences in the concentration of human settlements were present at all

levels. The number of streets with a location entropy value of primary human settlements greater than 1.5 was the largest and their specialization was the highest. A clear “concave” distribution indicated that the specialization of primary human settlements in central urban areas was low and that the living safety needs of the residents were sufficiently met. The concentration of intermediate human settlements had the most considerable difference between the north and south. High-level human settlement elements met the quality of life needs of residents, with the concentration in the south of Licheng District being the highest and that in Jiyang County, Shanghe County, and Laiwu District being low. The specialization of human settlements on the city scale was characterized by center–periphery, with a clear centrality of basic and high-level human settlements and obvious discrete features of primary human settlements.

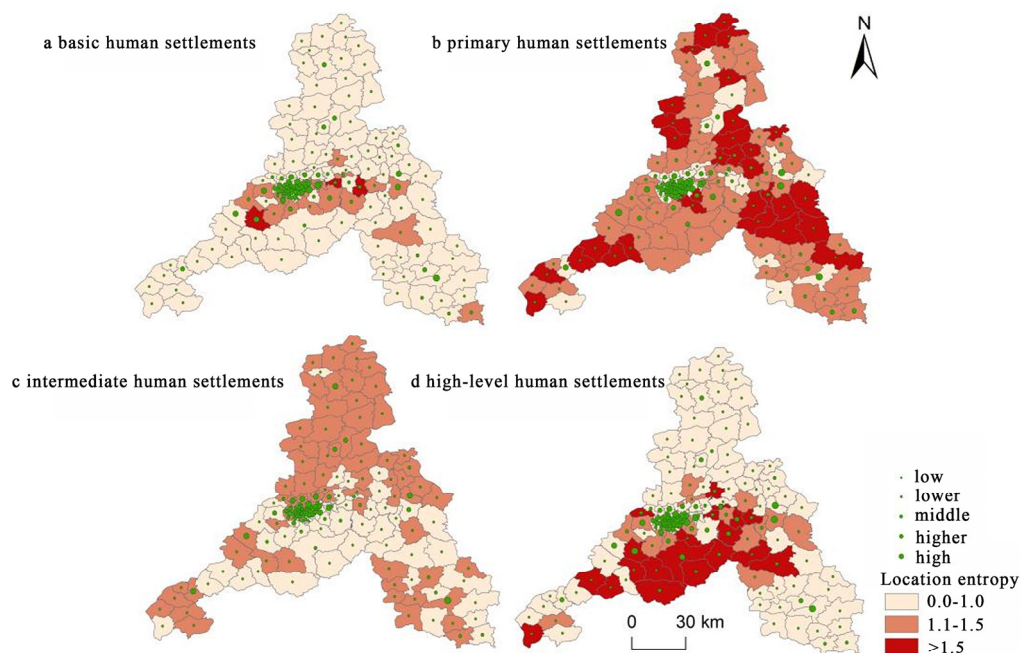


Figure 1. Quantitative grades and location entropy distribution of human settlement factors at different levels.

3.2. Composite Characteristics of Human Settlements

The composition of human settlements reflects the distribution of their elements and forms different composite characteristics of human settlements. Overall, the “north–central–south” spatial difference in the composition of human settlements was marked, that is, the south of Licheng District and Zhangqiu District in the middle had relatively high values, while the northern Shanghe and Jiyang Counties and southern Pingyin and Laiwu Districts had relatively low values. Based on the compositions of different types of human settlements, the composite characteristics of basic and intermediate high-level human settlements were similar, indicating that the high-level human settlements were dominant in these types of human settlements. The composite degrees of primary, intermediate, and high-level human settlement elements were the highest overall; that is, they were higher than those of each of the other elements and basic human settlements. Based on the relationship between the quantitative grade (Figure 1) and the composition of human settlement elements (Figure 2), the compositions of regions with more human settlement elements were low because there were more types of elements and no dominant element.

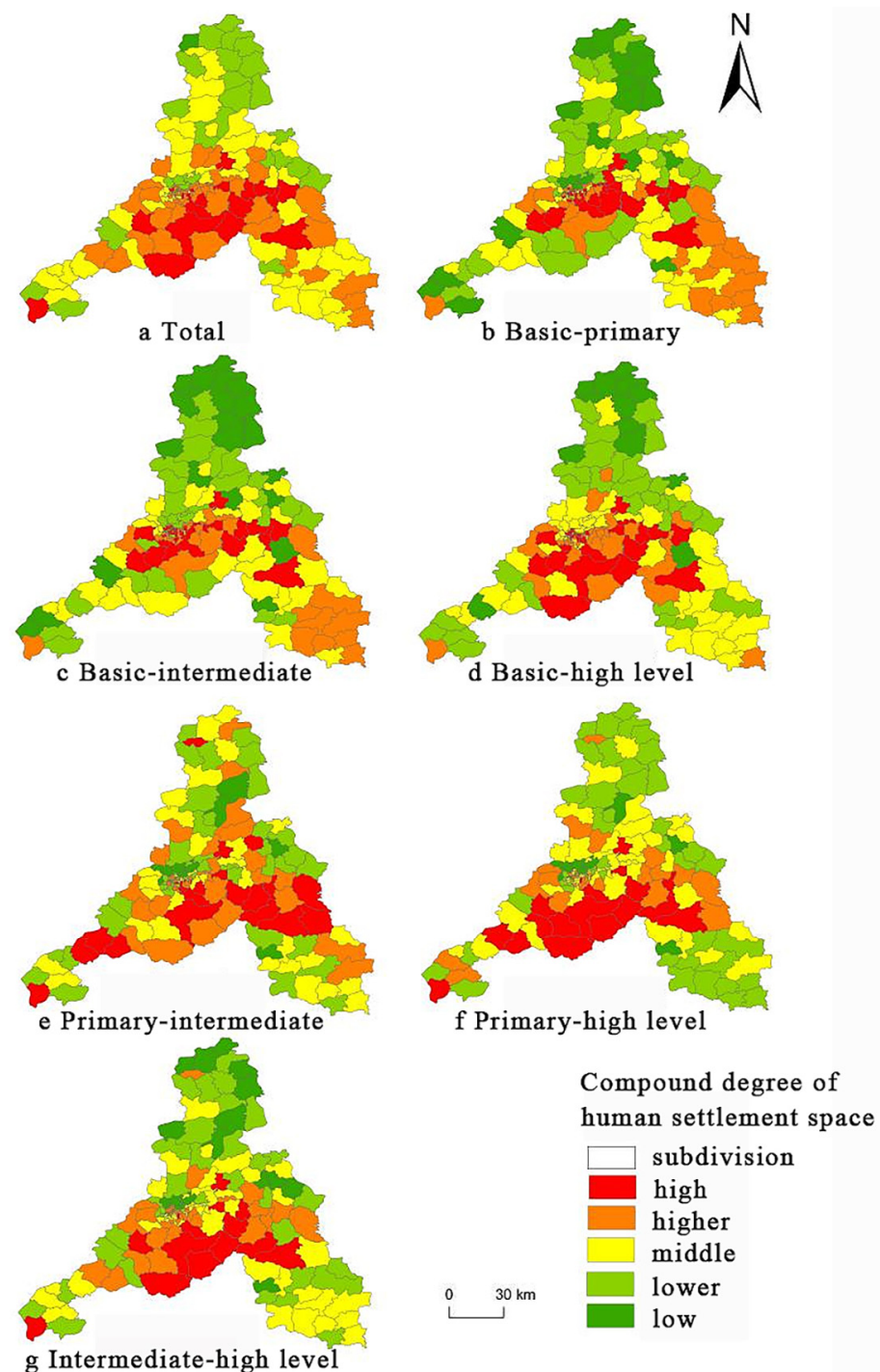


Figure 2. Composite distribution of human settlements in Jinan City.

3.3. Compatibility of Human Settlements

To clarify the human settlements and their compatibility using the location entropy, the composite types of human settlements were described (Figure 3). Statistical analysis showed that the location entropy values of two or more human settlement elements in each street were greater than 1, but only one was greater than 1.5. The results also showed that nine streets showed mature composites of basic and primary high-level human settlements (i.e., Q values are greater than 1.5), and 40 streets showed comprehensive composites of single human settlements. Additionally, in single human settlements, the primary and high-level human settlements were dominant. In composite human settlements, the primary

intermediate and primary high-level human settlements were dominant, while other types were relatively rare.

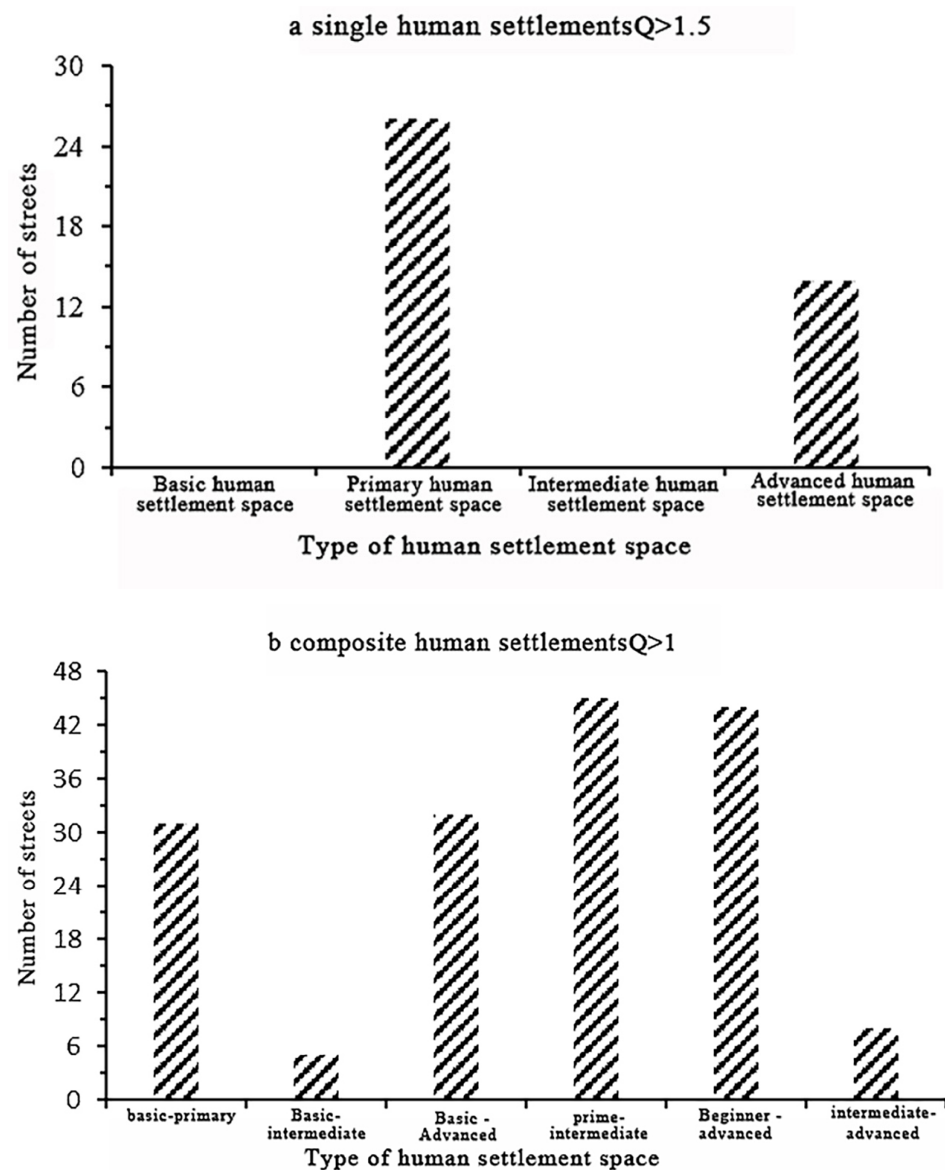


Figure 3. Quantitative characteristics of each type of human settlements.

In the human settlements that had concentrations higher than the regional average level (i.e., Q value greater than 1), the number of streets with primary, intermediate, high-level, and basic human settlements were 45, 44, and 31, respectively. A strong interaction between primary and intermediate human settlements was present, with a high compatibility between them, and high-level and basic human settlements had subsequently lower interactions and compatibilities. Furthermore, the compatibility between intermediate, basic, and high-level human settlements was weak, and exclusion existed between them.

4. Mechanism

4.1. Driving Factor Construction

Human settlements are influenced by internal attributes and external factors to form different types of human settlements. Based on the dichotomy, this paper selected the internal human settlement elements and the external factors to explore the formation mechanism of the composite characteristics of human settlements in Jinan. The internal

attributes include the total amount of human settlement elements at each level and street, and external factors include the infrastructure, land use, regional economic vitality, and population, which are characterized by road network density, land use mix, night light, and population size (Table 4).

Table 4. Construction of driving factors.

Type	Indicator	Connotation
Internal attributes	Human settlement elements X_1 – X_5	Constitute the basic elements of different types of human settlements
	Infrastructure X_6	Road network is the leading and basic factor that forms and affects human settlements. Select the road network density to represent the basic factor that affects human settlements.
External factors	Land use X_7	Land use structure directly affects the distribution of human settlements, and the land use mix degree is selected to represent the land use structure.
	Regional economic vitality X_8	Previous studies have confirmed that there is a positive correlation between night light and regional economy, and night light is selected to represent the economic vitality of street scale.
	Population X_9	The main body of residents is an important factor in the formation of human settlements. Places with large population density are more likely to produce composite human settlements. Select the number of population as an external factor to explore its impact on human settlements.

4.2. Driving Factor Detection

The overall comprehensive composite degree q value of the human settlements was 0.75, indicating that the composite characteristics of human settlements were impactful. We measured the q values of the human settlement compositions at all levels and found that primary and intermediate had a value of 0.66, basic and primary had a value of 0.63, basic and intermediate had a value of 0.62, primary and high-level had a value of 0.46, intermediate and high-level had a value of 0.45, and basic and high-level had a value of 0.43. Overall, clear differences were present in the compositions of human settlements at all levels, with the largest difference existing between the primary and intermediate, and the smallest difference existing between the basic and high-level.

We measured the q values of factors affecting the composition of human settlements using GeoDetector. X_1 represents the total number of human settlements, X_2 – X_5 represents basic, primary, intermediate, and high-level human settlements, and X_6 – X_9 represents road network density, land use mix, total amount of night light, and population, respectively (Table 5).

Table 5. Detection results of human settlement complexity factor.

Dependent Variable	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉
Total	0.11	0.14	0.12	0.09	0.24	0.10	0.18	0.20	0.08
Basic–primary	0.17	0.24	0.21	0.12	0.22	0.14	0.17	0.26	0.05
Basic–intermediate	0.33	0.43	0.37	0.21	0.44	0.29	0.28	0.28	0.07
Basic–high level	0.36	0.39	0.33	0.20	0.57	0.26	0.33	0.26	0.09
Primary–intermediate	0.13	0.08	0.03	0.25	0.03	0.05	0.02	0.18	0.14
Primary–high level	0.09	0.07	0.03	0.19	0.05	0.08	0.10	0.12	0.12
Intermediate–high level	0.06	0.07	0.06	0.07	0.20	0.06	0.18	0.14	0.09

Our results found that the high-level human settlement elements (X₅) and regional economic vitality (X₇) were the primary factors for the heterogeneity of their composite characteristics, and the population had the weakest influence on the heterogeneity. The basic and primary human settlements predominantly met the first and second levels of the residential needs and have little impact on the heterogeneity. High-level human settlement elements primarily met the highest needs of residents, and their distribution should be based on the realization of the first three levels of needs, which have a great impact on the heterogeneity. The vitality of the regional economy reflected the prosperity of the economy, and the degree of economic development was positively related to the diversity of residential needs and the composition of human settlements. As the basis of residential demand, the population size affected the diversification of demands to a certain extent; for example, the population was substantial, but the overall development was poor, and its demand was difficult to diversify.

Based on the influencing factors of different types of composition in the basic primary, basic intermediate, and basic high-level composite human settlements, except for the population factor, the influence of the other factors was higher than that of other composite human settlements. In the primary intermediate and primary high-level composite human settlements, the number of primary settlements had a greater influence. In the intermediate high-level composite human settlements, the influence of high-level human settlements, land use mixing, and regional economic vitality was higher than that of other factors. Overall, the influence of basic and high-level human settlements was significantly higher than that of other variables. The influence of regional economic vitality on the composition of all levels of human settlements was obvious, indicating that the economy was the dominant reason for the differentiation of the composite characteristics of human settlements. The road network density and population have the least impact on heterogeneity.

4.3. Driving Mechanism Analysis

The composition of human settlements is affected by various factors. Combined with the development of Jinan City, we proposed a mechanism of interaction between residential demands and human settlements (Figure 4).

Both residential self and social attributes impact the diversity of residential needs. In terms of the self attributes of residents, without a good population base, forming a large-scale demand is difficult; however, the higher the income, the easier high-level demand forms. Similarly, the level of education impacts demand diversity through income and other factors. The richer the age structure is, the stronger the heterogeneity of the residential demands. Furthermore, if other factors are equal, the age structure plays a positive role in the diversity of demand. The impact of social attributes on residential needs was mainly reflected by economy and facility perfection, which are the related preconditions for such needs. Specifically, the higher the degree of economic development, the easier it is to stimulate residents, thus generating and diversifying demand. The more perfect the regional facilities are, the more they can meet the needs of residents and promote the continuous generation of demand. However, the demand diversification promotes the increase of human settlement elements, making it possible to reduce the composition of human settlements without dominant human settlement elements.

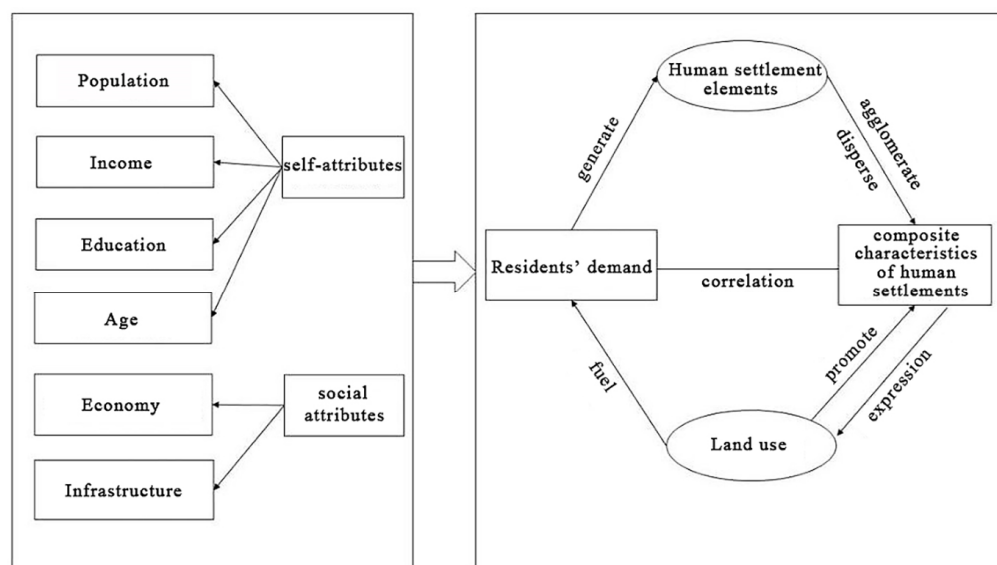


Figure 4. Mechanism of composite characteristics of human settlements.

A correlation existed between the interaction between residential needs and the composition of human settlements. Human settlement elements are media, and the satisfaction of demand promotes their generation. The agglomeration and dispersion of these elements directly affect the composite characteristics of human settlements. Simultaneously, this can also be shown through land use; that is, different types of human settlements have different land use characteristics, and the change of land use further expedites the diversification of residents' demand.

5. Conclusions and Discussion

Taking Jinan City as an example, this study analyzed the composite characteristics of human settlements at the street-level based on Maslow's demand hierarchy theory to reveal its formation mechanism. Our conclusions are as follows:

(1) The composite characteristics of human settlements in Jinan were impactful, the concentration of various types of human settlement elements differed, and the specialization of primary human settlements was the highest. The specialization of human settlements was characterized by center–periphery; the centrality of basic and high-level human settlements and the discrete features of the primary human settlements were obvious.

(2) The spatial differences of the composition of human settlements in the “north–central–south” were considerable, but the correlation between aggregation scale and the composition was weak. The composite characteristics of high-level human settlements were similar to those of the basic and intermediate human settlements. The composite degree of primary, intermediate, and high-level human settlement elements was the highest overall, and their composite degree was higher than that of the combination of them with the basic human settlements. The composite characteristics of human settlements reflected the relatively co-ordinated distribution of human settlements, which was weakly affected by the scale of human settlements.

(3) The composition of human settlements in Jinan was primarily single human settlements and was compatible with multiple types of human settlements. In the single human settlements, primary and high-level human settlements are the main types of settlement, and the composite human settlements were primarily composed of primary intermediate and primary high-level human settlements. The interaction between primary and intermediate human settlements was strong, and the introduction of primary human settlement elements had positive significance for the composition of human settlements. The compatibility of intermediate, basic, and high-level human settlements was weak.

(4) The heterogeneity of the composite degree of human settlements at each level was significant, and the high-level human settlements and regional economic vitality were the main factors for the heterogeneity. Both the internal and social attributes of residents had an impact on the diversity of needs, and they act on the composition of human settlements through the elements.

As a complex giant system, the composition and formation mechanism of human settlements also showed complexity, which deeply reflected the relationship between residential needs and human settlements and the spatial concentration and dispersion of human settlements. According to the needs of residents to the rational allocation of human settlement elements, the formation of a functional and complex human settlement space was the key point of Jinan's future urban development. This paper only made a basic analysis of the composite characteristics and driving mechanism of human settlements in Jinan. However, the needs of the Maslow's demand hierarchy are relatively broad, and it is difficult to fully express them with human settlements, so this study still has some limitations in the expression of human settlements. Secondly, limited by the availability of data, some data of the mechanism analysis had some impact on our results. In the future, we will acquire more accurate data and increase the accuracy of our conclusions to improve the driving mechanism.

Author Contributions: Conceptualization, J.G., D.S. and F.C.; methodology, Z.B.; software, Z.L.; validation, J.G.; formal analysis, J.G.; investigation, J.G.; resources, J.G.; data curation, J.G.; writing—original draft preparation, J.G.; writing—review and editing, J.G.; visualization, J.G.; supervision, J.G.; project administration, J.G.; funding acquisition, J.G. All authors have read and agreed to the published version of the manuscript.

Funding: Liaoning Provincial Department of Education Basic Research Project for Higher Education Institutions (J202154) 2022 Liaoning Provincial Social Science Planning Fund Project: Research on Countermeasures for Digitalization to Promote the High-quality Development of Liaoning Cultural Industry, (L22BJY009). 2023 Liaoning Provincial Social Science and Technology Union Project: Research on the Construction of Shenyang Palace Cultural Relics Data Platform Based on Digital Twin (2023LSLYbkt-010).

Data Availability Statement: The research data were obtained by the author through Python or official website.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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