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Special Issue Reprint

Trends in Real Estate Economics and Livability

Edited by
Yang Wang, Wangbao Liu and Pingjun Sun

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About the Editors

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Preface

This Reprint, titled “Trends in Real Estate Economics and Livability”, compiles a selection of peer-reviewed articles from the *Buildings* Special Issue of the same name. The diverse collection of studies compiled in this volume addresses critical dimensions of contemporary urban and rural development, housing markets, and socio-spatial dynamics. Spanning multiple geographical contexts from China to Riyadh and Poland, these works explore spatial–temporal variations in housing conditions, the impacts of demographic shifts on urban–rural integration, and the role of consensus-based measures in real estate markets. They delve into the socio-economic implications of housing affordability among floating populations, esthetic preferences shaping residential architecture, and the preservation of heritage buildings amid rapid urbanization. Investigations into gentrification linked to childhood left-behind experiences and sports participation, as well as spatial patterns of rural settlements under demolition policies, reveal the nuanced interplay between individual histories and urban transformation. The anthology further examines challenges posed by population shrinkage, the influence of educational resources on housing segregation, strategies for green urban renewal, historical districts in China, and retail forecasting during the COVID-19 pandemic.

We extend our sincere gratitude to all 15 contributing authors, whose rigorous scholarship and innovative perspectives form the backbone of this Reprint. Their work not only advances academic discourse but also provides actionable recommendations for policymakers and practitioners. Special thanks are due to Ms. Hilary Li, the Section Managing Editor, for her exceptional coordination and unwavering commitment to maintaining the highest editorial standards. We also acknowledge the invaluable contributions of the anonymous reviewers, whose expertise and constructive critiques ensured the intellectual rigor and relevance of each article.

This Reprint is designed for a multidisciplinary audience, including researchers in urban economics, policymakers addressing housing crises, planners balancing growth with sustainability, and educators shaping future leaders in real estate and urban studies. By synthesizing empirical findings, theoretical frameworks, and policy implications, this collection aims to inspire innovative strategies for fostering equitable, resilient, and livable cities. As urbanization continues to redefine human habitats, we hope these insights will catalyze meaningful dialog and action toward building inclusive communities where economic vitality and quality of life thrive in tandem.

Yang Wang, Wangbao Liu, and Pingjun Sun
Guest Editors

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Article

Spatial Variation Characteristics of Housing Conditions in China

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Abstract: The evaluation of housing conditions is a crucial aspect of determining the well-being of residents and the sustainable development of settlements. Assessing housing conditions at a macro-level is imperative to understand the differences in well-being and livability among residents in various regions within a country. Unfortunately, the spatial variation characteristics of housing conditions in China have not been extensively studied at the county scale. Thus, this study examines the housing conditions in China by using 2846 counties as the basic research unit. A housing condition evaluation index system, comprising seven indicators, is constructed based on three aspects: housing spaciousness, internal facilities, and elevator configuration. The entropy value method is used to determine the weights of the indicators, and the spatial difference patterns and spatial autocorrelation characteristics of the housing conditions and types of housing conditions in China are analyzed. The correlation analysis method is used to analyze the correlation between the subtypes of housing conditions and county fundamentals (population density, urbanization, foreign population, and rental housing). The results show that: (1) the configuration of elevators is the most important indicator of the differences in housing conditions in China; (2) the better housing conditions in China are distributed on the southeast side of the "Hu Line", while the worse areas are distributed on the northwest side of the "Hu Line", showing significant spatial clustering characteristics, while the distribution of the different subtypes of housing conditions and their distribution in the H–H and L–L zones also have significant variability; (3) housing conditions in China's urban areas are generally better than those in non-urban areas, and the internal infrastructure conditions of urban housing and the degree of elevator configuration are better than those in non-urban areas; and (4) the correlation between housing conditions and county fundamentals varies depending on the regional level. At the national and urban levels, a negative correlation exists between county fundamentals and housing spaciousness, although a positive correlation exists with internal infrastructure and elevator configuration. Urbanization has the greatest impact on housing conditions in these areas. In non-urban areas, there is significant variability in the correlation between county fundamentals and housing conditions.

Keywords: housing conditions; housing spaciousness; internal facilities; elevator configuration; spatial characteristics; correlation analysis; county fundamentals; China

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1. Introduction

Housing is a fundamental issue that determines the sustainable development of cities and regions. Improving the housing conditions of residents and their well-being, and building sustainable settlements, is an important approach toward sustainable development and a continuous effort in many countries around the world. Housing conditions are highly correlated with health, public safety, and life satisfaction [1–3]. With rapid economic development, housing conditions have become significantly differentiated across regions and the instability of housing conditions has increased, which has led to increased differentiation between groups with different socioeconomic backgrounds [4], highlighted by health inequalities [5], violent crime risk differences [6], and residential energy differences [7,8]. This reduces the well-being and identity of the population and exacerbates the instability of social development. Housing conditions are the most important factors affecting physical health [9] and residential satisfaction [10,11], and they are the core evaluation indicators for evaluating the livability of a city (or region) [12]. Indicators related to housing conditions also influence the level of housing prices or rents [13,14]. More importantly, housing conditions and sustainable development are closely related. Improving housing conditions is often considered an essential aspect of sustainable development, as it can contribute to residents' well-being and the overall livability of cities and regions. Therefore, assessing housing conditions is crucial for understanding the social, economic, and environmental dimensions of the concept of "sustainability". Therefore, conducting research on topics related to housing conditions is necessary. This is an important fundamental study of practical significance for building livable cities, solving urban problems, and promoting stable social development.

Housing conditions are an important topic in housing research [15]. It has been shown that spatial differences exist in housing conditions, mainly in the form of housing condition differentiation [16] and housing condition inequality [17], while the spatial clustering of such differential characteristics portrays the spatial structure of urban housing conditions [18]. The pattern of spatial differences in housing conditions is also an important entry point for reflecting the spatial structure of society [19] and the spatial structure of the housing market [20]. Therefore, research on spatial differences in housing conditions is fundamental and key to understanding their economic and social aspects. This research can be divided into two main areas: evaluation of housing conditions and factors influencing housing conditions. Morenikeji et al. used indicators such as housing type, decoration materials, water and electricity supply, and domestic toilet facilities to evaluate housing conditions in Nigeria and then analyzed their spatial patterns [21]; Li, Zhang, and Napiórkowska-Baryła et al. used indicators such as floor area per capita, number of bedrooms and number of users, and the presence of a living room or bathroom indicators, to assess housing conditions [10,22,23]; and Gu et al. proposed housing facilities, crowdedness, and housing tenure as indicators of housing conditions and then analyzed the spatial structure of housing conditions and health status in China [24]. In recent years, housing conditions have become a focus of attention during the COVID-19 global health crisis, with Tai et al. arguing that the spaciousness of indoor spaces and the configuration of indoor cleaning facilities affect residents' health [25,26]. In their study, Zarrabi et al. pointed out that natural light, ventilation, and open or semi-open spaces are the housing conditions considered most important by residents [27]. Peters et al. suggested that healthy housing conditions should have a balcony, a living room, and a focus on proper ventilation, lighting, and landscaping [28]. Ahmad et al. evaluated the housing conditions of US counties and regions based on four indicators, namely, overcrowdedness, the high burden of the cost of housing, incomplete kitchen facilities, and incomplete plumbing facilities [29]. Thus, the evaluation indicators of housing conditions are diverse and rich, and the main focus is generally on the level of facilities and spaciousness. However, most housing in Chinese cities is dominated by multi-story and high-rise buildings, and the elevator configuration is also an important aspect when determining housing conditions, as evidenced by the case of the regeneration of old urban neighborhoods [30]. Few studies of existing housing conditions have focused on elevators. In terms of factors influencing housing conditions, Bhattacharjee et al. indicated that education, home ownership, and family preferences influence the housing conditions of refugee immigrants in Dallas, Texas [31]; Babalola used the three main indicators of socioeconomic characteristics, objective housing characteristics, and subjective variables as important predictors of housing conditions [32]; and Nieuwenhuis et al. examined the impact of housing policies on the housing conditions of single mothers in Europe [33]. In macro-scale studies of factors influencing housing conditions, urban (or regional) fundamentals (e.g., population, urbanization, employment, and so on) may be influential factors in relation to housing conditions.

China has a unique urban housing market [5], and its housing problem has been the focus of attention in all sectors of society. The population of cities is increasing rapidly as urbanization continues to advance rapidly, generating a series of housing problems for the low- and middle-income classes and the mobile population [34–36], and conducting research on urban housing conditions in response to the current housing problems in China is necessary. Studies of housing conditions in China have mainly focused on housing conditions and health [5,24,37], housing conditions and satisfaction [10,38], housing conditions and the mobile population [39,40], and housing condition evaluation [41]. However, there is a lack of research on the spatial patterns of housing conditions in China at the county level, which is crucial for understanding and improving housing conditions.

To address this gap in the literature, further studies are necessary to address various issues, such as the differences in housing conditions across China, the characteristics of the spatial patterns of various types of housing conditions, discrepancies between urban and non-urban areas, and the relationship between housing conditions and county fundamentals. These inquiries require further studies and responses from the academic community. Thus, based on 2846 county-level research units, this paper constructs a comprehensive evaluation system for housing conditions in three aspects: spaciousness, internal infrastructure, and elevator configuration; analyzes the differences in housing conditions in China; derives the characteristics of spatial differences in housing conditions in China; and further analyzes the relationship between housing conditions and county fundamentals in China. Compared with previous studies, the innovation points and progress of this study are as follows. First, this study extends the connotation of housing condition evaluation by including elevator configuration into the evaluation system, which is more consistent with the actual housing conditions in China. Second, in terms of such large-scale evaluation of housing conditions in China, this study takes county-level administrative regions as the basic evaluation unit, which is more refined than previous studies' research units. Third, this study analyzes the relationship between housing conditions in China and county fundamentals (e.g., population density, urbanization, proportion of foreign population, and proportion of rental housing). Fourth, this study is concerned with the variability of housing conditions between urban and non-urban areas, which has been overlooked in previous studies. Through its findings, this study expects to provide a new perspective on the study of housing conditions at the macro scale, a new empirical case for the topic of the spatial pattern of housing conditions in China and a basic reference for the regional differentiation of housing policy formulation in China.

The remainder of the paper proceeds as follows. Section 2 provides a detailed description of the materials as well as the methodology of this paper, Section 3 presents the results of this study and their analyses, Section 4 is the discussion section of this paper, and Section 5 presents the conclusions, policy implications, and outlook for future research.

2. Materials and Methods

2.1. Study Area and Data Sources

Counties (including counties, districts, county-level cities, banners, special zones, and forest areas) were used as the study units (hereafter referred to as county-level units), with a total of 2846 (Figure 1), and the study area did not comprise the Hong Kong SAR, Macao SAR, or Taiwan Province. The data were obtained in 2020. The original data were mainly obtained from the 2020 China Population Census Sub-County Information. Among them, districts are municipal districts of municipalities directly under the central government, sub-provincial cities, and prefecture-level cities, with urban functional territories as the main focus, which are referred to as urban areas.

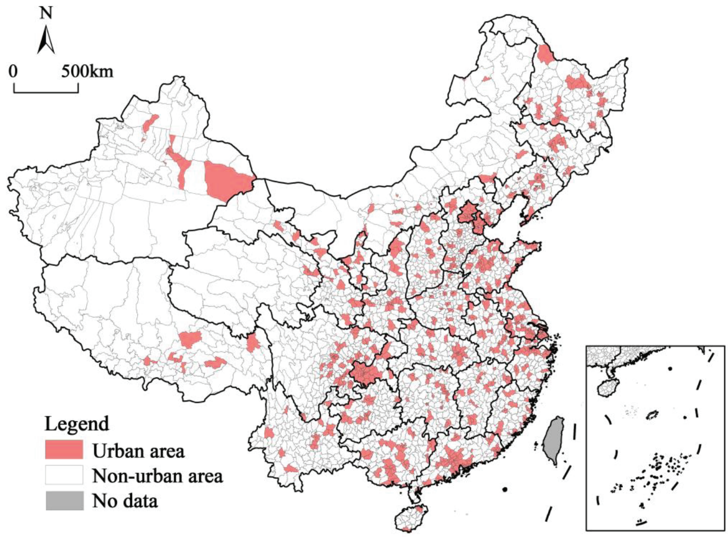

Figure 1. Study area and county unit division.

2.2. Research Design

The specific analysis process of this paper is as follows (Figure 2). First, we construct a comprehensive evaluation index system of China's housing conditions, including seven indicators from the aspects of housing spaciousness, internal facilities, and elevator configuration. Second, this study adopts the entropy value method to determine the weights of the seven indicators, after which it calculates the total score of China's county housing conditions and its three subtypes of scores. Then, we analyze the patterns of spatial differentiation in China's housing conditions. Third, spatial autocorrelation analysis is conducted to identify the spatial autocorrelation characteristics and the distributions of hotspot areas of housing conditions throughout China. Then, we use correlation analysis to explore the relationship and the direction between the county fundamentals and the three subtypes of housing conditions in China. Finally, we draw conclusions, discuss them, and raise policy implications.

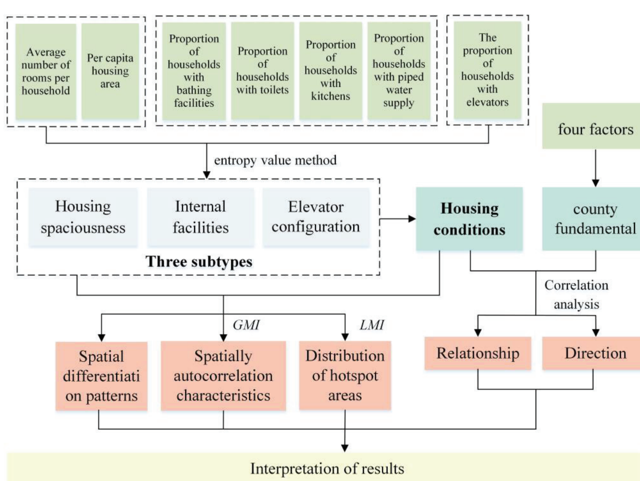

Figure 2. Research design.

2.3. Comprehensive Evaluation System of Housing Conditions

Based on the principles of systematicity, validity, and accessibility of data, the housing conditions of residents in county-level units in China are evaluated comprehensively in three aspects: spaciousness of housing, internal infrastructure, and elevator configuration. Among them, spaciousness is evaluated by the average number of rooms per household and housing floor area per capita, for example, indicators such as the floor area per capita, number of bedrooms, and number of occupants have been used to assess housing conditions in prior studies, e.g., [10,23]. Internal infrastructure is mainly reflected by the configuration of piped running water, as well as kitchen, toilet, and bathing facilities. Indicators such as finishing materials, water and electricity supply, and household toilet facilities were used to evaluate housing conditions in Nigeria in past studies, e.g., [21,22]. The configuration of elevators is based on the ratio of the number of households with elevators in the building where the housing is located. The elevator configuration is an important aspect of housing convenience; housing with elevators is more convenient for residents to go up and down, wherein housing conditions are better (Table 1 and Figure 3).

Table 1. Housing condition evaluation indicator system.

Major Categories	Evaluation Indicators	Abbreviations
Housing spaciousness	Average number of rooms per household (room/household)	AN_room
	Per capita housing area (m^2/person)	PCH_area
Internal facilities	Proportion of households with piped water supply in their housing (%)	PH_piped water
	Proportion of households with kitchens in their housing (%)	PH_kitchens
	Proportion of households with toilets in their housing (%)	PH_toilets
	Proportion of households with bathing facilities in their housing (%)	PH_bathing facilities
Elevator configuration	Proportion of households with elevators in the building where the housing is located (%)	PH_elevators

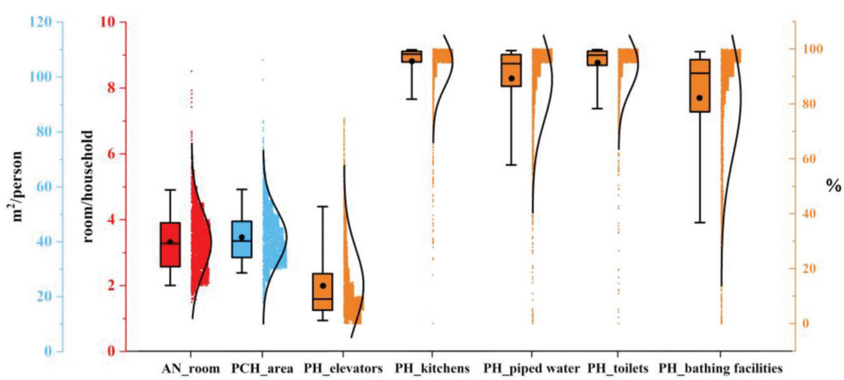

Figure 3. Box plots of the seven housing condition evaluation indicators based on county units in China.

2.4. Determination of Indicator Weights of Housing Conditions Using the Entropy Method

The use of the entropy method to determine weights eliminates the subjective factor of weight determination. The meaning of information entropy in social systems mainly refers to the measure of the degree of uncertainty of the system state. The higher the value of information entropy, the more balanced the system structure is and the smaller the variation; conversely, the more unbalanced the system structure is and the larger the variation is. According to the size of the entropy value of each indicator of housing conditions, the degree of variation is calculated and the weight is determined, and the main steps are [42]:

Standardization of the housing condition single indicator scores:

$$c_{ij} = \left(S_{ij} - S_{j\min}\right) / \left(S_{j\max} - S_{j\min}\right) \tag{1}$$

Calculation of the weight of the score value of the *j*th housing condition evaluation indicator for the *i*th county unit:

$$C_{ij} = c_{ij} / \sum_{i=1}^{n} c_{ij} \tag{2}$$

Calculation of the indicator information entropy:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} (C_{ij} \times \ln C_{ij}),\ 0 \le e_j \le 1 \tag{3}$$

Information redundancy:

$$d_j = 1 - e_j \tag{4}$$

Indicator weights:

$$W_j = d_j / \sum_{i=1}^{m} d_j \tag{5}$$

Total housing condition score for the *i*-th county unit:

$$HCS_i = \sum_{j=1}^{m} (W_j \times S_{ij}) \tag{6}$$

where S_{ij} is the score value of the *j*th housing condition evaluation index of county *i*, $S_{j\max}$ and $S_{j\min}$ are the maximum and minimum values of the matrix column where the *j*th evaluation index is located, *n* is the number of counties, *m* is the number of evaluation indexes, and the larger the score value of the housing condition HCS_i is, the better the housing condition would be. This method can be applied to the evaluation of the total score of comprehensive housing conditions as well as the score of each subsystem of housing conditions (e.g., housing spaciousness or internal facilities).

2.5. Exploring the Spatial Clustering Characteristics of Housing Conditions Based on Spatial Autocorrelation

Housing conditions in neighboring counties are generally spatially related and spatially correlated. The global autocorrelation index (*GMI*) and local autocorrelation index (*LMI*) can quantify the degree of spatial correlation and spatial pattern of housing conditions in China. The *GMI* is expressed as follows [43]:

$$GMI = \sum_{i=1}^{n} \sum_{j=1}^{n} (HCS_i - \overline{HCS})(HCS_j - \overline{HCS}) / Q^2 \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \tag{7}$$

where HCS_i is the residential housing condition score of the *i*th county, w_{ij} is the spatial weight matrix of each county, and the distance between counties within the set threshold distance is 1, and greater than that the distance is 0.

$Q^2 = \sum_{i=1}^{n} \left(HCS_i - \overline{HCS}\right)^2 / n$, Z-test value: $Z(G) = \frac{G - E(G)}{\sqrt{Var(G)}}$, where $Var(G)$ is the variance and $E(G)$ is the mathematical expectation of the housing condition score. If the Z value is significant, it indicates a pattern of spatial clustering of housing conditions in China.

Local autocorrelation between counties often tends to occur based on the global autocorrelation of housing conditions. Therefore, local autocorrelation is measured using the *LMI*, which can be expressed as follows [44]:

$$LMI = \sum w'_{ij} Z_i Z_j \tag{8}$$

where w'_{ij} is the row standardization of w_{ij}, and Z_i and Z_j are the standardized values of the housing condition scores. At less than a 0.05 significance level, if I_i and Z_i are positive at the same time, it means that the housing conditions of the *i*th county and its surrounding counties are better, i.e., high–high agglomeration (HH); similarly, if I_i is negative and Z_i is positive, it is high–low agglomeration (HL); if I_i is positive and Z_i is negative, it is low–low agglomeration (LL); while if both I_i and Z_i are negative, it is low–high agglomeration (LH).

2.6. The Relationship between Housing Conditions and County Fundamentals

Three subtypes of housing condition evaluation indicators (spaciousness, internal infrastructure, and elevator configuration scores) are used as dependent variables, and four factors influencing county fundamentals (population density, urbanization, foreign population, and rental housing) are selected as independent variables in this study to investigate the relationship between housing conditions and county fundamentals in China. The population density is calculated by dividing the resident population by the administrative area, and the urbanization rate (%), the proportion of foreign population (%), and the proportion of rented households (%) are used as indicators of urbanization, foreign population, and rented housing, respectively. Furthermore, this study conducts the bivariate autocorrelation analysis using SPSS 22 (https://www.ibm.com/products/spss-statistics, accessed on 2 May 2023).

A bivariate correlation analysis can quantitatively explain the strength of the statistical relationships between variables and determine whether two variables are correlated with each other. The method is fitted by least squares, and the Pearson correlation coefficient is used to describe the degree and direction of the correlation between two variables, which is calculated as follows:

$$r_{XY} = \frac{\sum_{i=1}^{n} (X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n} (X_i - \overline{X})^2} \sqrt{\sum_{i=1}^{n} (Y_i - \overline{Y})^2}} \tag{9}$$

where X and Y are the independent and dependent variables to be analyzed, X and Y are the means of the independent and dependent variables, i = 1, 2......n; r_{XY} is the correlation coefficient, $-1 \leq r_{XY} \geq 1$, when $r > 0$, it means that the two variables are positively correlated with each other; when $r < 0$, it means that the two variables are negatively correlated before. Here, $r = 1$ is completely correlated and $r = 0$ is no correlation.

3. Results and Analysis

3.1. Spatial Differentiation Patterns of Housing Conditions in China

Based on the information entropy method, the information entropies and weights of the seven indicators were calculated for 2846 counties in China (Table 2). The results show that PH_elevators has the highest weight of 0.593538, which is the most important indicator used to determine the inter-county differences in housing conditions in China, and also indicates that there are large differences in elevator configurations among various counties in China. Four indicators of internal facilities (PH_piped water, PH_kitchens, PH_toilets, and PH_bathing facilities) generally have lower weights, indicating that the internal facilities configuration of housing in China is generally better in 2020, and the disparity between counties is not large; therefore, the indicator of internal facilities is not the main indicator category that determines the difference between counties in China.

Table 2. Information entropies and weights of the evaluation indicator of housing conditions in China.

	Information Entropy	Redundancy	Weight
AN_room	0.983707	0.016293	0.195545
PCH_area	0.991551	0.008449	0.101402
PH_piped water	0.997729	0.002271	0.027257
PH_kitchens	0.999309	0.000691	0.008297
PH_toilets	0.999175	0.000825	0.009900
PH_bathing facilities	0.994662	0.005338	0.064060
PH_elevators	0.950545	0.049455	0.593538

Based on the weights in Table 2, the housing condition scores of each county were derived. Based on the data distribution, the housing conditions in China were classified into five grades: good (0.3–0.85 points), better (0.2–0.3 points), average (0.15–0.2 points), poor (0.1–0.15 points), and poor (less than 0.1 points). Based on the aforementioned data, GIS technology was used to derive the spatial differentiation pattern of housing conditions in China (Figure 4). The figure shows that the regions with good housing conditions in China are mainly urban areas, while the regions with poor housing conditions are mainly in the northeast and parts of the Qinghai–Tibet Plateau and Xinjiang. The regions with better housing conditions are generally distributed on the southeast side of the "Hu Line" (Heihe–Tengchong Line), while on the northwest side of the "Hu Line", housing conditions are relatively poor.

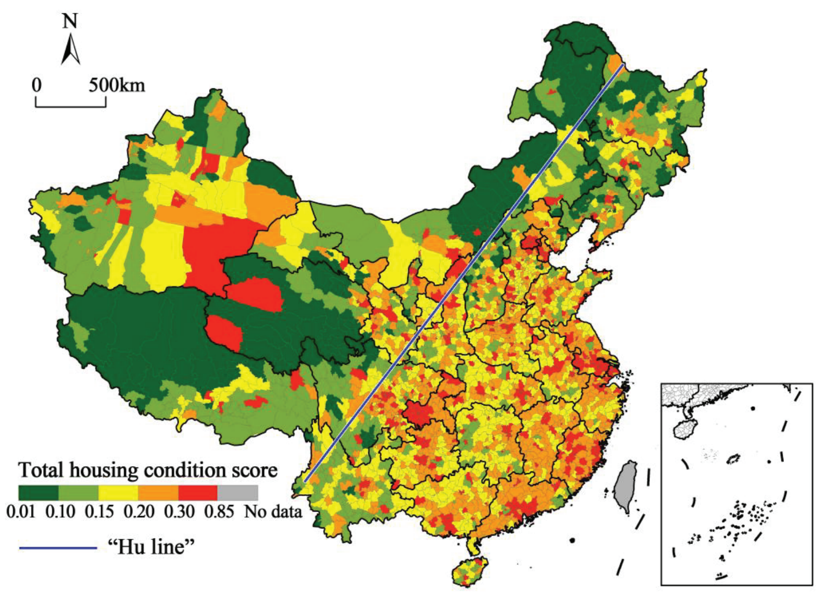

Figure 4. Spatial differentiation pattern of housing conditions in China.

The pattern of the spatial differences in housing conditions (spaciousness, internal infrastructure, elevator configuration) of the different subtypes was further analyzed (Figure 4), and the way the housing conditions of different classes of subtypes were divided is shown in the legend of Figure 5. A significant difference exists in the pattern of housing conditions of different subtypes. In terms of the spaciousness of housing (Figure 5a), it shows a difference pattern of high in the south and low in the north. In terms of internal facilities (Figure 5b), the scores of housing internal facilities in Northeast China, Inner Mongolia, Shanxi, and the Qinghai–Tibet Plateau are relatively low, while the rest of the regions have high scores. In terms of elevator configuration (Figure 5c), the elevator configuration scores in urban areas are generally higher than those in non-urban areas, showing a difference between urban and non-urban areas.

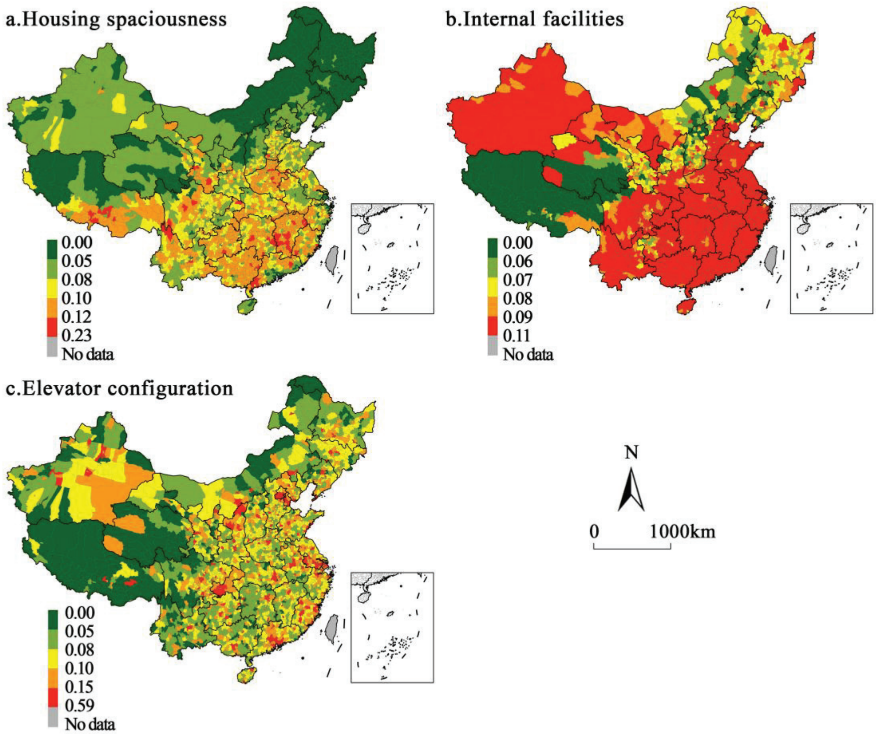

Figure 5. Spatial differentiation pattern of the housing condition subtypes in China.

3.2. Spatial Autocorrelation Characteristics and the Distribution of Hotspot Areas of Housing Conditions in China

The spatial association and clustering characteristics of the housing conditions and their subtypes in China were judged based on Moran's *I* index. The FD method (fixed distance) was used as the basis for judging the spatial weight matrix, and the threshold distance was set to 150 km, while Moran's *I* index and the Z-score and *p*-value derived from its expected value were derived as shown in Table 3.

Table 3. The global spatial autocorrelation indexes of housing conditions in Guangzhou.

	Total Score of Housing Conditions	Housing Spaciousness	Internal Facilities	Elevator Configuration
Moran's *I*	0.2101	0.4316	0.3419	0.2063
Z-score	51.0704	104.7961	83.1077	50.1602
p-value	0.0000	0.0000	0.0000	0.0000

Table 3 shows that Chinese residents' housing conditions generally show significant spatial clustering characteristics. Among them, housing spaciousness, a subtype of housing conditions, has the most significant spatial clustering characteristics, with Moran's *I* reaching 0.4316. Based on this, the local spatial autocorrelation characteristics of the housing conditions and its subsystems are judged based on the *LMI* (Figure 6).

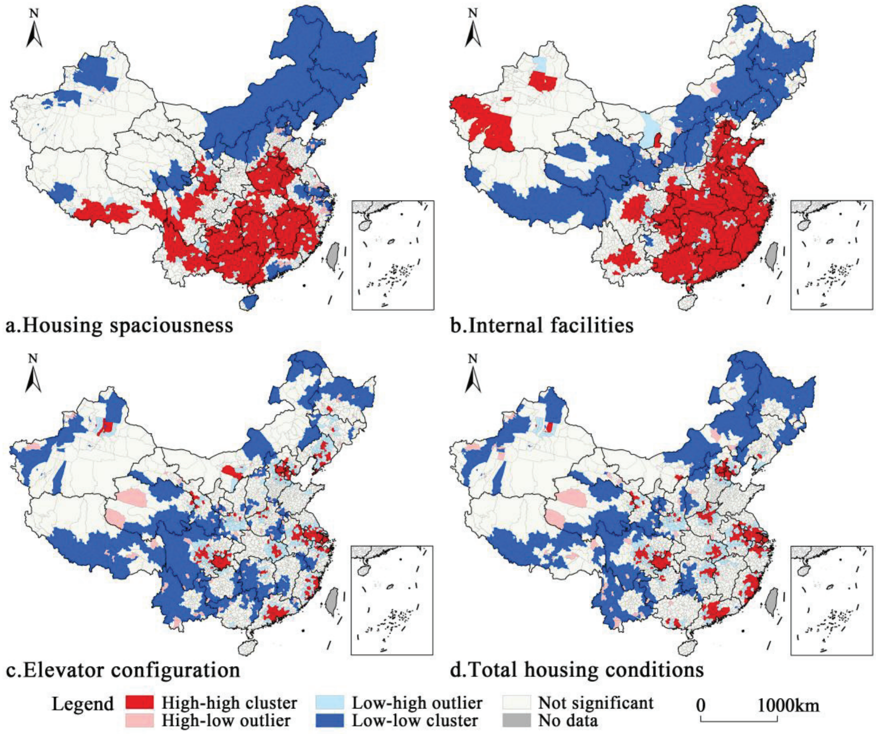

Figure 6. *LMI* maps of the housing conditions and their subtypes in China.

Figure 6a shows that the H–H zone of the housing spaciousness score is mainly concentrated in the southern region of China (Fujian–Jiangxi–Hunan–Guizhou–Guangxi–Yunnan, and western Hubei, western Sichuan, and southern Tibet) and in the northern region of Henan Province, while the L–L zone is concentrated in the northeast region—northern China, the Yangtze River Delta, Pearl River Delta, Shandong Peninsula, Hainan Province, Xinjiang's northern part, and the Sichuan–Qinghai border.

Figure 6b shows that the H–H zones of the internal facilities score are significantly clustered in China's eastern and central regions (except Shanxi). Guangxi, Chongqing, central Sichuan, central Yunnan, and western Xinjiang in the western region also show H–H clustering characteristics. L–L areas are clustered in the northeast region—Inner Mongolia, Shanxi, northern Shaanxi, southern Gansu, Qinghai, and southern Tibet, showing a concentrated contiguous distribution.

Figure 6c shows that the H–H zones of the elevator configuration scores are mainly distributed in city clusters and metropolitan areas, including the Yangtze River Delta city cluster, Pearl River Delta city cluster, Chengdu–Chongqing city cluster, West Coast city cluster, Liaoning–China-South city cluster, Beijing–Tianjin metropolitan area, Wuhan metropolitan area, and Urumqi metropolitan area.

In terms of the comprehensive housing conditions (Figure 6d), the H–H zones are (1) five urban agglomerations: the Yangtze River Delta urban agglomeration, the Pearl River Delta urban agglomeration, the West Coast urban agglomeration, the Central Plains urban agglomeration, and the Changsha–Zhuzhou–Xiangtan urban agglomeration; and (2) the Beijing–Tianjin metropolitan area, the Wuhan metropolitan area, the Chengdu metropolitan area, and the Chongqing metropolitan area. The L–L zones are mainly located in the northeastern and western regions.

3.3. Differences in Housing Conditions between Urban and Non-Urban Areas in China

Using whether the study unit was a municipal district as the judgment criterion, the county unit was divided into two sub-regions, urban and non-urban, to compare the differences in housing conditions between urban and non-urban areas of China. The mean scores of the urban and non-urban housing conditions are shown in Table 4, and the box plots are shown in Figure 7. Housing conditions in urban areas of China are generally better than those in non-urban areas, and in terms of housing spaciousness, the housing sizes in the latter areas are more spacious than those in the former due to the higher number of commercial housing units and the limited land supply in urban areas. However, most of the housing units in non-urban areas are self-built and have a much larger housing stock. In terms of internal facilities, the average score of urban houses is higher than that of non-urban houses, indicating a higher degree of internal facility improvement in urban housing. Similarly, in terms of the elevator configuration, urban housing shows a significantly better configuration than non-urban housing. This can be attributed to the fact that urban areas have a high number of high-rise dwellings and a high proportion of lifts allocated to them, which is why urban areas have a higher lift allocation score.

Table 4. Mean scores for urban and non-urban housing conditions.

Sub-Region	Average Score of Housing Conditions	Housing Spaciousness Average Score	Internal Facilities Average Score	Elevator Configuration Average Score
Urban area	0.353656	0.066264	0.100770	0.203361
Non-urban area	0.182871	0.087436	0.090764	0.061790

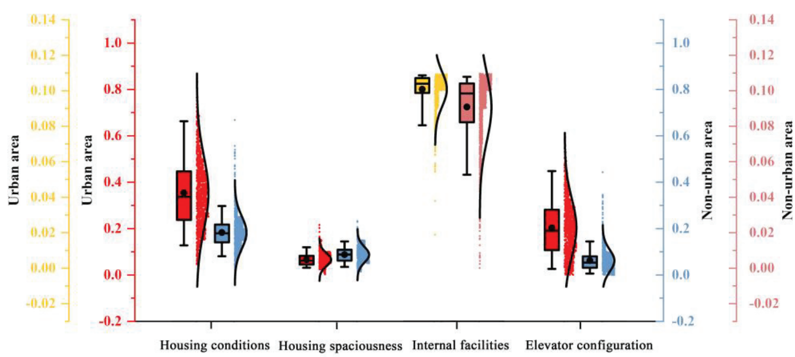

Figure 7. Box plots of the four housing condition scores for urban and non-urban areas.

As shown in Figure 7, the housing condition scores, internal facilities scores, and elevator configuration scores are generally higher in urban areas than in non-urban areas, with a relatively dispersed data distribution. Furthermore, the housing spaciousness in urban areas is lower than in non-urban areas, with a relatively concentrated data distribution.

3.4. Relationship between Housing Conditions and County Fundamentals in China

Using SPSS 22 software (https://www.ibm.com/products/spss-statistics, accessed on 2 May 2023), a bivariate correlation analysis was used to analyze the four influencing factors and three subtypes of housing conditions indicators containing 1846 county units according to all the counties, urban areas, and non-urban areas, respectively, to derive the correlation coefficients, and a two-sided test was conducted using the *t*-test method, defining a test value less than 0.01 as a significant correlation, and the results are shown in Table 5 below.

Table 5. Correlation analysis between housing conditions and county fundamentals in China.

Study Area (Number)	Housing Condition Indicators	Result Type	Influencing Factors			
			Population Density (person/km^2)	Urbanization Rate (%)	Percentage of Urban Floating Population (%)	Percentage of Renting Households (%)
All (2846)	Housing spaciousness	Coefficient	−0.277	−0.473	−0.185	−0.380
		Significance	0.000	0.000	0.000	0.000
	Internal facilities	Coefficient	0.197	0.390	0.189	0.118
		Significance	0.000	0.000	0.000	0.000
	Elevator configuration	Coefficient	0.484	0.724	0.505	0.535
		Significance	0.000	0.000	0.000	0.000
Urban areas (973)	Housing spaciousness	Coefficient	−0.386	−0.670	−0.174	−0.430
		Significance	0.000	0.000	0.000	0.000
	Internal facilities	Coefficient	0.237	0.363	0.171	0.220
		Significance	0.000	0.000	0.000	0.000
	Elevator configuration	Coefficient	0.374	0.602	0.436	0.461
		Significance	0.000	0.000	0.000	0.000
Non-urban areas (1873)	Housing spaciousness	Coefficient	0.154	−0.238	−0.010	−0.242
		Significance	0.000	0.000	0.651	0.0000
	Internal facilities	Coefficient	0.335	0.296	0.064	−0.104
		Significance	0.000	0.000	0.005	0.000
	Elevator configuration	Coefficient	0.413	0.466	0.228	0.221
		Significance	0.000	0.000	0.000	0.000

Note: Two-tailed test of significance was used.

For all the counties (with a sample of 2846 counties), the correlations between the three housing condition subtype scores, housing spaciousness, internal facilities, and elevator configuration, and the four county fundamentals factors are shown in Figure 6.

Table 5 and Figure 8 show that housing conditions are significantly correlated with county fundamentals at the national level, and that the four factors act in different directions on housing conditions. Among them, the most significant correlation between elevator allocation and county fundamentals is positive, with the magnitude of the correlation coefficients of the four factors—urbanization, renter households, floating population and population density—being 0.724, 0.535, 0.505, and 0.484, in that order; a significantly positive correlation exists between housing interior facilities and county fundamentals, with urbanization having the strongest effect on interior infrastructure; while a significantly negative correlation exists between housing spaciousness and county fundamentals, indicating that all four influencing factors of county fundamentals have a significant negative effect on housing spaciousness, with urbanization (−0.473) and renter households (−0.380) ranking as the top two in terms of the impact intensity.

A significant correlation exists between housing conditions and county fundamentals at the urban level. Housing spaciousness and county fundamentals are significantly negatively correlated, with the strongest correlation between housing spaciousness and urbanization, with a correlation coefficient of 0.670, indicating that urbanization has the greatest effect on housing spaciousness, and the higher urbanization has a relatively narrow housing size. Internal infrastructure and elevator configuration are positively correlated with county fundamentals, with urbanization having the most significant effect on housing internal infrastructure and elevator configuration. Thus, this shows that the urbanization rate has a greater impact on housing conditions in urban areas. On the one hand, the urbanization rate has a negative impact on housing spaciousness. On the other hand, the urbanization rate has a positive effect on housing internal infrastructure and elevator configuration.

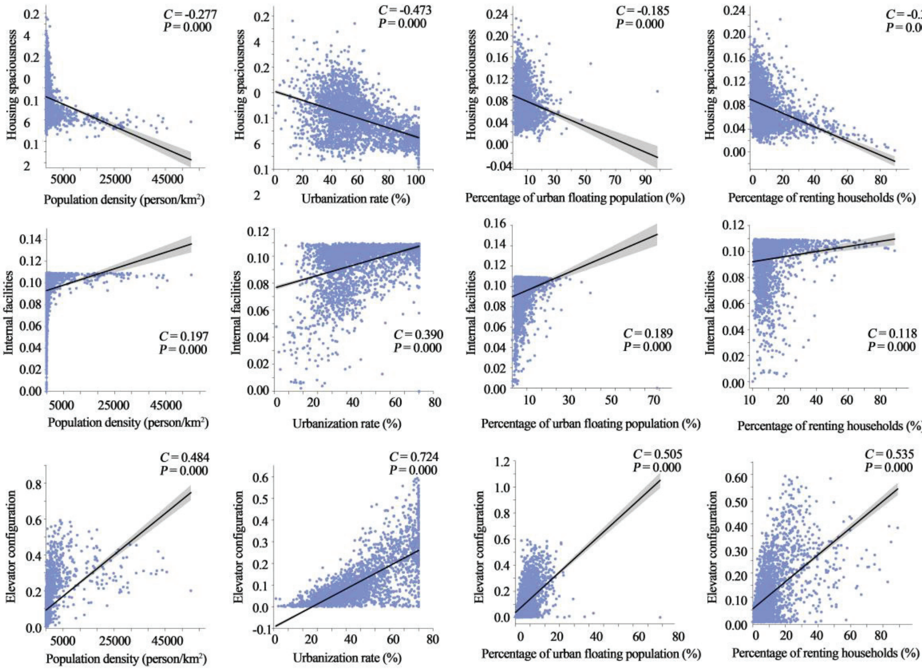

Figure 8. Scatterplot of the relationships between the housing condition scores and county fundamentals.

At the non-urban level, large variability exists between county fundamentals and housing conditions, with varying degrees as well as directions of correlation. The correlation between housing internal infrastructure and county fundamentals differs, with a negative correlation with renter households and a positive correlation with the rest of the factors, and the strengths of population density (0.335) and urbanization (0.296) ranked as the top two; county fundamentals and elevator allocation were positively correlated, with the strengths of urbanization, population density, floating population, and renter households in that order.

4. Discussion

Previous studies have neglected the importance of elevator configuration in determining housing conditions between counties in China. However, we recognize that elevators are an indispensable indicator of evaluating housing conditions, especially in the context of China's recent construction boom in multi-story and high-rise buildings. Elevators have a significant impact on housing conditions as an important facility for vertical transportation, especially in medium and high-rise dwellings. This result is similar to the findings of Au-Yong et al. [45] regarding the maintenance of lift systems in high-rise dwellings in Malaysia and of Kshetrimayum et al. [46] regarding the evaluation of housing conditions in the slums of Mumbai, and it should not be ignored in future studies.

Currently, the impact of internal facilities such as piped water, kitchens, toilets, and bathing facilities on housing conditions is limited as they have become a standard configuration in housing for Chinese residents due to improved living standards and economic and social development. Consequently, regional differences in these indicators are not significant, and they have become less important in evaluating housing conditions in China compared to previous studies.

To evaluate housing conditions accurately, it is important to consider the variations between urban and non-urban areas. This aspect often goes unnoticed in existing studies due to the stark differences in housing types between the two. Non-urban areas typically have a higher percentage of rural owner-occupied housing, whereas urban areas are dominated by commercial housing such as multi-story and high-rise buildings. Consequently, housing conditions vary greatly between these two subtypes and should be analyzed separately.

When analyzing the factors that influence housing conditions, considering the correlation between different subtypes of housing conditions and county fundamentals is important. For instance, the internal infrastructure of housing and elevator configuration show a positive correlation with county fundamentals, whereas the correlation between housing spaciousness and county fundamentals is in a different direction. This highlights the importance of using subtype indicators when studying the factors related to regional differences in housing conditions in China.

One limitation of this study is the difficulty in accurately distinguishing between commercial housing (mainly multi-story and high-rise) and self-built housing (mainly low-rise) when assessing housing conditions. This may affect the scores given to housing conditions, as factors such as the presence of elevators in commercial buildings or the spaciousness of self-built homes may not be fully accounted for. In addition, in the comprehensive evaluation index system for housing conditions, this study did not consider sustainability indicators, such as green and energy-saving as well as intelligent building indicators. Thus, we expect that this will be improved in future studies.

5. Conclusions and Policy Implications

5.1. Main Conclusions

This study examines the various housing conditions and subtypes in county units in China, and it investigates the correlation between housing conditions and county fundamentals. Elevator allocation is included in the comprehensive evaluation system for housing conditions. Chinese counties are used as the study units. The study also distinguishes between urban and non-urban subtypes, and it analyzes the relationship between housing conditions and county fundamentals such as population density, urbanization, proportion of floating population, and proportion of renter households. This study's contribution lies in its comprehensive approach toward evaluating housing conditions and its focus on Chinese counties as a unique study unit.

The following conclusions were obtained from this study. (1) The configuration of elevators is the most important indicator of the differences in housing conditions in China. (2) According to this research, areas with better housing conditions are primarily located on the southeast side of the "Hu Line," whereas areas with worse housing conditions are located on the northwest side. Variations exist in the distribution of the different subtypes of housing conditions. Chinese residents' overall housing conditions exhibit significant spatial clustering characteristics, and there are notable differences in the distribution of different subtypes of high–high (H–H) and low–low (L–L) zones. (3) Housing conditions in China's urban areas are generally better than those in non-urban areas. (4) The correlation between housing conditions and county fundamentals varies depending on the regional level. At the national level, a negative correlation exists between county fundamentals and housing spaciousness, although a positive correlation exists with internal infrastructure and elevator allocation. (5) Housing conditions vary considerably between urban and non-urban areas: urban housing has better internal facilities and elevators are better equipped than in non-urban areas; however, it is typically less spacious than in non-urban areas. At the urban level, a negative correlation exists between county fundamentals and housing spaciousness, although positive correlations are observed with internal infrastructure and elevator allocation. Furthermore, urbanization has the strongest effect on housing conditions. However, at the non-urban level, there is greater variability in the correlation between county fundamentals and housing conditions. The results also indicate a positive correlation between county fundamentals and elevator configuration, as well as a correlation of varying direction and strength with housing spaciousness and internal facilities.

This study examines the spatial differences in housing conditions in China and their correlation with county fundamentals. The findings offer valuable insights for future studies of housing conditions in China and the development of targeted housing policies.

5.2. Policy Implications and Perspectives

5.2.1. Policy Implications

Based on the conclusions of this study, it is recommended that the relevant management authorities improve housing conditions in China in the following ways. (1) In non-urban areas, the level of the internal infrastructure configuration of typical housing and buildings with more than six floors must be increased. All of them should be equipped with lifts so as to improve accessibility to vertical transportation. (2) In urban areas, especially in the downtown areas of large cities that are usually congested with city dwellers, the housing supply should be increased and the number of rooms per capita and per household should be raised. These goals can be achieved through urban renewal and efforts to encourage the population to move to the suburbs, thereby increasing the per capita living area and the average number of rooms per household. Ultimately, these will alleviate housing congestion. (3) In old urban areas, urban renewal should be actively promoted, which can be achieved through the renovation of facades, the installation of lifts, and through the adoption of new building technologies, energy-saving technologies, and smart technologies. Doing so can comprehensively remediate the living conditions of the housing stock, thus avoiding the old towns degenerating into slums and high-crime-risk zones in the future. (4) The housing conditions in the northwestern part of the Hu line must be actively improved through various measures, such as improving the conditions of the existing housing infrastructure and increasing the living comfort through the restoration and renewal of the old houses. Furthermore, housing conditions can be improved by rebuilding high-standard and modernized housing in different locations through resettlement.

5.2.2. Research Perspectives

In terms of research directions, future studies could be conducted in the following areas. (1) Future studies can investigate the differences in housing conditions among different housing types (e.g., commercial and self-built housing). Such studies could benefit from more precise data that allow for a separate analysis of commercial and self-built housing. (2) Although there are major differences between the housing within the built-up urban areas and the housing within rural geographies, it is difficult to distinguish between them using the current data. Therefore, in the future, we should further distinguish between urban and rural areas, study housing conditions in these areas separately, and propose countermeasures to improve the housing conditions accordingly. (3) In terms of the evaluation index system for housing conditions, more attention should be paid to sustainability indicators, such as intelligent building indicators and green and energy-saving building indicators. (4) Due to China's vast geographical scope and widely varying features, the strong spatial heterogeneity of the factors affecting housing conditions can be further investigated. This can be achieved by using geographically enhanced regression to analyze the relationship between housing conditions and county-level fundamentals.

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Consensus-Based Measures for Improvement of Off-Plan Sales Program of Housing Units in Real Estate Market of Riyadh City

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Abstract: This study aims to review the off-plan sales program to identify the financial and marketing challenges being faced by such programs in Saudi Arabia and formulate consensus-based measures to overcome these challenges. The study implies an analytical descriptive method to achieve its objectives, based on the opinion of experts involved in the off-plan sales program and analyzing the data using the Delphi technique. Various statistical parameters were calculated to validate the obtained results. The study found several challenges being faced by off-plan sales programs, including financing challenges such as mortgaging on the land deed, as well as marketing challenges, including low turnout of the buyers due to the long duration of project implementation. The study concludes with several suggested measures, the most important of which is to find an alternative to the condition of mortgaging the land deed, such as putting insurance on the project or providing a financial bank guarantee. The study contributes to the improvement of the real estate sector of Saudi Arabia and would benefit the construction and development sectors as well.

Keywords: off-plan sale; consensus; marketing; housing unit; real estate market; Delphi technique

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1. Introduction

The real estate sector is one of the most important economic sectors for any country, as it plays an important role in driving growth, providing many job opportunities, as well as moving economic activity in many industries and other related activities, whether in the pre-construction stage (engineering consultancy, economic and marketing studies), in the construction phase (contracting, building materials preparation, construction), or even after the completion of the construction phase (operation and maintenance). Therefore, the prosperity and development of this sector mean an increase in the growth of these activities and industries. In Saudi Arabia, the real estate sector is considered an important axis of the comprehensive development that the country is experiencing in the current era, as it constituted approximately 18.2% of the non-oil GDP for 2019 (9.9% for the real estate activities and 8.3% for construction and building) according to the Housing Data and Observatory Center [1]. Figure 1 shows the contribution of the real estate sector and buildings and construction in Saudi Arabia compared to other activities, which confirms the importance of these sectors and their impact on other activities [1].

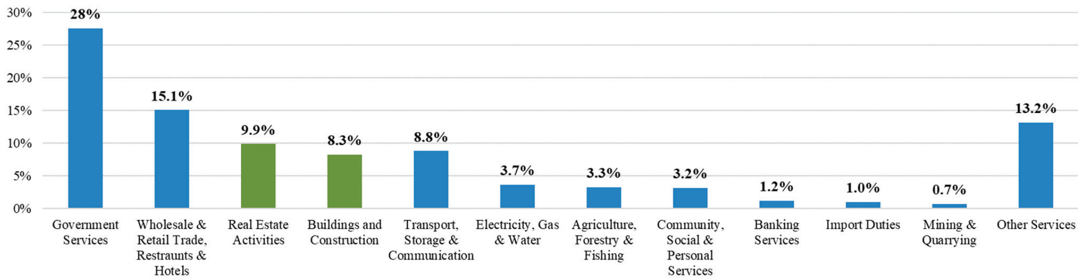

Figure 1. Contribution to Real Estate Activities and Construction in Saudi Arabia (shown in green).

Therefore, the real estate sector in the country has received great attention, especially in the field of housing, which is one of the largest areas of spending within the framework of the National Transformation Program (NTP) and the Saudi Vision 2030, with an allocated budget of approximately $15.7 billion over five years [2]. This represents a stimulating step for the real estate sector in general and housing in particular, which represents a share of about 65% of the total real estate market [3]. The Housing Program within Saudi Vision 2030 aims to provide housing solutions that enable Saudi families to own the appropriate housing according to their needs and financial capabilities. This is accomplished by (1) providing supported and appropriate financing solutions; (2) increasing the supply of housing units at reasonable prices, high quality, and in record time; (3) developing the legislative and regulatory environment for the housing sector; (4) enhancing the economic impact of housing; and (5) creating an attractive environment for local and international investors and enhancing their confidence in the national economy [2]. Undoubtedly, this leads to the creation of more job opportunities and the prosperity of the economic situation of the country [4].

The private sector in Saudi Arabia has played an important role in the citizens' ownership of their first home through the various housing programs prepared by the Ministry of Housing, where the percentage of citizens' ownership of their homes increased to 62%, exceeding the target of Saudi Vision 2030, which stipulated an increase in the percentage of ownership to 60 % at the end of 2020, and this came in partnership with real estate development companies and financing agencies [1,2]. Figure 2 shows the housing growth in the regions of Saudi Arabia for 2019 compared to 2018 [1]. One of the most prominent housing programs is the sale of housing units before or during the construction or development phase so that the housing units model are designed in their final form after the construction process as display units, and the real estate developer is committed to implementing the models according to the agreed designs and specifications, or what is known as the "Off-Plan Sales" [5]. The off-plan sales program aims to: (1) reduce the cost of acquiring housing units compared to ready-made units from the market; (2) preserve the rights of buyers through systems and procedures that obligate the developer to abide by the completion of the project following the signed contracts and the project time plan; (3) develop and stimulate competition between real estate development companies through a developer qualification and classification system; and (4) put an end to speculative operations that negatively affect real estate prices and inflation [6].

According to the experiences of the countries that were reviewed at the "Wafix 2019" exhibition, the off-plan sales system is one of the methods of owning real estate that has proven successful in international experiences [7]. This is because it aims to finance real estate development projects before and during implementation by opening the door for sale to buyers during the project launch period. Thus, real estate developers can finance their projects through buyers' payments and without interest rates, unlike other financing methods, and this leads to a reduction in the cost of the project to the developer, while the buyer obtains residential units at a lower cost compared to ready-made units. However, this system at the local level is still new, as some banks do not provide financing to buyers due to the high risks of construction, quality of implementation, and the high costs of building materials during the construction period; or the risks of using the financing amounts in a place other than the place for which they were given; as well as the inability and efficiency of the developer in completing all phases of the project as required in some cases [5].

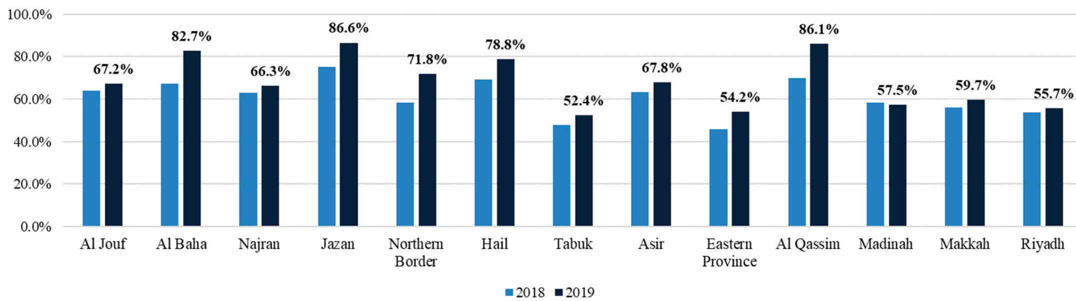

Figure 2. The Growth of the Number of Housing Units in Various Regions of Saudi Arabia.

However, despite the increasing demand for housing in the Saudi region, which amounts to 1.4 million applications (325 thousand applications in Riyadh alone), the number of off-plan sales contracts is still low compared to other types of housing contracts provided by the Ministry of Housing, such as ready-made housing, particularly in Riyadh [5,8]. In Riyadh, the number of off-plan sales contracts was only 204 out of the total number of contracts, which amounted to 26,012 contracts. This would confirm that there is a defect in the housing products offered by the real estate developers through off-plan sales programs, which do not keep pace with the increasing demand for housing in the country [9]. This defect could be attributed to many reasons, most significantly: the high cost and shortage of housing units; and the availability of housing units not being compatible with the social and economic characteristics of Saudi families [10]. Therefore, this study aims to identify the most significant challenges facing the off-plan sales program in Saudi Arabia and formulate consensus-based measures for addressing these challenges.

2. Literature Review

The real estate sector has become one of the most important economic sectors and has received great interest from investors. It is also one of the pioneering sectors in its rapid and striking growth, which has become an attractive factor for many real estate developers and even small investors. It can also be said that the real estate sector has become among the most important economic and investment sectors that have boosted the economies of many countries around the world and have become based on the real estate sector [11]. Real estate development has several concepts and is not only limited to projects intended for residential use only but also includes all projects for commercial, industrial, and tourist use and more. It is a process that aims to construct investment buildings, whether residential buildings, villas, or facilities, and prepare them for housing, commercial, industrial, or tourism purposes [12]. It consists of several stages that are linked to each other, starting with an idea and ending with the delivery of the real estate unit to the buyer. These stages include: studying the real estate market and its needs; choosing the project site and acquiring it; planning and designing the site; financing the project; establishing the project, and then conducting the project's marketing process [12]. Several methodologies explain the stages of real estate development, including Miles's method [13], which shows the stages of real estate development starting from the idea of the project until its management after the completion of its implementation, as shown in Figure 3.

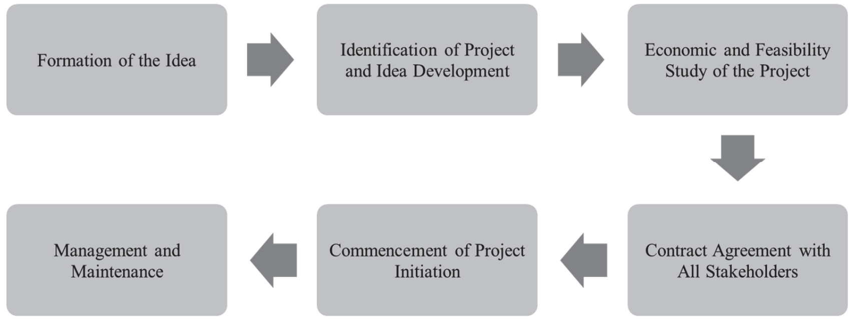

Figure 3. Stages of Real Estate Development.

Real estate development depends on several pillars, primarily financing and marketing. Real estate finance, in general, can be defined as providing the financial resources necessary for the implementation of investment projects to increase the production of goods and services [14]. While real estate marketing can be defined as a link between those who produce goods and provide services and those who buy and benefit from them, it aims to achieve the needs and desires of individuals, whether the property is land or housing, with the appropriate value and outstanding service to the customer [15]. During the past few years, the concept of real estate financing and marketing has developed significantly, and many programs have emerged that are aimed at developing the real estate sector, the most important of which is the off-plan sales program. The off-plan sales can be defined as selling a property with an approved design but has not yet been built or is still under construction, where the seller must complete and finish the implementation of the property, deliver it on time, and transfer its ownership to the buyer according to the contract signed between them [16]. It is also known as a netting contract in which the buyer owns a real estate unit with predetermined characteristics and specifications, whether it is existing or under construction, provided that the real estate developer is obligated to complete its construction according to the agreed period, in exchange for the buyer's obligation to pay the price, whether expedited or deferred [17,18].

Zhao and Zhang [19] describe an off-plan acquisition in China as buying a property before construction has started or been completed. The buyer can decide what to buy from the blueprints, plans, and computer-generated renderings of the proposed housing project. Before construction begins, the buyer can purchase the home by paying a down payment or by providing the developer with a letter of credit. The buyer then executes a contract with the developer and obligates him to pay the remaining amount in full or in installments according to the terms of the contract. According to Andrew and Larceneux [20], in a study conducted in France, the difference between an off-plan and a typical home purchase is that buyers of established properties could examine the property before consenting to the purchase. The buyer may acquire a feel for the property and decide if it matches their needs. Off-the-plan buyers are occasionally given a limited time to review promotional materials or a wish list provided by the developer. In these situations, the buyer must rely on the proven experience, skill, and reliability of the developer, as well as the terms of the contract, to ensure the job is completed on time and to the required standard. Michael Gapes [21] performed a study for Australia and stated that off-plan home buying might occasionally be preferable to buying an established home. Being able to buy a home at current costs while only paying the bulk of the purchase price is usually the biggest benefit a few months down the road. Developers' primary driving force is profit, while homebuyers' goal is to obtain decent housing at the lowest possible cost. When choosing the off-plan home buying approach as per [22], risk reduction on both sides is imperative. Furthermore, Larceneux and Guiot [23] developed a cognitive map of how experts and other stakeholders can see a specific risk management decision for the French off-plan housing market.

The real estate industry in Saudi Arabia is fundamentally cyclical, so an increase in construction activity triggered by rising demand may be followed by a decline a few years later [24–26]. Due to the different development of property values, and development costs, both tenant demand and development activity are cyclical [22,27,28]. When deciding to buy an off-plan unit, some investors do not create a budget or financial plan and end up in a challenging situation where they do not have enough amount to complete the purchase. In this situation, a trading financial professional often ends up passing the contract on to other speculators for absolutely no benefit [29], as observed in the United Arab Emirates. In the literature, there is broad theoretical and experimental evidence to support that poor site management and supervision, slow decision-making by the project team, customer-initiated changes, and unforeseen ground conditions can all lead to time overruns [23,30].

The off-plan sales program is characterized by a combination of financing and marketing at the same time compared to other sales programs. The developer can obtain financing by selling real estate units before their construction without adding and bearing bank fees and interests that are reflected in the cost of implementing the project and lead to an increase in the prices of housing units. At the same time, developers market their products on the map and know the extent of the buyers' satisfaction and acceptance of those products [14]. Each developer usually follows a specific mechanism in selling real estate units in the off-plan sales system according to the market demand and needs, and each mechanism involves a set of stages with different risk ratios that the real estate developer must know and analyze. Al-Shaalan [31] divided these stages into four main stages, and each stage has a certain number of risks: (1) selling before obtaining permits; (2) selling after obtaining all necessary permits; (3) selling after starting construction according to the completion phase; and (4) selling after construction is completed. As illustrated in Figure 4, the degree of risk in the off-plan sales system decreases as the progress rates of completion in the project.

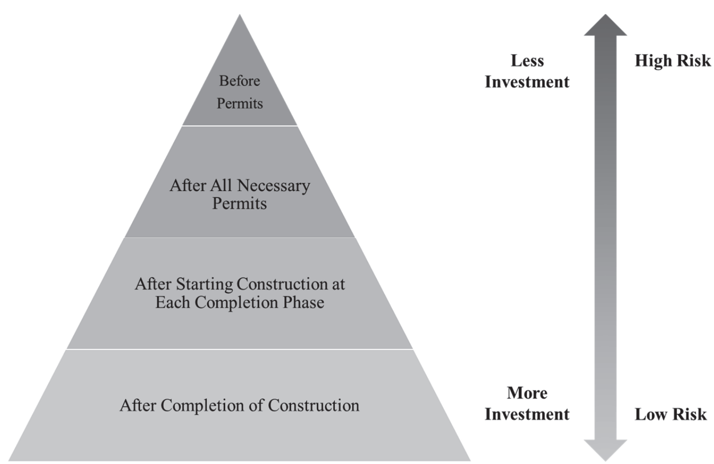

Figure 4. The Main Stages of the Off-Plan Sales Program Compared with Risk Levels.

The off-plan sales program offers various advantages, including reduced market value, ready-to-buy properties, the properties are usually in areas of demand that are easy to sell on, properties are complete and require no separate tradesmen to work on them, and housing units are new and therefore are energy efficient. However, it entails a few risks as well, which can be listed below.

- A developer may fail to deliver the project and may go bankrupt, and one could lose their deposit amount of money.
- The property may have architectural issues at the time of handing over.

- Excessive delays might mean the housing market falls, and one may lose money.
- Mortgage offers need to be updated and revised in case there is a significant delay in the delivery of the project.

Real estate developers also take the economic feasibility study into account to know and estimate the chances of success of the investment idea before starting its implementation. Al-Shaalan [31] stressed that the stage of the economic feasibility study is one of the most important stages of the real estate development process because it shows the real estate developer whether the project is economically feasible and achieves the desired goals or not. Additionally, the good marketing of the project reflects positively on the financial flows and increases the financial capacity of the real estate developer to implement the project with fewer financing risks, as the financial flows resulting from the buyers' payments contribute to reducing the interest resulting from borrowing to finance the project. However, there remain several obstacles that would increase the risk of financing in the off-plan sales program. Al-Shaalan [31] highlighted some of these obstacles, such as low prices of real estate products of all kinds; high annual interest rates; the high cost of building materials; economic stagnation; the bankruptcy of the real estate developer; and building and construction at a time of high prices.

As mentioned previously, the experiences of several countries have shown that the off-plan sales program is one of the methods of owning real estate that has proven successful in international experiences. Graham [32] studied off-plan sales in Australia, where the study touched on the most prominent risks and challenges facing developers in off-plan sales projects, such as the drop in the prices of housing units after the contract signing stage and before delivery, the difficulty of knowing the final form and the quality level of the building materials used, and the buyers' failure to pay the payments on due dates, which disrupts the real estate developer's financing sources. The study also emphasized the importance of reading all the details of the contract with the contractor executing the project, reviewing previous projects implemented by the contractor, knowing the final form of the project, determining the general location of the units, public parks, and future projects adjacent to the project.

Savage [33] reviewed the off-plan sales program in the United Kingdom (UK), where the study touched on the advantages and disadvantages of this program and also addressed the reasons for buyers' obtaining real estate units at lower prices compared to the prices of ready units, while at the same time exploiting payments by the developer to finance the project and obtain higher profitability. The study recommended those who wish to purchase real estate units with the off-plan sales program review the real estate market conditions and analyze the influencing factors to make the purchase decision at the most appropriate time. Stucklin [34] has prepared a study on the off-plan sales program in Spain, aimed at educating people who want to buy real estate units with the off-plan sales program and providing them with advice so that they do not fall into high-risk or unsecured projects. Stucklin's study concluded with several recommendations, the most important of which are verifying the legality of the company developing the project, making sure that the developer owns the land on which the project will be built, and reviewing the projects completed by the developer.

In the Middle East, Limuasa [35] studied the reality of the off-plan sales program in Algeria, which suffered from high unit costs due to inflation occurring in the country or due to the neglect of the real estate developer and an increase in the cost of implementation, which was reflected in the failure of projects and completion rates. The study identified the parties involved in the sale contract and the obligations of each party, in addition to the necessary permits that the real estate developer must obtain, namely: building licenses, retail licenses, construction certificates, in addition to a certificate of conformity. The real estate developer, upon receipt of the payments deposited by the buyers in the account of the Real Estate Development Operations Guarantee Authority, must spend them on completing the project and submitting it according to the agreed time plan, where the guaranteed authority guarantees the financial amounts paid by the buyer, according to the completion percentages of the project.

In his study, AlSaidi [36] touched on the seller's obligations in the off-plan sales contract in the United Arab Emirates (UAE), starting from obtaining the license until the building is ready to perform the purpose for which it was established, noting that the construction and its completion should be based on what was agreed upon and on time and specified period. AlSaidi pointed out the importance of defining the property descriptions in sufficient and clear terms, and the developer must mention in the property contract the specifications that the property will have, such as the area of the residential unit, the number of bedrooms, the dimensions and windows, the type of doors used, balconies and corridors, and other specifications that the developer is committed to handing over to the buyer. Given the large number of development projects and the multiplicity of developers who have experience and multiple development strategies, the UAE is considered one of the first countries to implement real estate projects under the off-plan sales system [37].

In Saudi Arabia, the off-plan sales program is considered one of the systems that stimulate the real estate developer to implement projects and complete them within their implementation in the agreed period and with high quality. It helps developers in the speed of their marketing, which contributes to motivating them to constantly develop their real estate products and their commitment to the highest quality standards to gain the trust of the buyers. Off-plan sales contracts force the real estate developer to abide by the requirements, which contributes to providing integrated and distinguished services and shortening many procedures, which is reflected in an increase in trust between the real estate developer and the buyer. It is believed that the developers should take advantage of the opportunity to obtain financing through the off-plan sales program in light of supporting this program and facilitating the procedures for obtaining the necessary licenses and permits, which aim in its entirety to reduce the gap between supply and demand for housing in the country.

Based on a review of the literature on housing and an exploration of the local housing context in Saudi Arabia and Riyadh, in particular, through some preliminary interviews with practitioners in the housing market, the questionnaire in this study was mainly built around four key issues:

(1) Financial challenges affecting the off-plan sales program in Riyadh.
(2) Marketing challenges affecting the off-plan sales program in Riyadh.
(3) Proposed measures to overcome financial challenges.
(4) Proposed measures to overcome marketing challenges.

The questionnaire contained six main questions focused on these four key issues. These questions, as well as the characteristics of the experts participating in this study, were analyzed and discussed in depth during the following sections of this study.

3. Materials and Methods

3.1. Study Area

The study is focused on Riyadh, the capital of KSA and the largest city in the country. It is located in the eastern part of the Riyadh Region, which lies in the middle of KSA as well as the center of the Arabian Peninsula at longitude 41°-28′ East, latitude 20°-00′ North, and about 600 m above sea level. Riyadh is characterized by its arid and hot climate, where the average temperature during the summer months reaches 45 °C [38]. In the past few decades, Riyadh has experienced significant demographic and physical growth and faced numerous issues in the process of urbanization. Indeed, it has witnessed a construction boom since the early 1970s following the oil boom, which increased the demand for housing units [39]. The population of Riyadh is estimated to be about 7.4 million in 2020, and it is expected to reach 10 million in the next few years, and they live in a total area of about 2435 km^2 [40]. In addition to its administrative importance and its large area, Riyadh was chosen in this study due to the small number of off-plan sales contracts in Riyadh compared to other products provided by the Ministry of Housing, despite the success of this idea in many countries around the world, such as Australia, UK, Spain, France, and UAE, as mentioned earlier. The total number of off-plan contracts recorded in Riyadh was 204 out of the 26,000 contracts in the whole of Saudi Arabia [1].

3.2. Data Analysis and Delphi Technique

The feedback questionnaire received from the experts and specialists was analyzed using SPSS, a predictive analytics program. Likert scale data were processed to generate descriptive statistics such as standard deviations, standard errors, weighted averages, etc. Consensus is critical to Delphi analysis, and data interpretation means for mean, median, and type or degree of variation such as standard deviation and interquartile range. Most of the research prefers to use the median value of the Likert scale [25,41–43]. As a result, the steps given below are combined to assess the consensus in this study.

1. Response Percentage: The following equation determines the percentage selection of the scale categories 1 to 5 for each question. For the statement in the individual questions to be agreed upon, the proportion must be significantly higher than others.

$$Response\% = \frac{No.\,of\ Responses\ to\ a\ Scale}{Total\ Number\ of\ Experts} \times 100\% \tag{1}$$

2. Standard Deviation: The consensus level is determined using the standard deviation [42]. The standard deviation was evaluated using the following equation. To reach a consensus level, the value must be low.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n-1}} \tag{2}$$

where n is the number of observations in the sample, $\overline{x}$ represents the overall sample means, and $x_1, x_2, x_3, \ldots, x_n$ are the values of the sample elements.

3. Standard Error: The standard error of a statistic is the standard deviation of its sampling distribution or an estimate of that standard deviation. It shows the reliability of the data [28].

$$SE = \frac{\sigma}{\sqrt{n}} \tag{3}$$

4. Weighted Average: Weighted average is a calculation that takes into account the varying degrees of importance of the numbers in a data set. In calculating a weighted average, each number in the data set is multiplied by a predetermined weight before the final calculation is made [28]. The weighted average of each factor was calculated by using the following formula.

$$A_w = \frac{\sum(Q_i n)}{\sum Q_i} \tag{4}$$

where A_w is the Weighted Average, Q_i is the number of respondents for a specific level n of the Likert scale, and the value of n ranges from 1 to 5.

The desktop study technique was used in this study to achieve the first purpose, which was to review the key related literature and global experiences and collect secondary data related to the off-plan sales program. The desktop study technique is considered one of the most widely used techniques for collecting secondary data and has been used in some similar studies [44]. The study used Google Scholar as one of the most popular search engines in addition to Science Direct to identify and collect the related literature by using keywords such as off-plan sale, mortgage, real estate, housing programs, housing in Riyadh, and off-plan sale in Saudi Arabia. Additionally, online sources such as published reports, journal articles, conference proceedings, and websites of international development organizations and government institutions were used. The study also used the Delphi technique, a consensus-based approach, to achieve the second purpose, which is to identify the most significant financial and marketing challenges facing off-plan sales programs in Saudi Arabia, with a focus on Riyadh, and formulate consensus-based measures to overcome these challenges.

According to Okoli and Pawlowski [45], the Delphi technique is a group decision technique that requires skilled experts with a deep understanding of the issue under investigation. The technique is derived from distributing the process into three rounds: (1) brainstorming; (2) narrowing down; and (3) ranking round, as illustrated in Figure 5, and it has been used in several scientific research projects [45–48]. In this study, it is believed that the Delphi technique is the most appropriate technique for such research compared with other consensus-based approaches such as Staticized and Interacting Groups or Nominal Group Technique (NGT). Indeed, the Delphi technique was realized to be a better approach in terms of comprehensiveness of the outcomes, although the study could be completed by employing a traditional survey approach. Studies using Delphi have richer data availability because of their numerous iterations and feedback, as the experts involved in these studies are mostly positive about follow-up interviews [45,49,50].

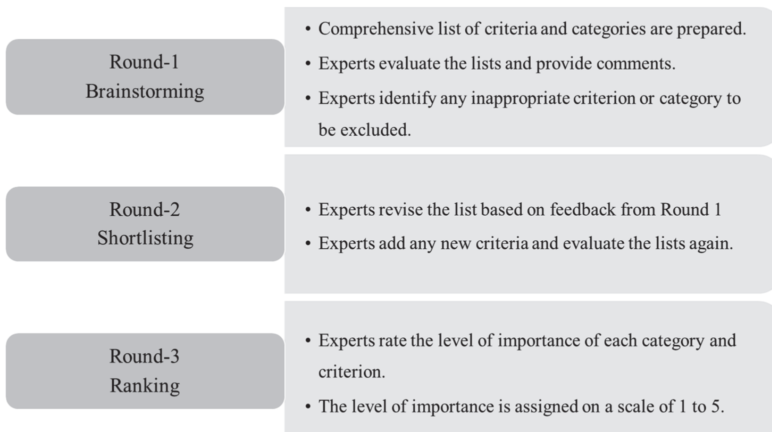

Figure 5. A Typical Delphi Technique Process.

The significance of Delphi experts has been emphasized by numerous studies [45,47,50]. This emphasis is because studies using Delphi rely primarily on team decisions rather than on a statistical sample that is representative of the entire population, and because of this, the team needs to have experienced experts with deep knowledge of the research area. Therefore, this study followed five main steps to select the experts based on the principles presented by Okoli and Pawlowski [45] and Schmidt et al. [50], as shown in Figure 6. The first and most significant step is the Knowledge Resource Nomination Worksheet (KRNW), which aims to avoid ignoring any certain group of target parties and helps classify the experts before they are recognized. The second step is to prepare a list of the names of the experts selected in KRNW and their contact numbers. The third step is to contact experts and ask them to participate in the study and nominate other experts. The fourth step is to categorize experts according to an appropriate list and rank them based on their qualifications, years of experience, achievements, etc. The final step is to invite experts to participate in this study.

The purpose of using the Delphi technique is to identify the most important financial and marketing challenges facing off-plan sales programs in Saudi Arabia, with a focus on Riyadh, to come up with the best measures that can be applied in the study area and to overcome these challenges. Consequently, while structuring the Delphi questionnaire, the study aimed to target the experts in the field of housing (e.g., professionals, real estate developers, and academics) from the public and private sectors as well as universities. Although it was possible to distribute hard copies of the questionnaire in this study, the online survey technique was used due to its being faster and more efficient [51–53]. The survey was conducted using QuestionPro, and the survey link was distributed to

KRNW's selected experts through email and social media. To reach the required sample size, the snowball sampling technique was used, which is one of the scientific sampling methods [54]. The questionnaire reached 54 experts, 38 of whom completed and submitted it. The Statistical Package of Social Science Software (SPSS) v26 was used in this study for the descriptive analysis of the data.

Figure 6. Procedure for Selecting Experts in Delphi Technique.

4. Results

4.1. Demographic Details of the Respondents

Table 1 shows the general characteristics of the experts involved in this study. Analysis of the characteristics of the respondents shows that most of the participants are male, representing 81.6% of the study participants, while 18.4% are female. Such low female participation is not unexpected in a patriarchal society, which is connected with the fact that local context and culture frown on women interacting with unrelated people. This low rate of female participation in Saudi Arabia has been reported in similar studies, such as 11% and 9% [55,56]. The analysis shows that most of the experts are highly educated, as the analysis indicates that a little over half of the respondents (55%) have a bachelor's degree, and approximately a third of them (29%) have postgraduate degrees, either a master's degree or a doctorate. The government sector is the main employer of this study's participants (63.2%), followed by the private sector (26.3%). The majority of respondents (47.4%) in this study have had years of experience in the housing sector for a period ranging between 11 to 15 years, followed by 5 to 10 years (26.3%) and 16 to 20 years (15.8%), while the participants with more than 25 years make up 5.3% of the total participants. Thus, it seems that most of the participants have enough experience to have a rational view of the financial and marketing challenges facing the off-plan sales program in Riyadh.

Table 1. Demographic Details of the Respondents.

Characteristic	Category	Absolute Value	Percentage
Age (Years)	25–34	9	23.7%
	35–44	14	36.8%
	45–54	11	28.9%
	55–64	3	7.9%
	65 Years or Older	1	2.6%
Gender	Male	31	81.6%
	Female	7	18.4%
Educational Level	High School	5	13.1%
	Diploma	1	2.6%
	Bachelor's Degree	21	55.3%
	Postgraduate	11	28.9%
Employment	Government sector	24	63.2%
	Private sector	10	26.3%
	Unemployed	3	7.9%
	Retired	1	2.6%
Experience (Years)	5–10	10	26.3%
	11–15	18	47.4%
	16–20	6	15.8%
	21–25	2	5.3%
	More than 25 Years	2	5.3%

4.2. Expert Opinion on Financial Challenges

The study participants were asked to indicate if they think the off-plan sales program in Saudi Arabia and Riyadh, in particular, is at risk of some financial and marketing challenges, and more than half of them (55.26%) answered in the affirmative, 15.79% answered no, and 28.95% did not know. Concerning financial challenges facing the off-plan sales program in Riyadh, several challenges were presented to the experts during the three rounds of the Delphi technique, and the outcomes of the questionnaire in the final round underline the significance of some of them. Experts ranked these challenges based on the influence of each challenge from their point of view and based on a five-point Likert scale, where five represented extremely influential, and one represented not at all influential. As shown in Figure 7, an analysis of the results shows that there is a consensus among experts regarding the influence of the presented financial challenges, with a weighted average of 4.03–4.18.

The "mortgage of the land deed" and "matching buyers' payments with project implementation phases" came in the first place as the most influent challenges with a weighted average of 4.18, followed by the challenge of "not all financing agencies and banks recognize off-plan sales program" with 4.16 weighted average. The analysis shows the similarity of the influence level of the "delayed approval of the buyer's contract" with the "buyers' obligation to pay on due dates," with a weighted average of 4.08 each. The challenge of "mechanism of work of financing agencies and bank" and the challenge of "high interested rate in the off-plan sale program due to potential risks (e.g., a default of the developer or buyer)" remained in the last positions with a weighted average of 4.03.

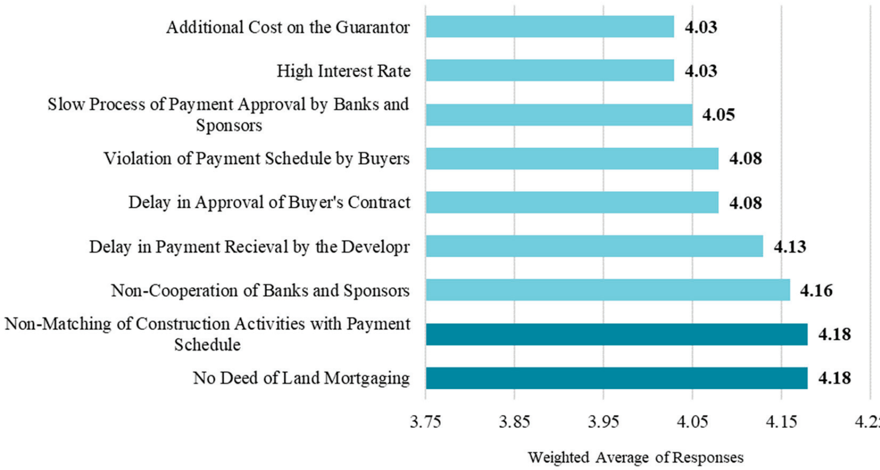

Figure 7. The Weighted Averages of Financial Challenges based on the Consensus of Experts.

4.3. Expert Opinion on Marketing Challenges

Several marketing challenges were presented to the experts, and they were asked to rate them based on the level of influence from their point of view by using a five-point Likert scale, as with financial challenges, where five represented extremely influential, and one represented not at all influential. As illustrated in Figure 8, an analysis of the results shows that there is a consensus among experts regarding the influence of the presented marketing challenges, with a weighted average ranging between 4.13 and 4.29.

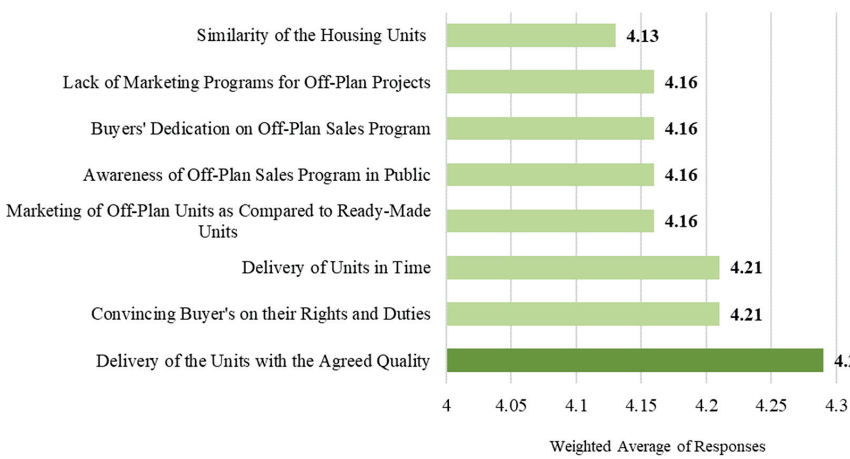

Figure 8. The Weighted Averages of Marketing Challenges based on the Consensus of Experts.

The “delivery of the units with the agreed quality” came in the first place as the most significant challenge facing marketing off-plan sales program with a weighted average of 4.29, followed by the challenge of “knowing buyers about their rights and duties” and the challenge of the “ability of the developer to deliver units on time” with 4.21 weighted average for each. The analysis shows the similarity of the influence level of the “knowing people about off-plan sales program”, “marketing units in off-plan compared to ready-made units”, “buyers’ conviction of the off-plan sales program”, and “lack of marketing programs for off-plan sales" with a weighted average of 4.16 for each. The challenge of "similarity of the housing units" came in last place with a weighted average of 4.03.

After the most influential financial and marketing challenges were presented to the experts, they were asked to express their views on whether it is important, in their view, to find some measures and solutions to confront and overcome these challenges. As it is illustrated in Figure 9, more than three-fourths (77%) of the study participants answered in the affirmative, and about 18% did not know, while only 5% answered No.

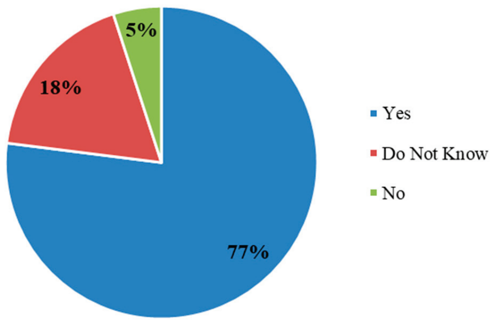

Figure 9. Expert Opinion on the Importance of Proposing Measures to Overcome Challenges.

5. Proposed Measures to Overcome Challenges

5.1. Proposed Measures to Overcome Financial Challenges

Several proposed measures were presented to experts for overcoming the financial challenges facing the off-plan sales program in Riyadh and in Saudi Arabia in general, whether accelerating the procedures or standardization of the contracts, and they were asked to rate these measures. The rating was based on a five-point Likert scale, where five represented extremely important, and one represented not at all important. As shown in Table 2, an analysis of the results shows that there is a consensus among experts regarding the importance of all proposed measures to overcome the agreed financial challenges, with a weighted average of 4.18–4.34. The standard error of the mean (SEM) has been used to specify the statistical uncertainty; the determined standard error was less than 0.1 for all the proposed financial measures.

Table 2. The Weighted Average of Proposed Financial Measures Opted by Experts.

Proposed Financial Measure	Std. Dev.	Std. Error	Weighted Avg.
Reducing Total Cost while Maintaining the Same Quality	0.33	0.054	4.26
Standardization of Mechanism of Property Exchange	0.28	0.045	4.21
Standardization of Contracts	0.51	0.083	4.18
Active Participation of Banks and Sponsors	0.34	0.055	4.32
Offering Financing Plans to Buyers	0.27	0.044	4.34
Reconsideration of the Interest Rate	0.10	0.016	4.24
Follow-up of Applications Regularly	0.18	0.029	4.32
Alternate to Mortgaging the Land	0.51	0.083	4.29
Accelerating the Procedures	0.24	0.039	4.21

The choice of "Providing financing offers to buyers" came in the first place as the most important proposed measure with a weighted average of 4.34, followed by the choices of "Follow-up of applications regularly" and "More participation of bank and financing agencies" with 4.32 weighted averages for each. Analysis of results shows that there is consensus among experts that providing financing offers to buyers is one of the most important measures that will motivate people to consider buying their homes through the off-plan program and, consequently, the success of the program. The options of

"Accelerate the procedures" of the purchasing process through the off-plan sales program, "Standardization of mechanism of exchange among stakeholders", and "Standardization of contracts" came in the last three places in the list of proposed measures to overcome the financial challenges facing the off-plan sales program in Riyadh, but it remains with a high weighted average of 4.21, 4.21 and 4.18, respectively.

5.2. Proposed Measures to Overcome Marketing Challenges

As with proposed measures of overcoming financial challenges, some proposed measures were presented to experts for overcoming the marketing challenges facing the off-plan sales program in Riyadh, whether Advertising the of-plan sales program through electronic marketing tools or making visual clips of the project in addition to the displayed unit, and they were asked to rate these measures. The rating was based on a five-point Likert scale, where five represented extremely important, and one represented not at all important. As shown in Table 3, an analysis of the results shows that there is a consensus among experts regarding the importance of all proposed measures to overcome the agreed marketing challenges, with a weighted average of 4.11–4.37. The option of "Quality of construction and design of housing units" came in the first place as the most important proposed measure with a weighted average of 4.37, followed by the option of "Advertising through social media" with a value of 4.34, a weighted average. The option of "Placing large advertisements in streets and on buildings" came in the last place in the list of proposed measures to overcome the marketing challenges facing the off-plan sales program in Riyadh, but it remains with a high weighted average of 4.11.

Table 3. The Weighted Average of Proposed Financial Measures Opted by Experts.

Proposed Marketing Measure	Std. Dev.	Std. Error	Weighted Avg.
Establishing Strong Marketing and Sales Department	0.47	0.076	4.26
Quality of Design and Construction	0.19	0.031	4.37
Competitive Prices of Housing Units	0.33	0.054	4.26
Highlighting the Prominent Services and Advantages	0.47	0.076	4.29
Creating Advertising Videos for Projects	0.34	0.055	4.32
Advertising through Marketing Applications	0.22	0.036	4.32
Advertising through Social Media	0.17	0.028	4.34
Large Advertisement Boards in Streets and on Buildings	0.44	0.071	4.11

6. Discussion on Key Findings

Through this study, the importance of the off-plan sales program has emerged as one of the most important key programs for the provision of housing units which must currently be considered by the relevant stakeholders. Indeed, the literature review, as well as the global experiences in the field of housing delivery, have a great role in shedding light on the significance of such a program. The reason for this is that the off-plan sales program can provide buyers with housing units at a lower cost compared to ready units and helps put an end to speculation that negatively affects the prices of housing units. Like other housing programs, the off-plan sales program in Riyadh and Saudi Arabia, in general, faces some financial and marketing challenges. In this study, the experts had the opportunity to review some of the financial and marketing challenges facing the off-plan sales program in Riyadh at present through the three rounds of Delphi technology, where the results of the final round confirmed the importance of some of the proposed measures to overcome such challenges.

As illustrated in Figure 10 and Table 2, experts stressed the extreme influence of both the mortgage of the land deed and matching buyers' payments with project implementation phases as the most significant challenges, with a weighted average of 4.18 for each, followed by the challenge of not all financing agencies and banks recognize off-plan sales program with 4.16 weighted average and length of time taken to deposit the amounts in developer's accounts with a weighted average of 4.13. The majority of experts participating in this study indicated that the requirement to marginalize the land deed in the off-plan sales system is mainly to preserve the rights of all parties and to ensure that the real estate developer does not dispose of the land when signing contracts with the buyers. However, some experts also indicated that this requirement is accompanied by some negatives that may affect the progress of the project, such as the delay in issuing building and marketing licenses in addition to the fact that landowners avoided entering their lands for off-plan sales projects, thinking that this requirement would make them lose control of the land. Therefore, some experts consider this requirement as one of the financing challenges facing real estate developers in off-plan sales projects. Additionally, experts highlighted that the requirement to marginalize the land deed has contributed to increasing the financing burden on the real estate developer, especially if the developer wants to mortgage the land and obtain financing, and according to Australian and UK experiences that were previously reviewed, this requirement is not applied due to the presence of other guarantees protect the rights of the buyer, including insurance on the project and its implementation, in addition to the presence of governmental control bodies that supervise withdrawals from the guarantor's account, according to the payments agreed upon in the contract and the percentages of completion in the project.

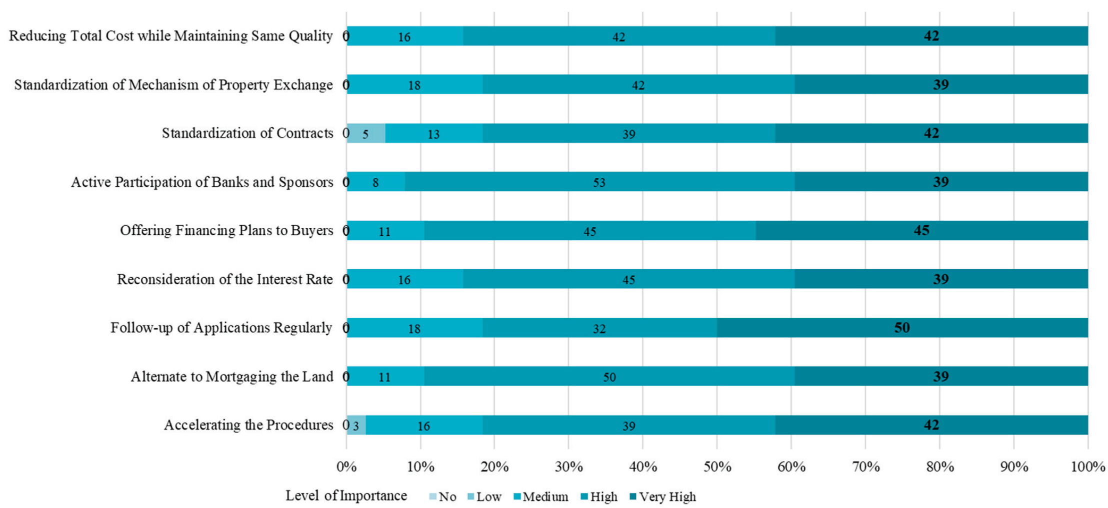

Figure 10. Response Percentage for each Proposed Financial Measure.

The results also shed light on one of the most important financing challenges facing the off-plan sales program, which is that many banks still do not recognize the financing of real estate projects using the off-plan sales system, which reduces the options available to buyers when making a purchase decision. The study found that despite the buyers' commitment to pay the installments according to the project completion rates and according to the plan set by the off-plan sales committee "Wafi", some banks still do not adhere to this plan, in addition to the delay in depositing the amounts of payments after receiving them from the buyers in the real estate developer's account although the developer has achieved the required percentage of completion. The finding shows the similarity of the influence level of the delayed approval of the buyer's contract with the buyers' obligation to pay on due dates, with a 4.08 weighted average for each. This finding is consistent to some extent with the literature, where some similar studies [31,32] have emphasized the significance of the buyers' failure to pay the payments on due dates, which disrupts the real estate developer's financing sources. The challenge of the mechanism of work of financing agencies and banks and the challenge of high interested rates in the off-plan sale program due to potential risks (e.g., a default of the developer or buyer) remained in the last positions, but it remains with a high weighted average of 4.03 for each. The additional cost of the guarantor's account came in the last place on the list with a weighted average of 4.03. The findings confirmed that the guarantor account does not constitute any additional costs to the total cost of the project if the relationship between the real estate developer and the financing agencies is good to motivate and attract customers. Conversely, if the developer does not have any prior dealings with the financing entity, additional fees will be charged upon disbursement and receipt of payments.

As illustrated in Figure 11 and Table 3, the study found that among the most influential marketing challenges facing the off-plan sales program is the delivery of the housing units with the agreed quality, with a weighted average of 4.29. Most of the experts stressed the difficulty of convincing people of a product that does not exist on the ground. This, of course, may be attributed to the fact that when people see the housing unit and like it, they want to move to it directly and not wait for a period that may increase due to many reasons. The finding shows the similarity of the influence level of knowing buyers about their rights as well as duties and the ability of the developer to deliver units on time with a 4.21 weighted average for each.

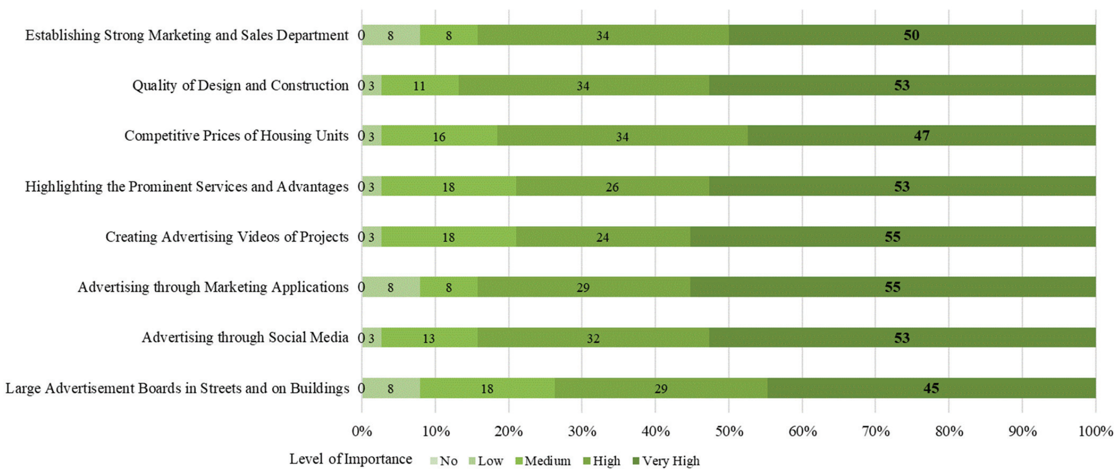

Figure 11. Response Percentage for each Proposed Marketing Measure.

In this study, the experts touched on the fact that many buyers are still ignorant of the reality of this program and are not aware of their full rights and duties, in addition to their fears of not receiving their unit on time and according to their initial perception of the unit. Additionally, experts indicated the significance of the ability of developers to deliver the agreed housing units on time as one of the main reasons for the reluctance of some buyers to purchase housing units through the off-plan sales program and emphasized the importance of looking at the name of the developer, his real estate reputation, previous experience, and the after-sales services provided by the developer. The findings determined that the project implementation period is one of the main reasons for the buyers' reluctance to purchase residential products under the off-plan sales system, especially if the agreed period is exceeded, due to the multiplicity of their financial obligations (e.g., paying rent), which places a heavy burden on the buyer.

The finding shows the similarity of the influence level of (1) marketing units in off-plan compared to ready-made units; (2) knowing people about off-plan sales programs; (3) buyers' conviction of the off-plan sales program; and (4) lack of marketing programs for off-plan sales with a 4.16 weighted average for each. Experts participating in this study determined that one of the marketing challenges facing the off-plan sale program is the lack of financial capacity of some real estate developers to carry out marketing programs that are commensurate with the size of the project. The study found that some buyers are still unfamiliar with the concept of the off-plan sales system. The study also found that some are ignorant of their rights towards the real estate developer and financing agencies, which leads to their non-acceptance of buying a product that does not exist on the ground. This is attributed to the weak marketing campaigns of the off-plan sales projects. The findings highlighted that although the off-plan residential units are less expensive compared to the ready-made housing units, this difference is not a great motivator for the purchase decision compared to other incentives, such as the location of the project and the reputation of the real estate developer, which confirms the great role that marketing plays in the success of such projects. Last but not least, the challenge of the similarity of the housing units in the off-plan sale program remained in the last position of the marketing challenges rating list, but it remains with a high weighted average of 4.13.

The findings of the study stressed the need to set several measures to overcome the financial challenges that are facing the off-plan sales program nowadays and enhance the current situation of the program not only in Riyadh but in Saudi Arabia as a whole. As illustrated in Figure 12, the most important proposed measure is the provision of financing offers to buyers with a weighted average of 4.34. This, without a doubt, will greatly encourage people to consider the off-plan sales program as one of the ideal options for buying their homes. The follow-up of applications periodically is also another important proposed measure that can help to accelerate the procedures within the off-plan sales program with a weighted average of 4.32. With the same level of importance, experts agreed that more participation from banks and financing agencies is urgently needed. The standardization of contracts came in the last place on the list of proposed measures to overcome the financial challenges, but it also remains with a high weighted average of 4.18.

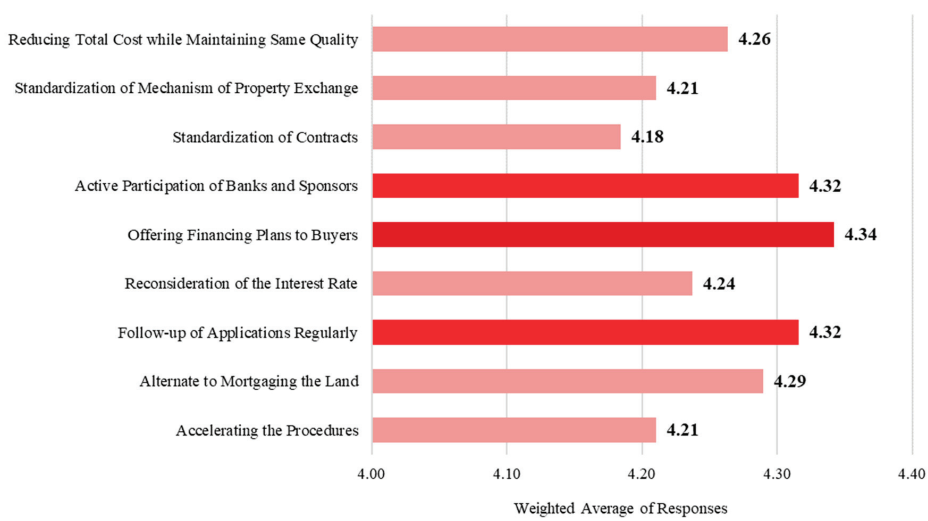

Figure 12. Consensus-Based Financial Measures as Proposed by Experts.

The findings of the study also underlined the necessity to propose several measures to overcome the marketing challenges that are facing the off-plan sales program at present and enrich the program. As illustrated in Figure 13, the most important proposed measure is the quality of the construction and design of housing units in the off-plan sales program, with a weighted average of 4.37, followed by the advertising of the off-plan sales program and its products through the social media with a weighted average of 4.34. Experts agreed on the same level of importance for both advertisements of off-plan sales projects through electronic marketing tools and making visual clips of the off-plan project in addition to the displayed unit, with a weighted average of 4.32 for each. Placing large advertisements in streets and on buildings came in the last place on the list of the proposed measures to overcome the marketing challenges, but it also remains with a high weighted average of 4.11.

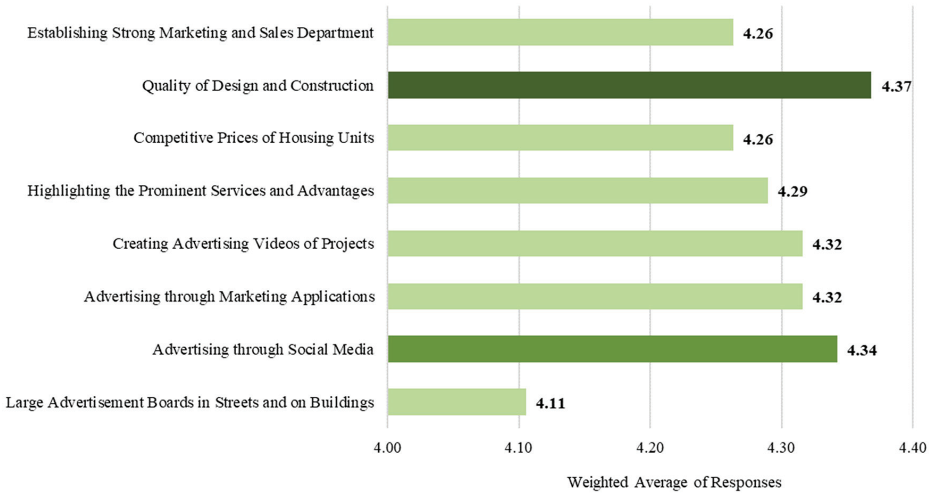

Figure 13. Consensus-Based Marketing Measures as Proposed by Experts.

7. Conclusions

During the past few years, the real estate sector in Saudi Arabia has received a great deal of attention, especially in the field of housing, which is one of the largest areas of spending within the framework of the National Transformation Program (NTP) and the Saudi Vision 2030. This represents a stimulating step for the real estate industry sector in general and housing in particular, which represents a share of about 65% of the total real estate market. From this study, it is very clear that the off-plan sales program is considered one of the most prominent housing programs that need to be supported. Based on the analysis of the opinions of 38 experts using the Delphi technique, this study argues that there are several financial and marketing issues facing the off-plan sales program in the country. Therefore, the purpose of this study was to review the off-plan sales program and the most prominent goals for which it was set and to identify the most significant financial and marketing challenges facing the program in Saudi Arabia, with a focus on Riyadh and formulating consensus-based measures to overcome these challenges.

The literature on the off-plan sale program and the expert's point of view had a great role in shedding light on the most significant financial and marketing challenges facing the off-plan sales program in Riyadh at present. For instance, regarding financial challenges, the findings underlined the importance of reconsidering the condition of marginalizing the land deed and finding alternatives that protect the buyer's rights and, at the same time, do not hinder the developer in completing the implementation of the project. Among the proposals is to ensure the implementation of the project through real estate insurance companies to ensure that the costs of the project default are incurred by all parties involved in the implementation, or the developer provides a bank guarantee with a certain percentage of the cost of the project, which will be returned upon completion of the project. The results also showed the importance of matching buyers' payments with project implementation phases and linking contracts electronically between real estate development companies and financing agencies and between the buyers to facilitate and expedite the completion of procedures, which is reflected in the progress of the project implementation.

Regarding the marketing challenges, the finding highlighted the importance of providing introductory programs by the Ministry of Housing about the off-plan sales program for the buyers to clarify the parties involved in this program and the most prominent rights and duties of the buyer and the real estate developer, as well as clarify the methods used to preserve the rights of all parties, which enhances the confidence of the buyers and increases the desire to buy residential products in the off-plan sales program. The real estate developer could also build several display housing units to give the buyer a perception of their future home, especially since some buyers do not feel the spaces drawn in the architectural plans. Moreover, providing basic services in the project, such as schools, parks, and other services, is important due to their significant impact on the marketing of housing units and influencing the purchase decision of the buyer.

Finally, this study included a series of fundamental phases to achieve the main purpose, starting with a review of the concept of an off-plan sale program and ending with a discussion of the key financial and marketing challenges. The study aspires to contribute to presenting some of the proposed measures to overcome the financial and marketing challenges facing the real estate developer in Riyadh and in Saudi Arabia in general while preserving the rights of all parties in the contractual process. Similar studies in this field are limited, making this study one of the pioneering attempts to investigate the reality of the off-plan sales program in the country. However, although the buyers' opinions are very important, they have not been addressed in this study because of the time limitation. Therefore, future research could focus on evaluating the off-plan sales program in Saudi Arabia based on the buyers' opinions to receive a better understanding of the program.

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Spatial–Temporal Differentiation of Housing Burden of Urban Floating Population and Migration in China

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Abstract: Housing costs, including rent, have become a significant economic burden for millions of floating population families in urban China, affecting their living standards and influencing migration decision-making. Using data from the China Migrants Dynamic Survey (CMDS) in 2012 and 2017, this study analyzes the spatial patterns of rent, family income, and the rent-to-income ratio among different regions, cities, and groups. Results show that rent and the rent-to-income ratio have an inverse correlation with the regional economy, with lower ratios observed in eastern coastal areas compared to the central and western regions, especially the northeast. High-level cities record higher incomes, higher rents, and higher rent-to-income ratios, and groups with higher educational levels and occupational characteristics exhibit higher affordability. Rent plays a role in the flow and changes of the floating population, and the housing burden has become a key constraint for long-term residence or migration. Developed provinces and municipalities in the eastern region and high-level cities remain major destinations for migrants, but rising house prices impede permanent settlement through commercial house purchases. The government should consider migrants' demands for housing and increase the supply of subsidized housing, such as public rental housing, for the floating population.

Keywords: floating population; social space; housing burden; rent-to-income ratio; housing-price-to-income ratio

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1. Introduction

Since 1978, with the continuous promotion of urbanization and the reform of the household registration system, the large-scale population movement in China has continued for more than 40 years with the surplus rural labor force as the main force, and the size of China's floating population was about 244 million in 2017, accounting for 18% of the total population (National Bureau of Statistics, 2018), profoundly affecting the socioeconomic development of both inflow and outflow areas, and also becoming the key to achieving the goal of common prosperity and to building a people's city and a sharing city [1]. The size of China's floating population has increased rapidly since 2000, reaching a peak in 2015, and has shown a downward trend during 2015–2019, with the return migration represented by Sichuan and Anhui provinces being a common phenomenon, which is caused by the size and structure of the population, as well as factors pertaining to changes in the comprehensive benefit and costs of the outflow and inflow areas [2]. The continued slowdown in the growth rate of the permanent settlement of the floating population poses new challenges to sustainable urbanization and has attracted the attention of governments and scholars [3].

The problem of population mobility or migration is not unique to China's floating population. Actually, both in developed countries and in developing countries represented by China, the domestic/international mobility of the population faces a difficult choice between settlement and backflow throughout the migration process. Foreign studies on the driving mechanisms of population mobility or migration can be traced back to the late 19th century, and theoretical models that elucidate the mechanism of population migration and decision-making processes have been proposed, including neoclassical economic migration theory [4,5], spatial interaction models [6,7], new migration economics [8], push–pull models [9,10], and social network theory [11]. Broadly speaking, the comprehensive comparison and evolution of input–output benefits in the inflow and outflow areas are the core decision factors of whether to migrate or whether to stay permanently/continue to migrate. The foreign residential rental market developed earlier and is more mature, and scholars' research on residential rents has included rental price effect, rental price index, rental policy effect, rental price forecast, rental income ratio, etc. [12–15]. Domestic scholars have conducted relevant studies from two perspectives: individual decision-making based on questionnaires; and regional comparison based on census data. Some scholars have studied the formation mechanism of the spatial pattern of the floating population from a macro perspective and found that wage and income levels, employment opportunities, industrial structure, capital investment, social and public services, population size, the household registration system, and the taxation system are significant, among which economic factors are the most important "pull" conditions [16,17]. Some scholars have analyzed the role of individual characteristics in population mobility decisions from the individual perspective, and they have concluded that factors such as age, education level, travel experience, and marital status among individual characteristics have a significant impact on population mobility decisions [18–20]. In conclusion, the size and spatial pattern of the mobile population can be seen as the result of a combination of economic, political, social, and individual factors. It is worth noting that China's unique household registration system and the large number of people moving within the country make the settlement process more complicated, and most studies have attributed the low growth of the permanently settled population to the restrictions of the household registration system, which has been reformed in recent years and has gradually weakened the restrictions on residents' willingness to settle [21,22]. The alternative to avoiding the account limit is to own a home in the city where they live, allowing the mobile population to enjoy the local welfare system and achieve permanent settlement [23,24]. However, existing studies have not reached a unanimous conclusion on the issue of housing affordability.

As homeownership becomes increasingly important, the expected utility of settling permanently in an inflow city determines whether migrants choose to migrate continuously or to settle [25,26]. It is widely believed that changes in housing costs affect the migration decisions and settlement intentions of mobile populations, especially when housing costs increase, which can have a "crowding-out effect" on the floating population. Several domestic and international studies have shown that housing costs are an important component of the living cost, and rising housing prices increase the cost of acquiring housing, reduce residents' housing affordability and well-being, and exclude low-income groups from the housing market, thus inhibiting the mobile population's willingness to move in and stay [27–30]. Scholars with the opposite viewpoint argue that rising housing costs, characterized by housing prices, are a signal of urban economic prosperity, implying better employment opportunities and public services, and that real estate is a stable and high-yielding investment which has an "attraction effect" on the mobile population [31,32]. Meanwhile, housing expenditure reflects the willingness to pay of the mobile population and, to some extent, has a positive effect on settlement viscidity. Other scholars combined the above two arguments and proposed that as the housing expenditure-to-income ratio increases, the floating population's residence willingness in cities shows an inverted U-shaped pattern [33], and once the housing expenditure-to-income ratio is higher than the "threshold", it will prevent the mobile population from moving in and settling for a long time [34,35]. In other words, the housing price has a push–pull effect in both directions, and the migrant population will weigh the magnitude of both forces when choosing a city to move in.

In general, previous studies have mainly explored the impact of housing pressure on the mobile population's residence willingness from the perspective of housing prices, while rent is equivalent to a "sunk cost" for the mobile population compared to the cost of housing purchase, and paying rent does not generate any investment return, nor does it provide access to urban services such as compulsory education, which are tied to residential property rights and only reduce the disposable income of mobile households and increase their living cost. Therefore, rent should be a more important indicator of the housing burden of the mobile population than housing prices. In recent years, although some scholars have explored the relationship between the rental or lease market and residence willingness, the following shortcomings remain: (1) Most of the existing research focuses on the impact of rural migrants' home ownership and government housing security on their willingness to settle permanently. As the core subjects and contributors to the urbanization process, the floating population, due to their poor employment stability and low-income status, rent as the main housing mode. (2) Few studies have visually portrayed the spatial and temporal patterns of rental burden among the urban floating population in China. In view of the above reasons, this paper analyzed the spatial variation and evolution of rent (absolute burden) and rent-to-income ratio (relative burden) of the urban floating population in China, compared the differences in rent burden among different regions, cities and groups, and then explored the intrinsic link between rent burden and population mobility and predicted the possible impact of increased housing burden on population mobility by combining the house-price-to-income ratio index, the willingness of the migrant population to stay in the local area, and the factors influencing the willingness to stay. Finally, based on the goal of common prosperity and the concept of people's city, we propose housing security for the urban migrant population in a targeted manner.

2. Data Source and Research Object

2.1. Research Area and Data Sources

According to the current administrative division system in China, a total of 309 prefecture-level administrative units are selected as research areas. Data on the urban floating population—i.e., for the inflowing population aged 15 years and above who have lived in the inflowing area for one month or more and are not registered in the household registration of the district (county or city))—were obtained from the annual National Floating Population Health and Family Planning Dynamic Monitoring Survey conducted by the National Health and Family Planning Commission(http://www.chinaldrk.org.cn/wjw/#/data/classify/population, accessed on 1 April 2020), which adopted a stratified, multi-stage, size-proportional PPS approach to sampling 31 provinces (autonomous regions and municipalities) and the Xinjiang Production and Construction Corps (excluding Hong Kong, Macao, and Taiwan) across China. Urban housing price data were obtained from the annual average price of second-hand house listings provided by the China House Price Quotation Platform (www.creprice.cn, accessed on 5 February 2020), which collected data from 50 million user releases and tens of thousands of real estate websites, and reorganized the collected data, filtered duplicates, and excluded abnormalities, then obtained comprehensive and objective property data after manual verification.

2.2. Data Processing

The CMDS data has now been updated to 2018, but the 2018 questionnaire data has not been used because the average monthly rent expenditure of mobile households is no longer separately counted after 2017. The years 2012 and 2017 were chosen as the time points; cities above the prefecture level were used as the spatial units, and the mobile population whose "housing nature" option in the questionnaire was "rented private housing" was used as the sample for the study. The median monthly housing rent and median monthly household income of the mobile population in the city, respectively, were used for urban rent and income, The urban rent-to-income ratio (RIR) is calculated in the form of "monthly housing rent"/"monthly household income". In order to systematically analyze and compare the spatial patterns of housing rent, household income and the RIR of the urban migrant population in China, the cities were divided into four regions: east, central, west, and northeast, and four classes: first-tier, new first-tier, second-tier, and third-tier and below, based on regional and class characteristics (The First Financial New Tier Cities Institute ranks cities above prefecture level according to five indicators: business concentration, urban hub, urban activity, diversity of life, and future plasticity, and classifies them into first-tier, new first-tier, second-tier, third-tier, fourth-tier, and fifth-tier cities (https://www.yicai.com/topic/101425010/ (accessed on 7 August 2022)). The mobile population samples with singular and missing values were excluded, cities with less than 10 mobile population samples were removed to avoid bias caused by too small a sample size, and the final valid sample sizes of the mobile population in 2012 and 2017 were obtained as 100,134 and 95,313, respectively, with the number of sample cities both being 309.

3. Spatial and Temporal Differentiation Pattern of Rental Housing Burden

3.1. Spatial Pattern and Evolution of the RIR

In addition to housing rent, it is also necessary to make a comprehensive judgment combined with household income to measure the degree of housing burden of the floating population. Therefore, this paper classified and visualized the rent, income, and RIR of the floating population in each city in 2012 and 2017(Figure 1), respectively, to observe the spatial patterns and changes of each indicator, and the main conclusions are as follows.

① Rent levels showed spatial dispersion and increased divergence. In 2012, the average rent in cities was 392.83 RMB/month; by 2017, the average rent in cities rose to RMB 539.68/month, and the gap between cities widened. ② Income levels showed a significant zonal difference pattern. In 2012, the average income level of the floating population was RMB 3686.4 per month, with nearly 80% (79.73%) of the urban population earning between RMB 2500 and 4500 per month, with Shanghai, southern Jiangsu, and northern Zhejiang becoming the high-income gathering areas, while the central and northeast regions were relatively low. In 2017, the average income rose by 42.35% compared with 2012, reaching RMB 5247.53 per month; 82.01% of cities' earnings were between 3500 and 6500 yuan per month, and, except for Beijing, high-income cities clustered in Shanghai, Jiangsu, Zhejiang, Guangdong, Fujian, and other eastern coastal provinces and cities, among which first-tier cities such as Beijing, Shanghai, and Shenzhen, and new first-tier cities such as Nanjing, Hangzhou, and Xiamen had monthly incomes of up to RMB 8000 or more. Income in the central and western regions had grown significantly. In contrast, income growth in the northeast region lagged, especially in Jilin and Heilongjiang provinces, where there were still many cities, such as Jixi, Suihua, Baicheng, Baishan, Mudanjiang, and Songyuan, with monthly incomes of RMB 3500 and below. ③ The RIR was misaligned with the regional economic level. Under the joint influence of rent and income, the average RIR of the mobile population nationwide increased from 13.81% to 14.92% during 2012–2017, indicating that rent increased faster than income during the five-year period, and the rental burden of the mobile population increased. At the same time, due to the variation in rent and income between regions, it is reflected that the RIR did not match the economic development level of the region. For example, in developed coastal provinces such as Shanghai, Zhejiang, Fujian, and Guangdong, although rents had increased, incomes had risen relatively faster, and the RIR had decreased rather than risen, from 15.09%, 9.00%, 11.3% and 13.72% in 2012 to 14.61%, 8.70%, 10.66%, and 11.81% in 2017, respectively, they became areas where the rent burden was relatively lighter. On the contrary, in the northeast, where economic development was lagging behind, rents were rising fast while income was growing slowly, resulting in the RIR of Heilongjiang, Jilin, and Liaoning rising from 15.00%, 16.41%. and 14.63% in 2012 to 19.26%, 18.79%, and 16.02% in 2017, respectively.

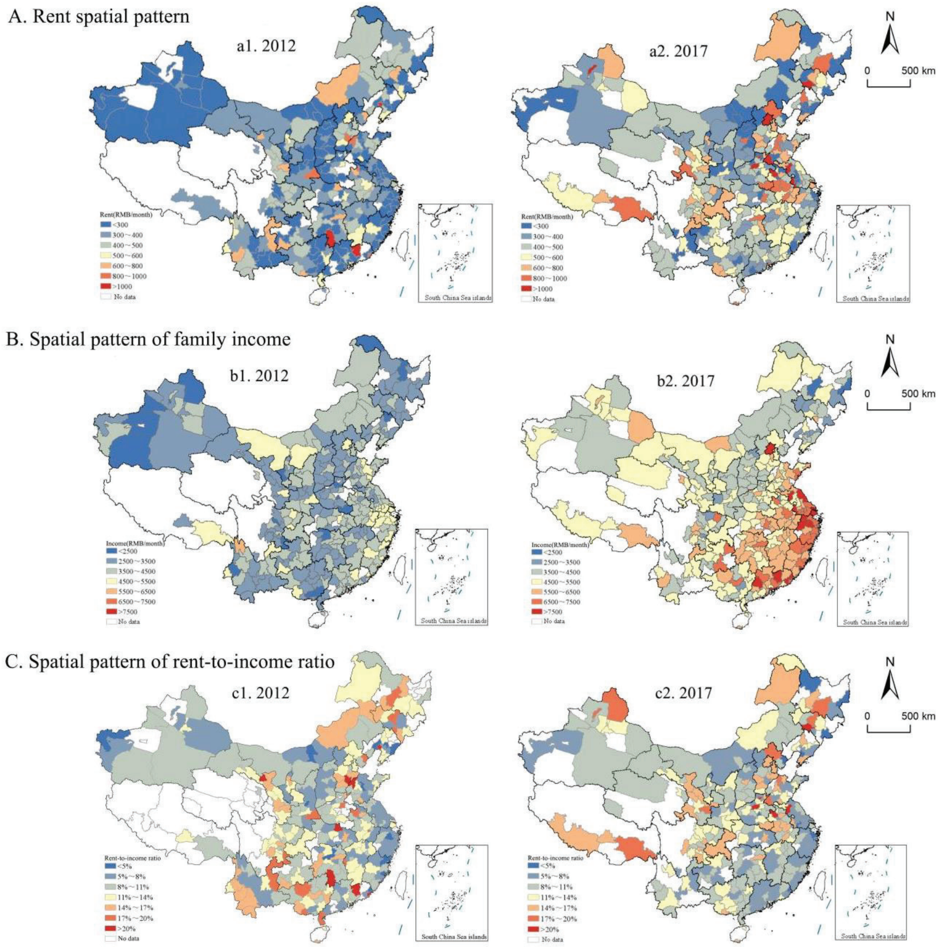

Figure 1. Spatial pattern of rent and family RIR of floating population, 2012 and 2017. Note: This figure is based on the standard map of the standard map service system of the Ministry of Natural Resources of China (review number: GS (2019) 1697), and the base map is not modified.

3.2. Differences between Different Educational and Occupational Groups

The large number and complex composition of the floating population groups make the differences in their rental affordability not only between regions and cities, but also within groups. The national mobile population was divided into different social groups according to education level and type of occupation, respectively, to observe the inter-group differences and changing trends in rent, income, and RIR.

In terms of education levels (Table 1), in line with conventional perceptions, higher education level groups had higher income, implying stronger rent affordability. The mobile population with a diploma of primary school and below, junior high school, high school and secondary school, and junior college and above showed a gradient increase in both rent and income, with the increase in rent being 49.62%, 44.73%, 51.33%, and 61.56%, respectively, and the increase in income being 26.91%, 36.25%, 42.82%, and 42.79, respectively, from 2012 to 2017. The RIR rose in the same gradient and increased for all groups, with larger increases for the highest and lowest educated groups.

Table 1. Rent, income, and the RIR of groups with different educational levels, 2012 and 2017.

Education Level	Rent (RMB/Month)			Income (RMB/Month)			RIR (%)		
	2012	2017	Growth Rates	2012	2017	Growth Rates	2012	2017	Growth Rates
Primary School and below	462.16	691.49	49.62%	4572.78	5803.19	26.91%	10.11	11.92	17.90%
Middle School	550.07	796.10	44.73%	4862.48	6624.94	36.25%	11.31	12.02	6.22%
High school and secondary school	669.27	1012.83	51.33%	5117.77	7309.26	42.82%	13.08	13.86	5.96%
Junior college and above	951.95	1538.00	61.56%	6206.92	8863.06	42.79%	15.34	17.35	13.14%

Differences between different occupational groups and changes in rankings between the two years were large (Table 2). Public officials and professional technicians had the highest rent and the second highest income and RIR in 2012, but in 2017, all three data rankings rose to first place, showing the "three highs" of high rent, high income, and high RIR; the most significant change was in the group of businessmen and merchants, where the rent increased by 108.4% while the income only increased by 29.47%, leading to the RIR from 8.89% to 14.30%, making this group with the largest increase in rental pressure. The rent and income of service industry practitioners and production and construction industry practitioners were relatively stable, and the RIR of service industry practitioners fell from first to third, while the RIR of production and construction industry practitioners had been significantly lower than that of other occupational groups.

Table 2. Rent, income, and the RIR of groups with different occupational characteristics, 2012 and 2017.

Occupation Type	Rent (RMB/Month)			Income (RMB/Month)			RIR (%)		
	2012	2017	Growth Rates	2012	2017	Growth Rates	2012	2017	Growth Rates
Public officials and professional technicians	723.44	1360.94	88.12%	5717.51	8685.97	51.92%	12.65	15.67	23.83%
Businessmen and merchants	527.14	1098.58	108.40%	5931.75	7679.85	29.47%	8.89	14.30	60.97%
Service industry practitioners	618.40	915.86	48.10%	4695.43	6537.58	39.23%	13.17	14.01	6.37%
Production and construction industry practitioners	351.03	555.86	58.35%	4709.62	6763.20	43.60%	7.45	8.22	10.27%

3.3. Differences between Different Regions and Urban Grades

City size and location factors can have spatially heterogeneous effects on the rent-to-income ratio of the mobile population. In terms of differences among different economic regions (Table 3), the rent in the eastern region is significantly higher than that in other regions, followed by the central region. In 2012, the rent in the northeast region was slightly higher than that in the west, while by 2017, the rent in the western region was higher than that in the northeast region. In terms of growth rates, the rent increases in the eastern, central, western, and northeast regions during the five years were 51.13%, 56.57%, 60.86%, and 47.00%, respectively. In terms of income, there was a stepwise decline in both income and income growth, with 42.55%, 32.22%, 32.10%, and 26.34% growth in the eastern, central, western, and northeast regions respectively, and the regional income gap widened; the RIR gradually increased from the east to the west and the northeast, with 0.71%, 2.18%, 2.60%, and 2.24% growth in each region, respectively, over the five-year period. The growth rate in the central and western regions and the northeast region was significantly higher than that in the eastern region, and the gap between the RIR of the regions had widened.

Table 3. Rent, income, and RIR of cities in different regions, 2012 and 2017.

Regions	Rent (RMB/Month)			Income (RMB/Month)			RIR (%)		
	2012	2017	Growth Rates	2012	2017	Growth Rates	2012	2017	Growth Rates
Eastern region	648.78	980.48	51.13%	5510.75	7855.68	42.55%	11.77	12.48	6.03%
Central region	563.38	882.09	56.57%	4754.98	6287.15	32.22%	11.85	14.03	18.40%
Western region	535.01	860.61	60.86%	4486.85	5927.17	32.10%	11.92	14.52	21.81%
Northeast region	562.64	827.07	47.00%	4114.91	5198.59	26.34%	13.67	15.91	16.39%

In terms of the differences among cities in different classes (Table 4), rent was highest in first-tier cities, followed by new first-tier cities. The rent was lowest in second-tier cities in 2012 and lowest in third-tier cities and below in 2017. The rent from first-tier to third-tier cities and below increased by 79.20%, 64.44%, 63.35%, and 45.28%, respectively, in 5 years, and the rent gap between city classes was increasing. The pattern of income was similar to that of rents, which means there was a gradient difference between city grades, with increases of 57.22%, 46.26%, 43.00%, and 27.66% respectively, indicating that the higher the grade, the higher the income and the faster the growth, and also indicating that the increase in income was lower than the increase in rent in cities of all grades. In terms of RIR, there was no mismatch with the level of economic development, with first-tier cities still being the highest, followed by new first-tier cities. However, the RIR in third-tier cities and below was higher than that in second-tier cities, and the RIR increased in 2017 in all tier cities, with the largest increase (1.9%) in first-tier cities.

Table 4. Rent, income, and RIR of cities at different levels, 2012 and 2017.

Urban Grades	Rent (RMB/Month)			Income (RMB/Month)			RIR (%)		
	2012	2017	Growth Rates	2012	2017	Growth Rates	2012	2017	Growth Rates
First-tier	862.81	1546.18	79.20%	6234.29	9801.85	57.22%	13.84	15.77	13.98%
New first-tier	594.37	977.36	64.44%	4848.48	7091.39	46.26%	12.26	13.78	12.43%
Second-tier	508.39	830.48	63.35%	4727.87	6760.97	43.00%	10.75	12.28	14.23%
Third-tier and below	512.56	744.66	45.28%	4623.31	5902.23	27.66%	11.09	12.62	13.80%

4. Population Mobility Tendency under the Influence of Housing Burden

4.1. Spatial Characteristics of Population Mobility

In terms of the direction of population flow between different regions, the overall flow was dominated by the flow from the central and western and northeastern regions to the economically developed eastern coastal regions. Taking 2017 as an example (Figure 2), we observe the following: (1) The proportion of internal flow in the eastern region was as high as 85.7%, with mutual mobility between cities of different levels within the region; another 12.3% of the population went to the central and western regions and 1.9% of the population went to the northeast region. Meanwhile, the first-tier and new first-tier cities in the east attracted a large inflow population from the central and western regions and the northeast region. (2) The proportion of internal mobility in the central region (47.8%) was the lowest among all regions, with as much as 38.5% of the population flowing to the east, and mainly concentrating in the first- and second-tier cities; the proportion flowing to the western region was also 11.8%, with more flowing to the third-tier cities; the proportion flowing to the northeast was relatively low, with the new first-tier and provincial capital cities dominating. (3) The proportion of internal flow was higher in the western region (76.1%), and most of the rest flowed to the eastern region (20.3%), mainly to second-tier cities; the proportion of flow to central China was 3.1%, the majority of which flowed to third-tier cities; the proportion of flow to the northeast region was as low as 0.4%, mainly to the new first-tier cities. (4) The proportion of internal population flowed in the northeast was 73.4%, and the rest 21.8% of the population flowed to the eastern region, among which first-tier and new first-tier cities were more favored; another 4.7% of the population entered the central and western regions and differed from those flowing to the eastern region, who mostly chose the third-tier cities in the central and western regions.

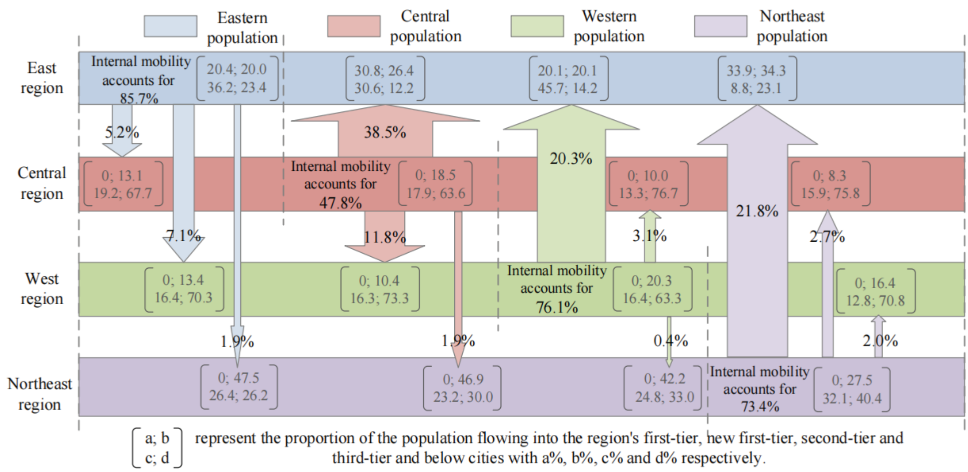

Figure 2. Direction of population movement by region, 2017.

The "push–pull theory" suggests that the driving force of population migration is a combination of push (repulsion) and pull (attraction) forces from both the inflow and outflow regions [36]. In addition, it is generally believed that mobile populations prefer to move to cities with better job opportunities and income growth prospects [37,38]. In addition, the level of public service supply level, quality of education and medical resources, social security improvement, and sense of local cultural identity and belonging are also important factors influencing population migration [39,40], while the increased cost of living, represented by the housing burden, constitutes the main push force of migration into the city on the mobile population. Xin Dong [41,42] found that the residence intention in a city shows an inverted U-shaped pattern of change as the "housing expenditure-to-income ratio" increases, and that high housing prices in incoming cities have formed a disincentive to migrate, but the impact of rent expenditure on the migration willingness is not considered significant. However, by analyzing the pattern of rental affordability and the characteristics of population mobility, this paper found that rental affordability may also have a constraint on the migration behaviour and residence decision of the mobile population.

The scatter plot compares rent and income of the mobile population in each province to better determine the degree of correlation between rent and income. The scatter plot of average income and rental burden of the mobile population by province and city (Figure 3) showed that Beijing and Shanghai, as well as the eastern provinces such as Zhejiang, Guangdong, Jiangsu, and Fujian, had consistently higher incomes, so it can be judged that the level of regional income was an important factor in attracting population inflow. At the same time, it can be seen that income was not the only consideration for population inflow. For example, in Inner Mongolia, Hunan, Anhui, and other places, although the income of the floating population was higher than the average level, they still needed to bear relatively high rent, which reduced the attractiveness to the population, while in Xinjiang, although the income was the lowest among the provinces, the rent cost was low at the same time; thus, it could still attract a large inflow of low-skilled laborers. Looking at Guangdong (11.13%), Jiangsu (10.8%), Fujian (10.08%), and Zhejiang (7.94%), which had the lowest RIR of the mobile population in 2017, all were provinces with the highest ratio of mobile population size to the resident population and the highest ratio of the mobile population in foreign provinces, according to the data published in the seventh population census. In the Heilongjiang, Jilin, and Liaoning provinces, there was the largest population loss and relatively high RIR. Thus, it can be seen that the combined input–output factors, including income (earnings) and rent (costs), influenced the flow of the mobile population and its changes, and the increase in housing burden may have some negative impact on population mobility.

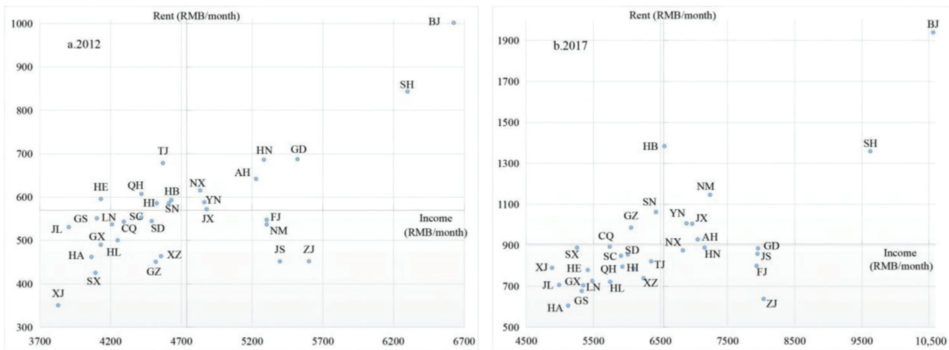

Figure 3. Rent and income of floating population by province, 2012 and 2017.

4.2. Impact of Increased Housing Burden on Population Mobility

The migration behavior wherein the population flows out of the original place and finally settles in the inflow place can be divided into three successive processes: First, the floating population flows out of the original place of residence to the inflow place out of the pursuit of a better life and the expectation of a higher quality of life, of which the comprehensive assessment of the input–output effect is usually the core decision basis [5], and, as mentioned above, areas with relatively high income and low rent are more attractive to the floating population. Second, in the survival stage of entering the inflow and maintaining the separation of households, and under the combined effect of the external environment and their own conditions, the migrant population forms the decision of long-term residence or continued migration based on their overall satisfaction with living in the inflow place, and whether they have the willingness to stay for a long time and whether they can afford the living burden such as rent are the key influencing factors [43]. Third, under the premise that they have the will and financial ability to settle, they mainly achieve account migration, complete identity change, and eventually stay in the place they move to through the purchase of commercial housing. In the context of high housing prices, the housing affordability of the mobile population is increasingly becoming a key constraint for their permanent settlement or choice of outflow/backflow [44].

This paper used the question "Do you plan to stay here for some time to come" in the questionnaire as a measuring base, and if somebody selected "Yes", it indicates that he/she had the settlement intention. (1) The settlement intention of the floating population was strongest in high-ranking cities in developed regions. From the comparison of the settlement intention of the mobile population in Table 5, we can find that the settlement intention was the strongest in the mobile population in the eastern first-tier cities, especially in Beijing, Shanghai, Guangzhou, and Shenzhen, where as many as 93% of the mobile population of northeastern origin said they were willing to stay; followed by the new first-tier cities, where the mobile population, also from the northeastern region, showed a higher settlement intention; and in the second-tier cities and the third-tier cities and below, the difference was not significant. Although residing in first-tier and new first-tier cities required higher rent and RIR, higher income, more opportunities, and better services make it easier for the mobile population to obtain higher absolute gains, and they would subjectively prefer long-term residency or even settlement in higher-tier cities, provided that they can afford the relatively higher cost of residency in higher-tier cities.

Table 5. Settlement intention of floating population in different cities, 2017 (%).

Outflow Areas / Inflow Cities	First-Tier Cities	New First-Tier Cities				Second-Tier Cities				Third-Tier Cities and Below			
	East	East	Central	West	North	East	Central	West	North	East	Central	West	North
Eastern region	0.90	0.87	0.80	0.79	0.82	0.85	0.76	0.78	0.74	0.83	0.77	0.75	0.75
Central region	0.88	0.83	0.80	0.84	0.86	0.80	0.83	0.78	0.80	0.77	0.84	0.76	0.78
Western region	0.86	0.76	0.78	0.85	0.84	0.77	0.79	0.81	0.65	0.75	0.79	0.80	0.68
Northeast region	0.93	0.90	0.76	0.86	0.90	0.79	0.84	0.82	0.81	0.79	0.89	0.77	0.85

(2) The housing price and income burden of high-grade cities in developed regions had the most significant impact on the settlement intention of the mobile population. From the choice of "reasons for residence difficulties" in the inflow cities expressed by the floating population in 2017 (Table 6), it can be seen that "income is too low" and "cannot afford housing" were the top two factors, accounted for 40.12% and 33.51% of the total sample, respectively, and nearly 36% of the migrant population in first-tier cities chose "cannot afford housing", which was higher than "income is too low" and became the most common difficulty. In the northeast region, due to the relatively low housing prices, the proportion of those who chose "cannot afford housing" was much lower than that of other regions, and although the income of the mobile population in the northeast region was the lowest among all regions, the proportion of those who chose "income is too low" was much lower than that of other regions. This indicated that the judgment of the mobile population about the high or low income was influenced by the housing burden or house price, i.e., the housing-price-to-income ratio index can be used to measure the difficulty of the mobile population in settling in the inflow place.

Table 6. Percentage of floating population's difficulties in different regions and cities, 2017 (%).

City Level	Location	Cannot Afford Housing	Income Is Too Low	Difficult to Find Jobs	Business Is Hard to Do	Look down upon by Locals	Children's Schooling Problems	Not Used to Local Life	Other Reasons
First-tier cities	East	35.92	31.71	15.37	17.68	6.66	18.80	4.62	4.52
New first-tier cities	East	31.36	31.33	15.64	19.47	6.25	15.73	4.47	3.61
	Middle	33.72	39.34	16.05	32.96	6.25	16.77	4.65	3.45
	West	32.48	42.22	24.01	23.22	5.86	16.86	4.73	4.41
	Northeast	20.95	29.25	15.23	12.60	5.13	8.68	3.55	3.35
Second Tier Cities	East	35.79	36.83	17.17	20.59	5.36	16.54	4.77	4.97
	Middle	28.46	39.30	20.66	24.70	5.07	20.40	3.47	3.75
	West	41.94	49.24	33.13	37.66	7.68	23.74	5.70	7.75
	Northeast	24.98	26.98	19.53	15.63	3.93	8.63	5.35	3.15
Third-tier cities and below	East	34.55	39.92	21.05	24.23	5.21	17.74	5.00	4.88
	Middle	34.93	48.46	27.43	35.15	6.02	19.73	5.65	5.23
	West	33.85	47.35	28.75	36.44	5.88	18.66	6.59	8.14
	Northeast	20.28	37.10	24.82	17.68	4.80	10.20	5.04	4.78
Overall		33.51	40.12	22.08	26.46	5.86	17.55	5.18	5.33

(3) The higher the urban hierarchy was, the heavier the housing burden was, and there were significant differences in the affordability and response to the housing burden among the mobile population groups (Table 7). Within the same rank city, the mobile population with higher education and occupational attributes could afford a higher RIR and needed to bear a relatively smaller housing price-to-income ratio, i.e., housing burden. For example, for the mobile population with a junior college degree and above, the purchase of a 1 m^2 residence in 2017 in first-tier and third-tier or lower cities was equivalent to 2.99 and 0.78 months of income for their households, while for mobile households with

elementary school diplomas or lower, it took 6.41 and 1.13 months of income. In terms of occupational differences, the lowest house-price-to-income ratio was for public and professional technicians in first-tier cities, while in other classes of cities, it was for business and merchant groups, and service industry practitioners earned more than production and construction industry practitioners in first-tier and new first-tier cities, and less than them in second-tier and third-tier cities and below.

Table 7. Housing-price-to-income ratio and house affordability ratio of groups with different education levels and occupational characteristics, 2017.

Floating Population Groups		Education Level				Occupational Characteristics			
		Junior College and Above	High School and Secondary School	Junior High School	Primary School and Below	Public Officials and Professional Technicians	Businessmen and Merchants	Service Industry Practitioners	Production and Construction Industry Practitioners
RIR (%)	First-tier	18.95	15.63	13.13	13.78	17.35	16.32	16.40	9.69
	new first-tier	17.55	14.78	12.55	11.69	14.98	15.17	15.23	8.18
	Second-tier	16.72	13.26	11.26	10.10	14.50	13.73	13.55	7.58
	Third-tier and below	14.17	12.63	11.92	12.89	13.43	13.59	12.02	8.40
Housing-price-to-income ratio (month/m^2)	First-tier	2.99	4.67	5.87	6.41	3.22	3.72	5.21	5.98
	new first-tier	1.86	2.19	2.39	2.62	1.96	1.87	2.41	2.47
	Second-tier	1.70	1.87	2.01	2.20	1.79	1.63	2.10	1.95
	Third-tier and below	0.78	0.86	0.94	1.13	0.83	0.78	0.98	0.94
Cannot afford housing (%)	First-tier	28.55	35.99	40.44	43.84	38.61	30.54	37.89	41.44
	new first-tier	23.31	29.21	32.95	38.07	34.58	22.60	27.38	36.05
	Second-tier	25.79	32.98	36.71	42.21	37.14	26.85	32.86	38.60
	Third-tier and below	21.77	30.17	34.80	40.53	36.37	21.83	32.23	35.89

(4) The issue of "cannot afford housing" can roughly predict the residence decision and mobility tendency of different socioeconomic groups in the context of high housing prices (Table 7). In terms of education level, similar to the proportional structure of the housing-price-to-income ratio, the lower the level of education, the higher the proportion of those who "cannot afford housing". In terms of occupation type, the group of businessmen and merchants had the lowest proportion of "cannot afford housing" due to their higher income, while the group of public officials and professional technicians had the strongest will to purchase housing and settle down due to their stable work, leading to a higher proportion of "cannot afford housing", while those working in the production and construction industry had the highest proportion of difficulty in purchasing housing. As a result, low-level and skilled migrants (e.g., elementary school diplomas and below, production and construction industry practitioners), despite their high willingness to settle down and lowest RIR, would be the first to be "squeezed out" of high-ranking cities to move to areas/cities with relatively low housing burden or become "tidal population", i.e., return to their origin due to their weak job stability and low incomes in an environment of increasing housing burdens. Even the mobile population with higher educational and occupational characteristics (e.g., junior college diplomas and above, public officials and professional technicians) would face rising pressure to purchase housing and would have to pay higher and higher rental costs for long-term residence in the city or purchase small or remote housing, which would lead to lower life quality and happiness, and even to the dilemma of "wanting to settle down but not being able to settle down".

5. Conclusions and Discussion

Based on the data from the 2012 and 2017 National Survey on Health and Family Planning Dynamics of the Mobile Population, this paper took cities above the prefecture level as the spatial unit and presented the spatial patterns of average rent, income, and RIR of the mobile population and their evolutionary characteristics, compared the differences in rental affordability among different regions and cities of different levels and different mobile population groups, and analyzed the rental burden patterns and the spatial characteristics of population mobility. The main findings are as follows.

(1) The rental burden is lower in economically developed regions. Between 2012 and 2017, rents for the migrant population generally increased nationwide, and unlike the regional economic development pattern, economically developed eastern coastal provinces

such as Jiangsu, Zhejiang, Fujian, and Guangdong had higher incomes and lower rents, and the rental burden was much lower than that in central and western and northeastern regions. The spatial dislocation between the rent burden and the level of economic development can have a heterogeneous effect on the willingness of the mobile population to migrate. (2) High-ranking cities and groups with high education and social attribute values can afford higher rents. First-tier and new first-tier cities had the heaviest rental burden, but the relative rental burden, i.e., RIR, is higher in third-tier and lower cities than in second-tier cities. In addition, groups with higher education levels and more stable occupation types had higher income levels and rent affordability. (3) Housing affordability was an important factor affecting population mobility, but the rental burden and housing price burden affected it in different ways. Influenced by comprehensive income and cost, the population flowing from low-income, high-rent inland areas to high-income, low-rent eastern coast was an inevitable choice. Despite the higher rental costs in high-ranking cities, they were still the most attractive inflow places for the mobile population due to their comprehensive advantages such as higher income and improved services. Housing prices have a more negative impact on the willingness to stay of the mobile population than rent, which may lead to a lower life quality and relocation to cities with relatively lower housing burden, such as lower-tier cities in developed eastern regions.

China's floating population, which accounts for more than a quarter of the total population, plays an indelible role in China's new urbanization and modernization, and is also a group that needs to be focused on to effectively solve the problem of balance. The housing burden is an important reality for the urban floating population, and the statistical survey of the National Population and Family Planning Commission found that in 2017, 77.11% of the floating population flowed from rural areas to cities, with relatively insufficient economic, social, and cultural capital; 57.08% of the floating population rented housing in cities; and only 2.26% of the floating population lived in public rental housing or security housing. Although the rent-to-income ratio is in a reasonable range in most cities at this stage, there are still certain shortcomings in the housing problem of the floating population and housing burden reduction. In this regard, the following suggestions are made: strengthen the quality of education and vocational education levels in the outflow areas of the population; improve the employment skills and income level of the mobile population; improve the labor security and income increase mechanism of the mobile population; continuously improve the housing affordability of the mobile population; strengthen government services for the mobile population; regulate the housing rental market; reduce the rental risk and financial burden of the mobile population as much as possible; establish and improve the housing provident fund system and housing security system for the mobile population; and increase the supply and coverage of security housing for the mobile population group. Since this paper does not analyze the rental housing burden of the mobile population through quantitative analysis methods, future quantitative analysis can also be conducted for the current state of rental housing demand and the housing or rental housing supply of the mobile population, which is conducive to a deep understanding of the inner formation mechanism of the high and low mismatch of the rent-to-income ratio. The spatial scale of this paper is large, and future research can also go deeper into the inner city in order to form more scientific and effective policy recommendations.

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buildings

Article

Forecasting Offline Retail Sales in the COVID-19 Pandemic Period: A Case Study of a Complex Shopping Mall in South Korea

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Abstract: This study examines the case of a shopping mall in Seoul, South Korea, based on its offline retail sales data during the period of the enforcement of the COVID-19 pandemic social distancing policy. South Korea implemented strict social distancing, especially in retail categories where people eat out, due to the danger of spreading infectious disease. A total of 55 retail shops' sales data were analyzed and classified into five categories: fashion, food and beverage (f&b), entertainment, cosmetics and sport. Autoregressive integrated moving average (ARIMA) and exponential smoothing (ETS) models were employed, and the autocorrelation (ACF) and partial autocorrelation (PACF) of each retail category's sales data were analyzed. The mean absolute percentage error (MAPE) was used to determine the most suitable forecasting model for each retail category. In this way, the f&b and entertainment retail categories, in which people eat out, were found to have been significantly impacted, with their 2022 sales forecasted to be less than 80% of their 2018 and 2019 sales. The fashion retail category was also significantly impacted, slowly recovering sales in 2022. The cosmetics and sport retail categories were little impacted by the COVID-19 outbreak, with their retail sales having already recovered by 2022.

Keywords: sales forecasting; offline retail; COVID-19 pandemic; ARIMA; exponential smoothing

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1. Introduction

Governments in various countries implemented lockdown or social distancing policies to prevent the spread of the COVID-19 pandemic, leading to significant changes in various industries. From a business owner's perspective, lockdown or social distancing policies introduced the need for unexpected, novel operating patterns. In particular, the retail industry was subject to business restrictions, such as reducing the operating hours of offline stores and limiting the number of customers per unit space. In South Korea, COVID-19 was first reported in January 2020, and a social distancing policy was implemented in March of the same year. Strict social distancing was believed to prevent the spread of COVID-19; however, it shrunk business activities and changed the business model [1]. The spread of COVID-19 also affected consumer psychology, and was well reflected in the consumer composite sentiment index (CCSI), which reflects consumers' willingness to purchase. According to the index in South Korea, consumer willingness to purchase during the pandemic was even lower than that during the 2008 economic crisis [2].

Fear of COVID-19 infection decreased the CCSI in the offline market, leading to unexpected and unpredictable shrinking of retail activities and sales [2,3]. Consequently, inventory management was challenging owing to the mismatch between actual and predicted demand. That mismatch resulted in excess inventory, which led to company losses. Accurately predicting demand is crucial for a successful business [4–7], but despite the importance of estimating the inventory properly, social distancing during the COVID-19 pandemic hindered researchers and sales managers from obtaining accurate time-series sales data.

The retail industry is shifting toward online platforms [8]. Online platforms have a strong advantage in that they do not require a physical space to experience or display the items or services. In the context of this trend and the COVID-19 pandemic, studies from the retail field mostly focus on online retail platforms [9]. This situation might be interpreted to indicate that the retail industry will shift to online-only; however, offline retail importantly offers brand, spatial, product and service experiences that online retail businesses cannot [10]. Furthermore, Roberts [11] described how consumers' offline retail mall visits are still required for services tailored to individual preferences.

This study analyzed and forecasted offline retail sales during and after the COVID-19 pandemic period. A shopping mall in Seoul, South Korea, was selected as the retail sales data source. The majority of the shops in this center faced no closure after the COVID-19 outbreak. A total of 94 retail shops are located in the shopping center, which can be classified into the following five retail categories: fashion, food and beverage (f&b), entertainment, cosmetics and sport. Among those retail shops, 55 were selected for analysis as those were the ones that faced no closure during the COVID-19 pandemic. South Korea did not implement a lockdown policy; instead, it implemented a strict social distancing policy, with particular strict restrictions on in-store eating. The f&b and entertainment retail categories can be classified as associated with eating out more so than the others. Accordingly, and based on existing research, the following research hypotheses were drawn up: (1) the f&b and entertainment retail categories were more greatly impacted by social distancing than the other retail categories; and (2) the f&b and entertainment retail categories had not yet been able to overcome the impact of the COVID-19 (at the time of this investigation, in 2022).

To analyze offline retail sales patterns during the COVID-19 pandemic, this study adapted autoregressive integrated moving average (ARIMA) and exponential smoothing (ETS) models. These are the most traditional and basic linear models for forecasting economic data, such as retail sales or stock. Unfortunately, forecasting models still have limitations in that they cannot be applied to evaluate the forecasted values compared to the actual values. To overcome this limitation, an evaluation method is required to determine the most suitable forecasting model. The mean absolute percentage error (MAPE) is one of the most popular methods used for evaluating forecasting models. MAPE discerns the error percentage, where a lower number indicates a more accurate model. In this study, the most suitable forecasting models were selected using MAPE, and 2022 future sales values were forecasted. In this way, we could estimate the annual sales patterns based on the retail category.

Section 2 presents a review of retail, pandemic and sales-forecasting studies. The research methodology of this study, comprising forecasting models, ARIMA, ETS and model evaluation, is described in Section 3. Section 4 presents the results of this study, and Section 5 provides concluding remarks.

2. Literature Reviews

2.1. Offline Retail and the COVID-19 Pandemic

Retail is defined as the behavior that occurs in the final step of consumers deciding which product to buy. This occurs based on consumers' thoughts and is termed consumer behavior, which is difficult to clearly measure or define [12,13], though many researchers have tried to explain consumer behavior and identify its influencing factors [14,15]. Consumer behavior is largely dictated by personal, social and cultural factors [16,17]. Among these, social factors are the most unpredictable and difficult to control [18]. Among them are the weather and pandemic diseases. With the former, the temperature [18,19] and fine dust concentrations [20] affect consumers' likelihood of visiting stores and buying retail products. Pandemics can also be considered an important social factor affecting consumer behavior. The severe acute respiratory syndrome (SARS) outbreak in China in November 2002 affected South Korea, with 8465 confirmed cases and 801 deaths. At the time, all industries experienced economic losses in South Korea [21] and Hong Kong [22].

Seven years after the SARS outbreak, the novel wine-origin influenza A outbreak in South Korea in April 2009 caused further economic loss, especially in tourism [21,23]. The most recent pandemic was Middle East respiratory syndrome (MERS) in June 2015, which led to an estimated 63.7 billion won loss of output, 34.2 billion won loss of value added and 14.9 billion won loss of income [24].

The COVID-19 outbreak began in December 2019 and arrived in South Korea in January 2020. Shin [25] described how COVID-19 caused a loss of sales, with that loss correlated with the previous scale of sales. The COVID-19 pandemic lowered consumers' appetite to make purchases in person [3], which meant that retail sales at large shopping malls, duty-free shops and urban retail quarters were greatly impacted. This was reflected in the CCSI [2], which was 70.8 in South Korea in April 2020, lower than that during the 2008 economic crisis (77.9). A social distancing policy was implemented to prevent the spread of COVID-19 [26,27], which, along with the fear of contagion, led people to stay indoors, triggering a reduction in offline retail sales [28–30].

2.2. Sales Forecasting

Retail is a part of logistics management, and as with all logistics management, uncertainty of demand presents an important challenge [31]. Sales forecasting is the most efficient method to overcome demand uncertainty in the retail industry [4–6]. It can enable managers to effectively control the product inventory, which prevents losses due to a lack of or excess product inventory [32]. Retail sales data, which are considered time-series data, have different characteristics from the data normally used for general regression analysis, which makes future data difficult to predict accurately. To achieve higher accuracy, sales forecasting using past sales data patterns to forecast future sales [33] can be conducted through various statistical methods. ARIMA and ETS are the most representative forecasting analysis models [34]. They are widely used in the retail industry for the restaurant [35–37], fashion [34] and entertainment [38,39] retail categories, to analyze and forecast retail sales. This study aimed to forecast shopping mall retail sales during the COVID-19 pandemic using the ARIMA and ETS forecasting models.

3. Materials and Methodology

3.1. Time-Series Analysis

Time-series data have a continuous time feature [40]. That can take one of a variety of forms, such as a trend, seasonality or cycle. These forms make time-series data high-dimensional and nonstationary, and accordingly, difficult to analyze using normal mathematical formulas [40]. Reducing the dimensions of time-series data, without omitting important information, is thus important for analysis. Through reduction to low-dimensionality, stationary data [41], the ARIMA and ETS models are the most popular and representative models to analyze time-series data [33,37,42–45].

3.1.1. Autoregressive Integrated Moving Average (ARIMA)

Box and Jenkins [43] first introduced the ARIMA model. In this model, the number of differencing transformations required to make the time series stationary is added to the autoregressive moving average (ARMA) model, which combines the autoregressive (AR) and moving average (MA) models [4,46]. The ARIMA model can thus be applied to analyze nonstationary raw data. The first step in using the ARIMA model is to check whether the time series is stationary or nonstationary [44]. The autocorrelation function (ACF) is a representative method for checking the stationarity of the time-series data. It is used to measure the linear relationship between the lagged values of time-series data [41]. The autocorrelation value (ρ_k) measures the linear relationship between time-series data at time t (Y_t) and time $t-1$ (Y_{t-k}), written as

$$\rho_k = \frac{\sum_{t=k+1}^{n}\left(Y_t - \overline{Y}\right)\left(Y_{t-k} - \overline{Y}\right)}{\sum_{t=1}^{n}\left(Y_t - \overline{Y}\right)^2} \tag{1}$$

where n is the total number of time-series data, and Y_t is their value. When ρ_k is close to 1, the time-series data show a highly linear relationship between Y_t and Y_{t-k}. Conversely, if ρ_k decreases smoothly as the lag increases, the time-series data show a limited (or no) relationship between Y_t and Y_{t-k}.

The most representative phenomenon behind time-series data with a strong relationship is that they are nonstationary. Nonstationary time-series data have properties that depend on the time at which the data were observed. This occurs when time-series data exhibit a trend or seasonality. Before analyzing nonstationary time-series data, it is necessary to reduce the data's high dimensionality, such as trends or seasonality. Differencing is the most representative method to do so [41]. The form of differencing is as follows:

$$\nabla_m^d Y_t = (1 - B^m)^d Y_t \tag{2}$$

where B is the backward shift operator, m is the cycle of time-series data and d is the number of differences.

If the model is stationary (both with and without differencing), the ARIMA model can be used to analyze the time-series data. The model is written as $ARIMA(p, d, q)$, and follows the form

$$\phi_p(B)(1 - B)^d Y_t = \theta_q(B)\varepsilon_t \tag{3}$$

where

ε_t is white noise at observed time t,
$\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p$ and
$\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q$.

If there is a need to analyze seasonal features at the same time, the seasonal ARIMA model can be written as $ARIMA(p, d, q)(P, D, Q)_m$. The seasonal ARIMA model has the following form:

$$\phi_p(\mathrm{B})\Phi_P(B^m)(1 - B)^d(1 - B^m)^D Y_t = \theta_q(B)\Theta_Q(B^m)\varepsilon_t \tag{4}$$

where

$\Phi_P(B^m) = 1 - \Phi_m B^m - \Phi_{2m} B^{2m} - \ldots - \Phi_{Pm} B^{Pm}$, and
$\Theta_Q(B^m) = 1 - \Theta_m B^m - \Theta_{2m} B^{2m} - \ldots - \Theta_{Qm} B^{Qm}$.

The ARIMA model can analyze time-series data over time sequence t and forecast future values using the pattern determined by the model.

The ACF and PACF are helpful in selecting the order of the ARIMA model [46]. As shown in Table 1, both ACF and PACF are helpful for finding $MA(q)$ and $AR(p)$, and ACF is also helpful for defining the number of d.

Table 1. Method of finding the order of the ARIMA model.

Category	AR(p)	MA(q)	ARMA(p, q)
ACF	Tail off	Cut off, q lag	Tail off
PACF	Cut off, p lag	Tail off	Tail off

3.1.2. Exponential Smoothing

ETS is an analytical method that effectively reflects recent influences by reflecting stronger weights as it approaches the present time [46]. The naïve ETS model is used when there is no trend or seasonality in time-series data. However, since most time-series data exhibit real-world trends or seasonality, time-series analysis methods and the ETS model must consider those [41]. Winters [47] analyzed time-series data with trends and seasonality using ETS via the Holt–Winters ETS (HW ETS) method. HW ETS is separated based on the pattern of seasonality into HW additive ETS and HW multiplicative ETS.

When the cyclic amplitude of the data maintains a stable scale, HW additive ETS is the more suitable model of analysis, whereas when the cyclic amplitude of the data increases over time, HW multiplicative ETS is more suitable.

3.1.3. Model Evaluation

A forecasting model can only set expectations based on previous data. This means that the accuracy of the forecast cannot be ensured [48]. The error between the actual data and forecasted data is usually used to determine the validity of the results of the forecasting model. The MAPE and root mean square error are mostly used to evaluate a forecasting model's accuracy.

The MAPE is normally used to assess the accuracy of a forecasting model by percentage [46,49]. However, if there is a zero value in the observation data, the MAPE cannot be calculated. The MAPE produces a percentage value of comparativeness with other models. The MAPE form is

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \times 100 \tag{5}$$

where n is the total number of datasets, y_t is the actual value at time t and $\hat{y}_t$ is the forecasted value at time t.

3.2. Data Collection

The data for this study were collected from a shopping mall in Seoul, South Korea. The majority of the stores in this shopping mall faced no closure during the COVID-19 pandemic. The data collection period was set to 4 years, 2 years either side of the COVID-19 outbreak in 2020. This shopping center has 94 tenant shops that can be divided into the following five categories: fashion, f&b, entertainment, cosmetics and sport. The retail categories had 30, 43, 8, 8 and 5 retail shops, respectively; however, for this study, only 55 retail shops' data were used, the ones that did not face closure during the data collection period.

3.3. Forecasting Model Determination

Each data category had different properties. To determine the most suitable ARIMA model for each category, we analyzed the ACF of each category's sales time-series data, as listed in Table 2. It was confirmed that the time-series data for the f&b and entertainment retail categories showed nonstationarity as the ACF decreased smoothly. To remove nonstationarity and ensure stationarity, differencing was performed on the f&b and entertainment retail categories' sales data. Subsequently, as described in Section 3.1.1, ARIMA models suitable for each category were derived through ACF and PACF, as listed in Table 3.

Table 2. ACF of each retail category's sales.

Lag	ACF				
	Fashion	**f&b**	**Entertainment**	**Cosmetics**	**Sport**
1	0.573	0.707	0.814	0.325	0.423
2	0.113	0.49	0.68	0.027	−0.173
3	−0.01	0.449	0.616	−0.225	−0.251
4	0.049	0.468	0.626	−0.277	−0.094
5	0.342	0.409	0.63	−0.181	0.221
6	0.566	0.353	0.563	−0.195	0.448
7	0.313	0.394	0.538	−0.094	0.273
8	−0.003	0.377	0.431	−0.212	−0.307
9	−0.123	0.313	0.324	−0.063	−0.51
10	−0.076	0.226	0.286	0.167	−0.144
11	0.2	0.17	0.276	0.173	0.179
12	0.366	0.144	0.271	0.463	0.326
13	0.089	0.065	0.163	0.179	0.207
14	−0.201	0.009	0.06	0.055	−0.144
15	−0.31	0.003	−0.002	−0.114	−0.402
16	−0.235	0.046	−0.041	−0.101	−0.285

Table 3. ACF and PACF of each retail category's sales.

Lag	**ACF**					**PACF**				
	Fashion	**F&b_diff**	**Entertainment_diff**	**Cosmetics**	**Sport**	**Fashion**	**F&b_diff**	**Entertainment_diff**	**Cosmetics**	**Sport**
1	0.573	−0.084	−0.139	0.325	0.423	0.573	−0.084	−0.139	0.325	0.423
2	0.113	−0.358	−0.200	**0.027**	−0.173	−0.320	−0.368	−0.224	**−0.088**	−0.428
3	**−0.010**	**−0.101**	−0.231	−0.225	−0.251	**0.146**	**−0.202**	−0.318	−0.233	**0.051**
4	0.049	0.177	**0.038**	−0.277	**−0.094**	0.037	0.001	**−0.140**	−0.151	−0.057
5	0.342	0.023	0.215	−0.181	0.221	0.449	−0.067	0.077	−0.055	0.296
6	0.566	−0.269	−0.191	−0.195	0.448	0.220	−0.276	−0.257	−0.204	0.244
7	0.313	0.093	0.237	−0.094	0.273	−0.242	0.026	0.255	−0.094	0.042
8	−0.003	0.154	0.042	−0.212	−0.307	−0.012	−0.021	0.175	−0.317	−0.433
9	−0.123	0.021	−0.210	−0.063	−0.510	−0.094	0.016	−0.208	−0.095	−0.093
10	−0.076	−0.058	−0.099	0.167	−0.144	−0.014	0.070	−0.021	0.074	0.052
11	0.200	−0.115	−0.113	0.173	0.179	0.135	−0.103	−0.161	−0.113	−0.006
12	0.366	0.151	0.433	0.463	0.326	−0.029	0.098	0.162	0.362	0.146
13	**0.089**	**−0.020**	**−0.008**	0.179	0.207	−0.251	**−0.016**	**0.104**	**−0.077**	**0.056**
14	−0.201	−0.124	−0.113	**0.055**	**−0.144**	**−0.048**	−0.083	−0.007	0.061	0.044
15	−0.310	−0.088	−0.101	−0.114	−0.402	−0.132	−0.115	−0.009	0.074	−0.109
16	−0.235	0.116	−0.044	−0.101	−0.285	0.007	−0.008	0.038	0.123	−0.217

The ACF and PACF of the cosmetics retail category both cut off after lags 1 and 12; therefore, the $ARIMA(1,0,1)(0,0,0)_{12}$ model was selected as the most suitable forecasting model for the cosmetics retail category.

The ACF of the sports retail category cuts off after lags 3 and 13, and the PACF cuts off after lags 2 and 12. $ARIMA(2,0,3)(0,0,1)_{12}$ was thus the most suitable forecasting model for analyzing the sport retail category.

To select the most suitable ETS model for each retail category, a trend and seasonality analysis was performed. Figure 1. Shows the trends and seasonality of retail categories. All retail categories have strong seasonality with similar amplitudes. Cosmetic and sport retail categories' sales show no significant trend. Fashion and f&b retail categories can also be considered non-trend and decreasing trends. Finally, the entertainment retail category shows a decreasing trend.

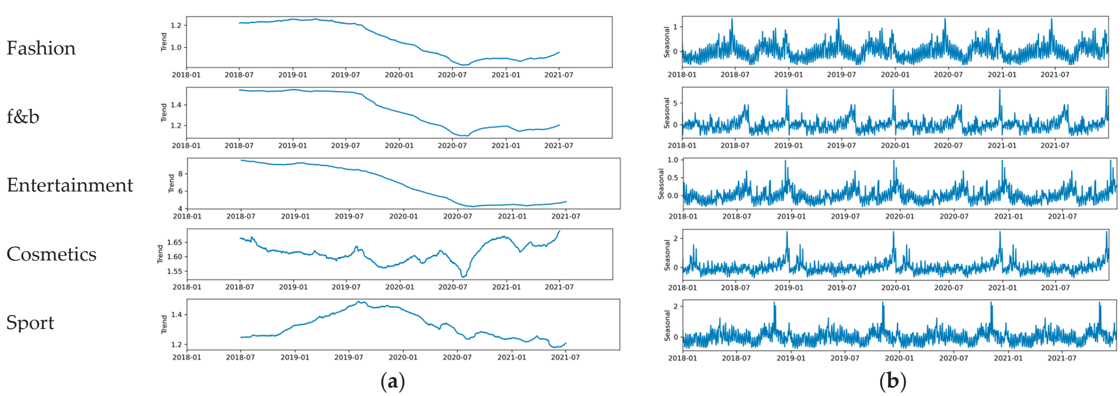

Figure 1. Breakdown of each retail category's sales: (**a**) trend analysis; (**b**) seasonality analysis.

Therefore, both naïve seasonal ETS and HW additive ETS models were selected for the fashion and f&b retail categories, the HW additive ETS model for the entertainment retail category and the naïve seasonal ETS model for the cosmetics and sport retail categories. Table 4 presents the forecasting models used for each retail category.

Table 4. Forecasting models for each retail categories.

Category	ARIMA Model	ETS Model
Fashion	$ARIMA(2,0,2)(1,0,0)_{12}$	Naïve seasonal ETS
		HW additive ETS
f&b	$ARIMA(2,1,2)(0,0,0)_{12}$	Naïve seasonal ETS
		HW additive ETS
Entertainment	$ARIMA(3,1,3)(0,0,0)_{12}$	HW additive ETS
Cosmetics	$ARIMA(1,0,1)(0,0,0)_{12}$	Naïve seasonal ETS
Sport	$ARIMA(2,0,3)(0,0,1)_{12}$	Naïve seasonal ETS

4. Results

4.1. Descriptive Analysis

As shown in Figure 2, the descriptive analysis of sales data showed that, in March 2020, there was an impact on sales data for each retail category due to the outbreak of the COVID-19 pandemic. In particular, the fashion, f&b and entertainment categories' retail sales were impacted, whereas cosmetics and sport were not significantly affected by COVID-19. Since the fashion, f&b and entertainment retail categories made up a high proportion of the total sales, changes in these categories had a crucial impact on the whole shopping mall.

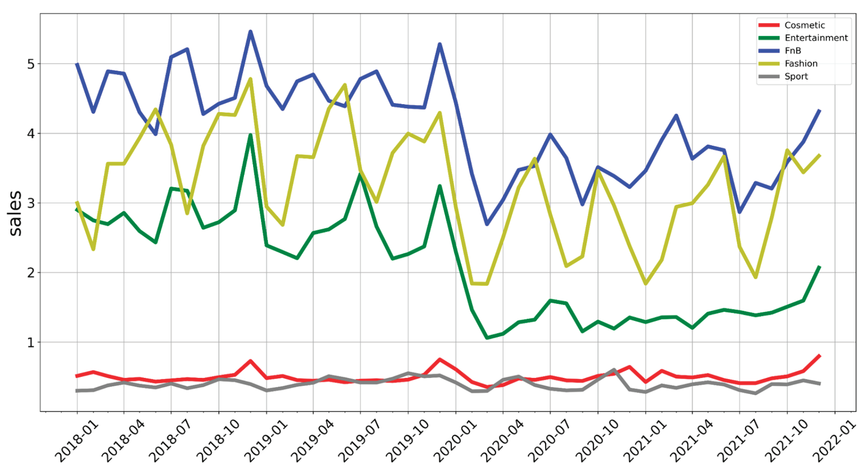

Figure 2. Retail sales of shopping mall from 2018 to 2021.

The trend in retail sales can also be observed through the results of our descriptive analysis. Retail sales in the fashion, f&b and entertainment categories were hugely impacted on retail sales and did not recover until December 2021. In contrast, the cosmetics and sport retail categories were not significantly impacted, maintaining stable retail sales until December 2021.

4.2. Evaluation of ARIMA and ETS Forecasting Models

Figure 3 shows the sales in each retail category as the actual observed value (grey), naïve seasonal ETS forecasted value (yellow), HW additive ETS forecasted value (green) and ARIMA forecasted value (blue). Comparing forecasted values with actual values shows the accuracy of the forecasting model. The MAPE was used to find the most accurate forecasting model, as outlined in Table 5.

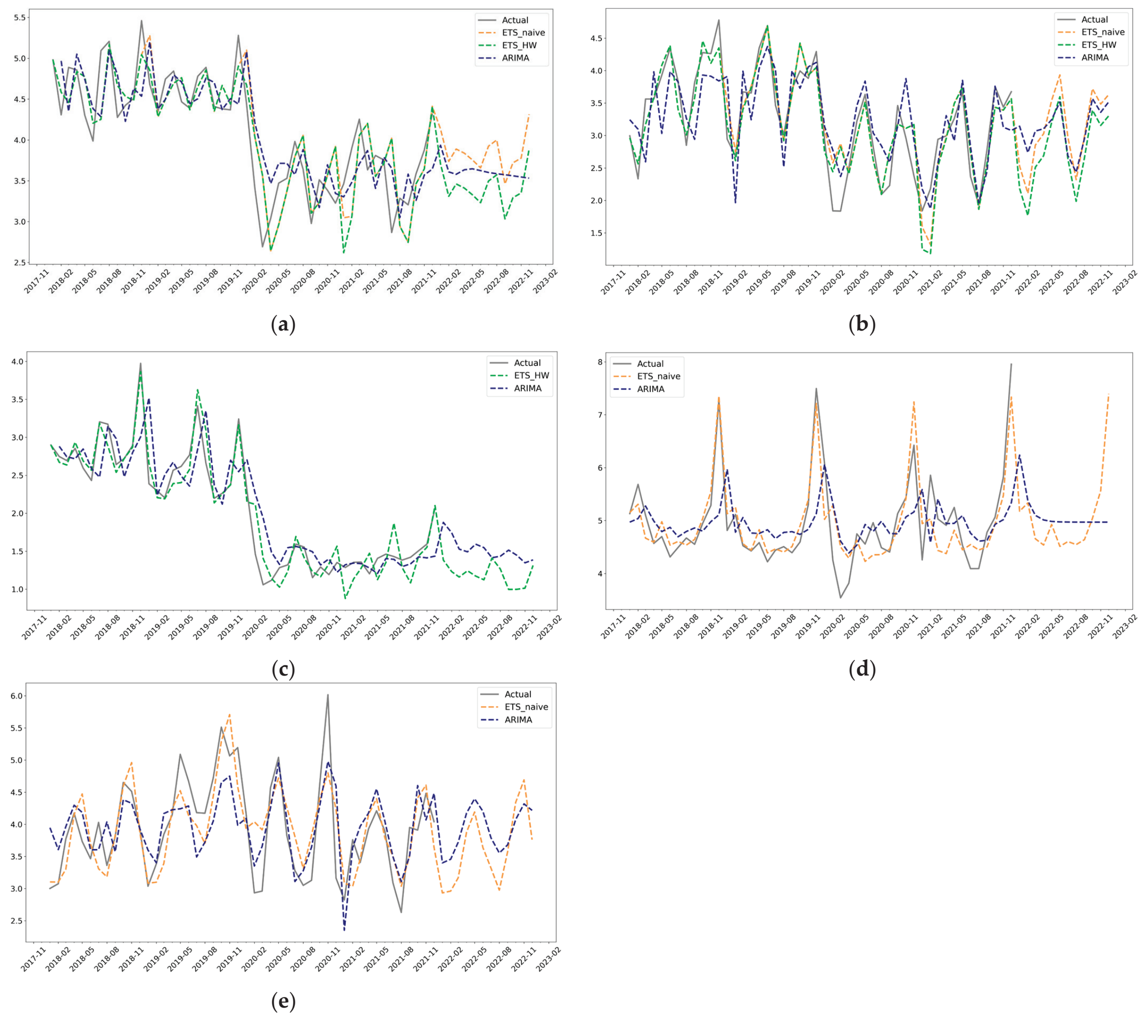

Figure 3. Actual sales (gray) and predicted sales (orange—naïve ETS, green—HW ETS, blue—ARIMA) in each retail category. (**a**) Fashion; (**b**) f&b; (**c**) entertainment; (**d**) cosmetics; (**e**) sport.

Table 5. Evaluation of each retail sales forecasting model.

Category	Forecasting Model	R^2	MAPE	BIC	Ljung–Box Q
Fashion	$ARIMA(2,0,2)(1,0,0)_{12}$	**0.586**	**14.478**	**40.689**	**0.049 ***
	Naïve seasonal ETS	0.617	9.169	39.494	0.032 *
	HW additive ETS	0.588	9.353	39.610	0.009 *
f&b	$ARIMA(2,1,2)(0,0,0)_{12}$	0.208	9.622	40.400	0.705
	Naïve seasonal ETS	**0.544**	**8.548**	**39.891**	**0.103**
	HW additive ETS	0.533	8.414	39.610	0.011 *
Entertainment	$ARIMA(3,1,3)(0,0,0)_{12}$	0.220	13.660	40.310	0.042 *
	HW additive ETS	**0.487**	**11.764**	**39.157**	**0.066**
Cosmetics	$ARIMA(1,0,1)(0,0,0)_{12}$	**0.144**	**10.973**	**36.729**	**0.065**
	Naïve seasonal ETS	0.692	6.470	35.314	0.000 *
Sport	$ARIMA(2,0,3)(0,0,1)_{12}$	**0.506**	**11.453**	**36.301**	**0.118**
	Naïve seasonal ETS	0.758	10.215	35.605	0.000 *

Regarding the fashion category's retail sales, the Ljung–Box Q test of the naïve seasonal ETS model was significant, with a p-value of <0.05, and the naïve seasonal ETS model and HW additive ETS model were rejected due to doubts about their suitability. The p-value of the ARIMA model was 0.049, which was less than 0.05; however, the p-value was around the probability of significance. Therefore, $ARIMA(2,0,2)(1,0,0)_{12}$ was selected to forecast the fashion category's retail sales.

For the f&b category, the ARIMA and ETS models underwent the Ljung–Box Q test, and the HW additive ETS model was rejected because its suitability was doubted. The MAPE value of the naïve seasonal ETS model was 8.548, which was lower than that of ARIMA (9.621). The naïve seasonal ETS model was thus selected as the forecasting model for the f&b category's retail sales.

The entertainment category's forecasting model evaluation results showed that both models' Ljung–Box Q test results were significant. The MAPE value of the HW additive model was 11.764, which was less than the 13.445 of the $ARIMA(3,1,3)(0,0,0)_{12}$ model.

As for the cosmetics and sport categories' retail sales, the Ljung–Box Q test of the naïve seasonal ETS model had a significance of <0.05; therefore, this model was rejected because of doubts about its suitability. $ARIMA(1,0,1)(0,0,0)_{12}$ and $ARIMA(2,0,3)(0,0,1)_{12}$ were selected to forecast the cosmetics and sport categories' retail sales, respectively.

4.3. Retail Sales Forecasting in 2022

Using the forecasting model determined in Section 4.2, 2022 retail sales were forecasted for each retail category and Figure 4 shows annual sales of each retail category.

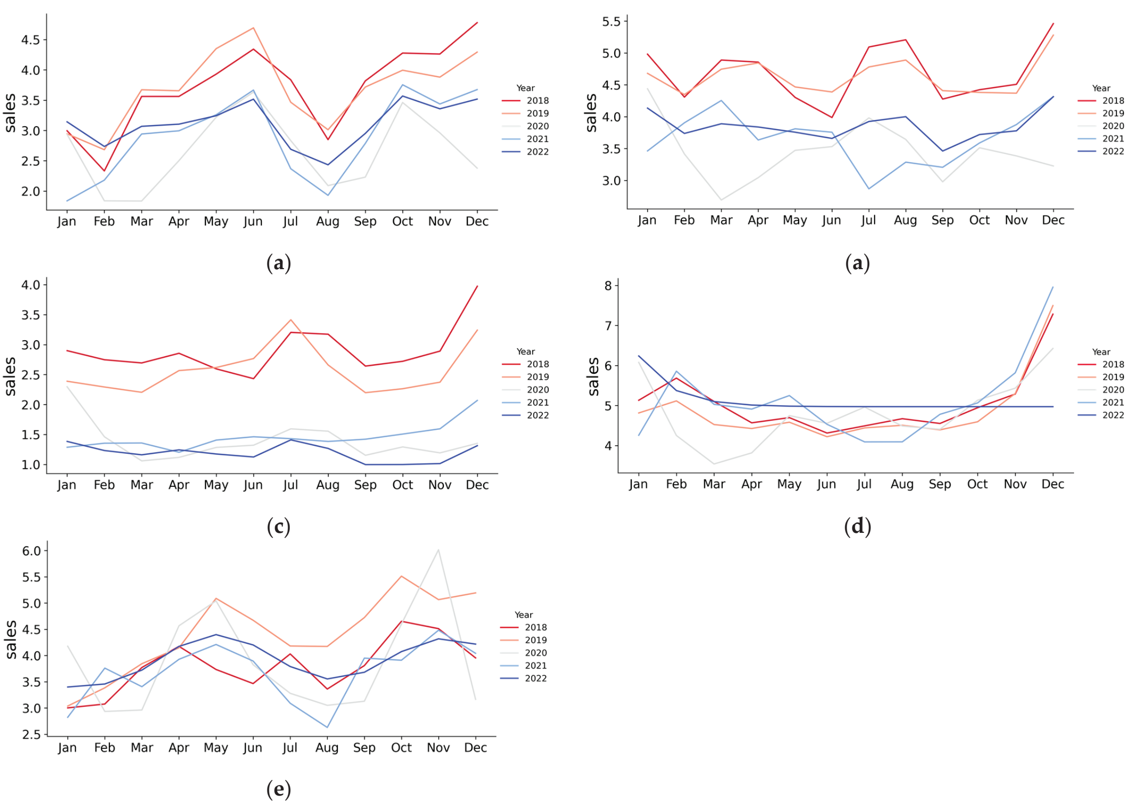

Figure 4. Annual sales in each retail category including precited 2022 sales. (**a**) Fashion; (**b**) f&b; (**c**) entertainment; (**d**) cosmetics; (**e**) sport.

Annual sales graphs—2018 (red) and 2019 (orange) sales graphs are pre-COVID-19, 2020 (gray) is when COVID-19 occurred and 2021 (sky blue) and 2022 are projected sales (light blue) after the COVID-19 outbreak—provide an overview of the impact of the COVID-19 pandemic and the degree of recovery.

It was confirmed that fashion sales were notably impacted, based on the graph from 2020, and would show a recovery trend over time, implying that, in 2022, they would have recovered to a level similar to that before the COVID-19 outbreak.

The f&b sales were also impacted by the COVID-19 outbreak and recovered over time. However, it was confirmed that there would be difficulty in recovering the sales to the level before the outbreak. This is assumed to be because f&b stores were directly affected by social distancing policies, such as limiting the number of people in a store.

Furthermore, entertainment sales were hit hard by the COVID-19 outbreak, with sales falling over time. This seems to reflect the impact on movie theaters, which account for a large proportion of the entertainment category. Postponement or cancellation of the release of many movies due to COVID-19 are held up as causes of the harm to the sales category.

Cosmetics and sport sales showed similar characteristics to one another. In both, the COVID-19 outbreak's impact was not significant, and sales showed a stable pattern each year. Similar sales were forecasted to be recorded by 2022 to those pre-COVID-19.

5. Discussion

This study contributes a comprehensive analysis of the sales performance of brick-and-mortar retail stores that remained operational despite the COVID-19 pandemic. The lockdown and social distancing policies imposed globally challenged the collection of sales data for offline retail sales, hindering the analysis of their sales performance during the COVID-19 pandemic. Hence, this study serves as foundational research for further studies in the business and retail fields, providing critical insights and explanations.

The impact of various factors, including the weather, weekends, events, promotions and economic conditions, on retail sales has been researched in the past. In particular, it has been noted that the fashion retail category is marked by a significant difference between the summer and winter seasons due to the changing retail prices of products. In addition, sales in the entertainment industry are highly related to the release of blockbuster movies. Sales across retail categories during the COVID-19 pandemic varied not only based on the number of confirmed cases or social distancing policy level but also according to factors such as the high interest in personal hygiene and growth in demand for at-home substitutions for normal purchases, for instance, with premade products such as meal kits. Retail industry research should consider those important trends, and to support such research, in this study, we conducted descriptive research that enabled us to contribute basic foundational knowledge. The findings of this study can serve as a basic guide for offline retail research in the future.

This study is limited in how its findings can be generalized to the whole offline retail sector since it only focused only on retail categories most associated with eating out. In addition, the retail industry encompasses various types of stores, such as department stores, duty-free, shopping malls, boutiques and the high street, each with distinct characteristics, customers and strategies. Additionally, the factors affecting consumer behavior are diverse, including the weather, promotions, sales and holidays, and comprehensive understanding of these factors is required.

This study found that the COVID-19 pandemic impacted retail categories differently, even within the same shopping mall, thus requiring varying retail management strategies. However, this study focused only on linear regressive analysis methods that cannot consider nonlinear patterns. Using nonlinear methodologies, such as machine learning neural networks or long short-term memory, offers an advanced methodology to analyze complex patterns in time series [37,50]. In future research, applying machine learning will be beneficial to analyze offline retail sales during the pandemic.

Similarly, the MAPE was used as a predictive model evaluation method, but methods using root mean square error (RMSE) and mean absolute error (MAE) can offer a more comprehensive analysis. Further research is needed to determine the best approach to utilizing these methods.

6. Conclusions

The negative impact of the COVID-19 pandemic on offline retail sales is evident; however, the enforcement of lockdown and social distancing policies around the world limited the data that were captured to support analyses of offline retail sales. This study analyzed offline retail sales data from before and during the COVID-19 pandemic and applied those to forecast the sales in 2022 by retail category.

Our results showed that entertainment and f&b categories, which were directly affected by social distancing, such as a maximum capacity in-store, seats blocked out and business hour restrictions, were impacted by COVID-19, and sales in these retail categories did not easily recover. Any further outbreaks of COVID-19, and resulting social distancing policy enforcement, will continue to most impact the entertainment and f&b retail categories. The fashion category mostly recovered from the impact of COVID-19 and was expected to reach the same sales levels in 2022 as before the COVID-19 outbreak, even if COVID-19 and social distancing policies continued. The cosmetics and sport retail categories were not notably impacted by the COVID-19 pandemic, except for the month of the outbreak. Based on these results, it can be noted that even in the same shopping mall, each retail category faced different types and degrees of impact by the COVID-19 pandemic. Each category came to be impacted by different aspects of consumer behavior theory, which need to be studied [51]. Accordingly, each retail category was required to adopt a specific strategy to manage and overcome the pandemic's impact, with a particular challenge presented in retail categories associated with eating out, which needed the greatest support to overcome the COVID-19 pandemic impact.

Nowadays, offline shops are no longer simply physical spaces for purchasing goods, but have become environments that cater to the needs and desires of potential customers. To effectively engage with customers, offline shops are designed to satisfy two key requirements: (1) matching consumer needs and desires and tailoring the buying experience to individual preferences, and (2) affectively eliciting specific emotions in the consumer through their experience. This study highlights that the impact of COVID-19 varied by retail category, even within the same building. This can be linked to consumer behavior in each retail category and impulse or panic buying due to the pandemic. Panic buying, driven by anxiety and fear [52–54], such as during natural disasters, pandemics or long strikes [54–56], should be considered in future studies. Furthermore, the different impacts between retail categories emphasize the importance of developing targeted strategies to overcome the impact of a pandemic, particularly for categories that rely on consumers eating out. Overall, this study confirms that the COVID-19 pandemic had varying effects on different types of offline retail stores, meaning post-pandemic sales forecasts differed by retail category. A key implication of these findings for researchers is that it is crucial to establish a nuanced research strategy for the offline retail field.

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buildings

Article

Spatial Quality Evaluation of Historical Blocks Based on Street View Image Data: A Case Study of the Fangcheng District

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Abstract: Urbanization in China has reached a mature stage, and research on spatial quality has become an important topic in urban research. This paper employs a machine learning method using a large set of street view image data to explore the spatial quality for historical districts, specifically in terms of vitality, safety, and landscape. The Fangcheng district is taken as the research object to evaluate the spatial quality of historical blocks. The results suggest that the following: (1) The spatial quality of the Fangcheng district presents a pyramidal structure. (2) High-quality streets are mainly distributed in the core areas of historical protection and commercial areas, medium-quality streets are mainly distributed in residential areas around the core areas of the historical district, and low-quality streets are mostly streets with poor accessibility. Based on the findings, we proposed several spatial quality improvement recommendations for the Fangcheng district in Shenyang.

Keywords: historical blocks; spatial quality; street view image data; machine learning; the Fangcheng district

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1. Introduction

With the rapid rate of urbanization in China, the diverse functions of streets in cities have been weakened, the original social space of streets has been shrinking, residents' activities have shifted from outdoor to indoor, and vehicle traffic has gradually replaced pedestrian traffic, resulting in a series of problems such as traffic congestion, street inactivation, and environmental degradation [1]. Through this rapid urban development, many historical districts lose their original functionalities, such as the embodiment of culture, leading to commercialization and, therefore, the homogenization of historical blocks. As a result, an increasing number of historical blocks are becoming deserted, the number of pedestrians whose purpose is to visit historical blocks is reduced, and the spatial attraction of historical blocks is greatly reduced [2].

At present, urbanization in China has reached a mature stage, and the focus of urban planning has shifted from the policy revision of the incremental mode to the refined design of the stock mode. In other words, the goal of urban planning has shifted from the speed of development to improve the quality of space [3]. As the embodiment of the historical process and the unique features of a city, historical blocks hold great significance for urban development. Furthermore, the quality of streets reflect the cultural features of the historical district [4]. With the concept of the smart city and prevalence of big data applications (such as street view images, point of interest (POI), and DMSP/OLS nighttime light images data), it is of paramount importance to establish an evaluation system for the spatial quality of the historical districts. Furthermore, scientific and comprehensive evaluations of the spatial quality of historical blocks can provide support to improve urban images and the renewal of historical districts.

Research on street spatial quality evaluation in China and elsewhere can be divided into three aspects: qualitative research, quantitative research, and research under the background of big data. In terms of qualitative research, scholars in China and elsewhere have summarized and categorized the elements of street spatial quality from different disciplinary perspectives and roughly divided them into two dimensions: material space and subjective perception. This aspect of research has laid a solid theoretical foundation for follow-up research on street spatial quality [5–8]. However, an evaluation system for street spatial quality constructed only from the theoretical level is greatly influenced by subjectivity, especially in regard to evaluating subjective feelings. This issue limits the scientific validity and persuasiveness of the street spatial quality evaluation system. Subsequently, research on street spatial quality evaluation has gradually shifted from qualitative research to quantitative research. Based on qualitative research, quantitative research constructs a relatively scientific street spatial quality evaluation system through field investigations, questionnaires and field interviews, expert scoring methods, and the analytic hierarchy process [9–11]. However, the data accuracy of the traditional methods in the quantitative analysis is relatively low and the data collection process is difficult, resulting in the confinement of the research scope [12,13] and further limits to the universality of the street spatial quality evaluation system [14].

In addition, the application of big data can also shed some light on existing urban issues, such as the inaccurate depiction of utilization of urban space [15]. Scholars have established various scoring matrixes including and not limited to manual scoring [16], hue, saturation, and value (HSV) [17], semantic segmentation [18], and machine learning [14]. They have evaluated the spatial quality of streets in various contexts, touching on a wide range of domains including urban health [19], urban activities [20–22], urban change [23,24], built environment quality [25], urban mobility [26,27], urban perception [28–33], sidewalks [34,35], signalized intersections [36], and so on.

There have been many studies on the evaluation of urban street spatial quality, but there are few studies on the evaluation of street spatial quality in historical blocks. Additionally, most of them are based on research on urban public space quality. Although previous studies have introduced street view image data, they are limited by the large amount of data and difficult processing techniques. Thus, most of them select only a small number of street view image data for manual scoring. Few studies have analyzed a large amount of street view image data, meaning that research has not fully utilized the advantages of big data and that the scientificity and universality of the quality evaluation system for historical blocks are limited. The machine learning approach provides the capability to classify massive amounts of street view images rapidly, incorporating multi-dimensional characteristics, which are lacking comparing to the traditional methods [37]. Street space is complex and needs a more comprehensive and unified evaluation system. The combination of street view image data and machine learning methods has made it possible to achieve large-scale, high-precision, and multidimensional street spatial quality evaluations of historical blocks [38].

The Fangcheng district is one of the oldest historical district in China. It was constructed originally in Qing Dynasty, and it witnessed the rise and fall of the urban development to this day. The Shenyang Fangcheng Renovation project with the theme of "a City in the City of Shenyang" was launched on 29 July 2022. Therefore, we take a look at the Fangcheng district in the city of Shenyang, Liaoning. It is surrounded by four streets: Dongshuncheng Street, Nanshuncheng Road, Xishuncheng Street and, Beishuncheng Road. Both the east-west and north-south direction lengths are 1.3 km, and the overall area covers approximately 1.7 km^2. This paper takes the Fangcheng district as the research object and selects street view image data and POI data to establish a historical block street spatial quality evaluation database. Machine learning is used to semantically segment street view image data, and a spatial quality evaluation system for historical blocks is constructed based on three aspects: vitality, safety, and landscape. On this basis, the street spatial quality of the Fangcheng district is evaluated, and corresponding quality improvement recommendations are proposed for the three different levels of high-, medium-, and low-quality streets in the Fangcheng district.

2. Methodology

2.1. Data Sources

(1) Road Network Data

First, the road network data were crawled through the OSM (OpenStreetMap) using Python. Then, the crawled road network was rectified and calibrated by combining field research and street view images. Finally, all roads were processed into single lines by converting multilane roads into single-lane roads, and thus created the vector data for the Fangcheng district (Figure 1).

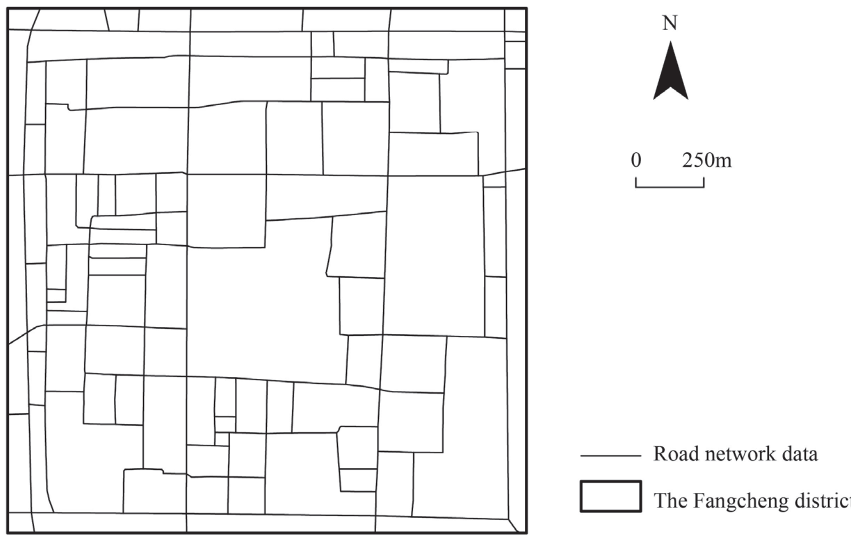

Figure 1. Vector diagram of the road network data.

(2) POI data

The POI data for various categories within the scope of the Fangcheng district were obtained through Python software and the Gaode Map application programming interface (API). The dataset contains 2765 entries, which are divided into 13 types of businesses, including shopping, catering, medical treatment, commerce, science and education, transportation, sports, companies and enterprises, public facilities, life services, financial services and insurance, accommodation services, and government agencies. The 13 types of POI were reclassified into three categories (Table 1): B (commercial service facilities), R (residential facilities), and S (road and transportation facilities).

Table 1. List of POI data reclassification.

Reclassification	Types of POI
B (commercial service facilities)	shopping, catering, commerce, companies and enterprises, financial services, and insurance
R (residential facilities)	medical treatment, science and education, sports, public facilities, life services, accommodation services, and government agencies
S (road and transportation facilities)	transportation

(3) Street view image data

The street view image data of the Fangcheng district were obtained from the Baidu Street View Map API through Python; the sampling distance of this study is set as 30 m. The field of vision (FOV) parameter (the horizontal direction range of street view image shooting) in the crawling program was set to 90 degrees, which means that each sampling point is crawled from four directions: front, back, left, and right (as shown in Figure 2). Thus, the total image set is 9562 street view images after the classification process.

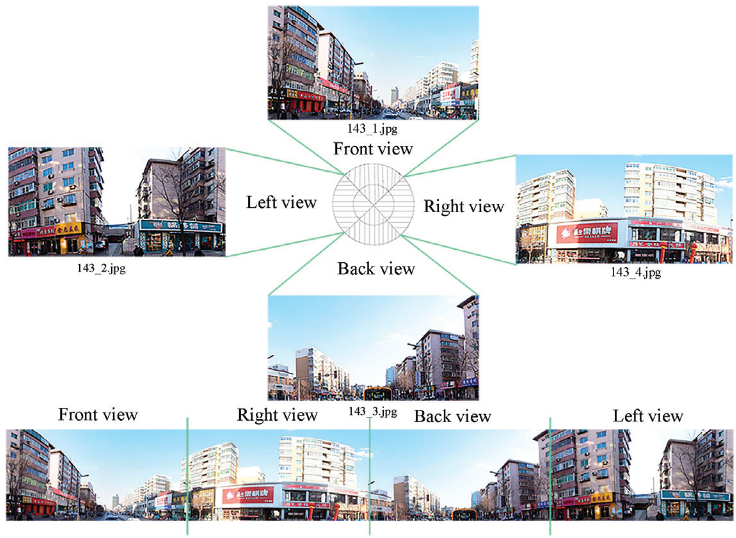

Figure 2. The street view image data.

After crawling the street view image data, semantic segmentation was performed on the acquired street view image data [39]. Through the algorithm, the street images have been classified into 18 types, including sidewalks, roads, cars, buses, trucks, electric vehicles, streetlamps, traffic lights, monitors, indicators, people, walls, architecture, skyscrapers, trees, grass, plants, and the sky (as shown in Figure 3). In addition, we use python to calculate the pixel proportion of each type of element for the street view image dataset, and then perform the semantic segmentation process for all images.

Figure 3. Intelligently recognized elements of street view images.

2.2. Methods

2.2.1. Selection of Measurement Indexes of the Spatial Quality of Historical Blocks

Urban vitality, urban safety, and urban landscape are important indicators of city quality [40,41]. Researchers believed that spatial vitality could be defined through diverse human activities and interactions [42]. Therefore, spatial vitality was measured using the convenience index, diversity index, and crowd concentration index. In the computer vision community, traditional street visual quality indicators (such as enclosure, greenery, openness, and visual pavement) are commonly evaluated using physical components extracted from street view image data [43,44], with the view index of vegetation, building, sky, and road as the most representative indicators among them [45]. Therefore, we calculated the walking index, vehicle interference index, interface transparency index, interface enclosure index, green visibility index, and sky visibility index from the extracted physical components. Then, they are cataloged into safety and landscape.

By summarizing the measurement index of urban street spatial quality at different scales and combining the availability of relevant data, this paper used street view image data and POI data to catalog them into nine indexes based on three aspects: vitality, safety, and landscape (Table 2).

Table 2. List of quality evaluation indexes of historical blocks.

Aspects	Indexes	Calculation Formula	Explain
Vitality	Convenience Index	$CI_i = \frac{Count\_POI_i}{length_i}$	$Count\_POI_i$ is the total number of POIs in the 50 m buffer of the street numbered. i. $length_i$ is the length of the corresponding street space.
	Diversity Index	$DI_i = -\sum_{i=1}^{n}((N_i/N) \times \ln(N_i/N))$	N is the number of POI categories in the 50 m buffer of the street numbered. i. N_i is the total number of POIs of a certain category within the 50 m buffer of the street. N is the total number of all POIs in the 50 m buffer zone of the street.
	Crowd Concentration Index	$CCI_i = \frac{P_i}{A_i}$	P_i is the number of pixels in the spot area of people identified in the street view image. A_i is the total number of pixels in the street view image.
Safety	Walking Index	$WI_i = \frac{W_i}{R_i}$	W_i is the number of pixels in the spot area of sidewalks identified in the street view image. R_i is the number of pixels in the spot area of all roads identified in the street view image.
	Vehicle Interference Index	$VII_i = \frac{C_i}{A_i}$	C_i is the number of pixels in the spot area of cars, buses, trucks, and electric vehicles identified in the street view image.
	Interface Transparency Index	$ITI_i = \frac{T_i}{A_i}$	T_i is the number of pixels in the spot area of streetlamps, traffic lights, and monitors identified in the street view image.
Landscape	Interface Enclosure Index	$IEI_i = \frac{W_i}{A_i}$	W_i is the number of pixels in the spot area of walls, architecture, and skyscrapers identified in the street view image.
	Green Visibility Index	$GVI_i = \frac{G_i}{A_i}$	G_i is the number of pixels in the spot area of trees, grass, and plants identified in the street view image.
	Sky Visibility Index	$SVI_i = \frac{S_i}{A_i}$	S_i is the number of pixels in the spot area of the sky identified in the street view image.

2.2.2. Evaluation System for the Spatial Quality of Historical Blocks

In order to deal with the various magnitude of each measurement index in this historical district, the data is standardized through the dimensionless pure value conversion to calculate the weight of the measurement index.

Further, to minimize the substantial influences on spatial evaluation of the above measurement indexes, we invited five college professors and five students with relevant backgrounds to make pairwise comparisons for manual scorings to evaluate the spatial quality of the Fangcheng district. Finally, the weight of each measurement index of the spatial quality evaluation of historical blocks was determined by using the analytic hierarchy process (AHP). The final weight of each index was obtained through the consistency test, and then we established the spatial quality evaluation system for the Fangcheng district. The weight and type of each measurement indicator are shown in Table 3.

Table 3. Street spatial quality evaluation system for historical blocks.

Target Layer	Criterion Layer	Weight	Scheme Layer		Weight	Type
Street spatial quality of historical blocks	Vitality	0.2445	CI	Convenience Index	0.0942	Positive
			DI	Diversity Index	0.0271	Positive
			CCI	Crowd Concentration Index	0.1232	Positive
	Safety	0.4270	WI	Walking Index	0.0492	Positive
			VII	Vehicle Interference Index	0.3148	Negative
			ITI	Interface Transparency Index	0.0630	Negative
	Landscape	0.3287	IEI	Interface Enclosure Index	0.0411	Negative
			GVI	Green Visibility Index	0.1438	Positive
			SVI	Sky Visibility Index	0.1438	Positive

3. Results

3.1. Overall Quantification of Street Spatial Quality

3.1.1. The Overall Numerical Distribution Presents an Obvious Pyramidal Structure

The overall quality score of the Fangcheng district is obtained through normalizing and assigning weights to each quality measurement index. The statistical results suggest that the total quality score is in the range of [0.247, 0.631], with an average of 0.471. The overall numerical distribution presents an evident pyramidal structure (Figure 4). As shown in Figure 4, most of the streets are medium quality, while the number of high-quality and low-quality streets are small. Among them, 81.86% of the streets are distributed in the range of [0.400, 0.550] and fluctuate around the average of the total score of street spatial quality. The proportion of streets with street spatial quality values less than 0.400 is 9.22%, and the proportion of streets with street spatial quality values greater than 0.550 is 8.92%. With the increase in the distance between the street spatial quality score and the average value, the street sample size gradually decreases.

3.1.2. Medium-Quality Streets Occupy a Dominant Position

The overall quantitative analysis of the evaluation of the spatial quality of the Fangcheng district shows an obvious pyramidal structure. However, the specific and accurate numerical segmentation points cannot be obtained, and the evaluation of the spatial quality of the Fangcheng district cannot be accurately classified. In this paper, by drawing the scatter plot of the spatial quality evaluation of the Fangcheng district, it is found that there are five key points in the overall value distribution (Figure 5): one key point of the highest value ①, one key point of the lowest value ②, one key point of the average value ③, and two key points that are abrupt inflection points in the slope (④ and ⑤). It is obvious that the spatial quality of the Fangcheng district can be divided into three quality intervals through the two abrupt inflection points in the slope. The first interval is composed of key points ① to ④, constituting high-quality streets. The score of street spatial quality is distributed in the range of [0.570, 0.631], accounting for only 5.8%. The second interval is composed of key points ④ to ⑤, constituting medium-quality streets. The score of street spatial quality is distributed in the range of [0.370, 0.570], accounting for 92.12%. The third interval is composed of key points ⑤ to ②, constituting low-quality streets. The score of street spatial quality is distributed in the range of [0.247, 0.370], accounting for only 2.08%. Overall, medium-quality streets dominate the street space of Shenyang Fangcheng.

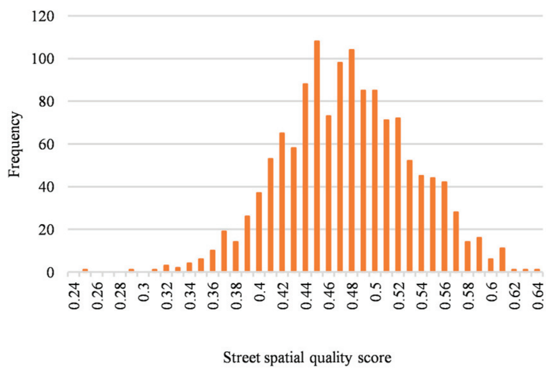

Figure 4. Numerical statistics of the street spatial quality evaluation of the Fangcheng district.

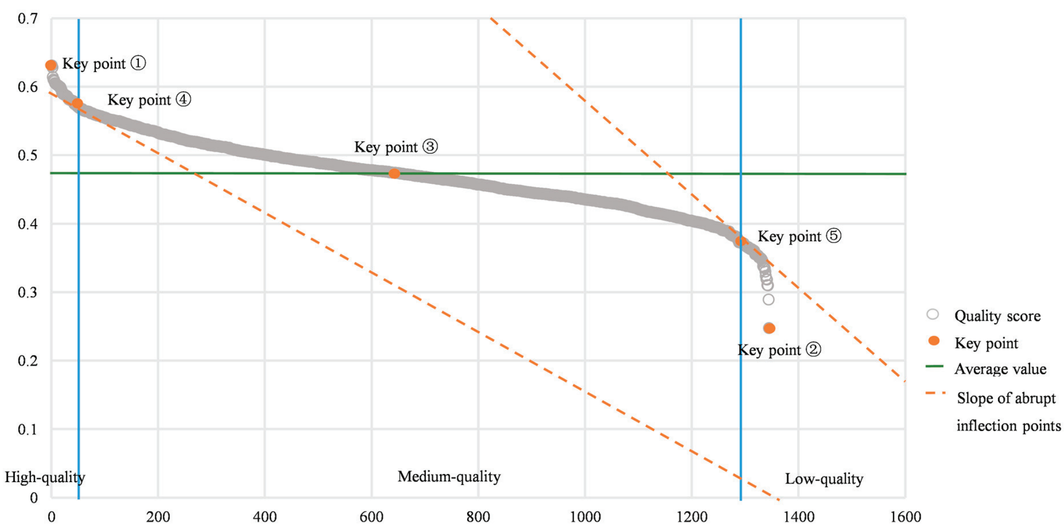

Figure 5. Classification of the street spatial quality of the Fangcheng district.

In 1986, when the State Council announced the second batch of national famous historical and cultural cities, the concept of protecting historical blocks was formally proposed given that a large number of historical blocks had disappeared and the historical features were seriously damaged. Included in the second batch of national famous historical and cultural cities announced by the State Council, the Fangcheng district is dominated by medium-quality streets. It can be seen that some achievements have been made in the protection of historical and cultural blocks in China. However, there are still some low-quality streets in the Fangcheng district, indicating that in the long process of transformation and renovation, there are still some spatial landscapes and traditional environments that have been damaged. Additionally, medium-quality streets, which occupy a large proportion, still have great room for improvement. These spaces will be the key to improving the spatial quality of the Fangcheng district in the future.

3.2. *Spatial Quality of Streets in Fangcheng District*

We use the isoline construction tools in ArcGIS (10.8) to depict and analyze the street spatial qualities. Figure 6 illustrates the three spatial quality of streets. The darker the color, the higher the street spatial quality.

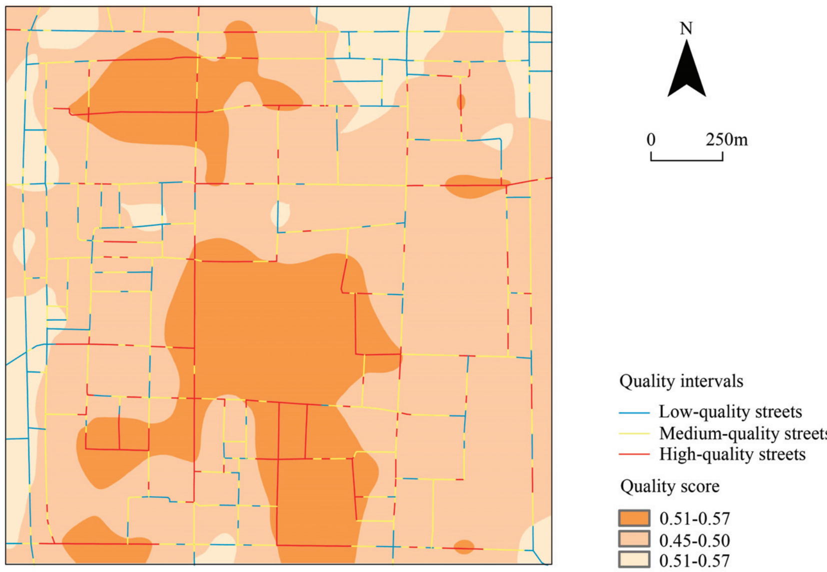

Figure 6. Spatial distribution of the street spatial quality evaluation of the Fangcheng district.

From the spatial distribution of high-quality streets, high-quality streets in the Fangcheng district are mainly distributed in the center of the historical preservation district and key commercial areas. Within the Fangcheng district, the Shenyang Imperial Palace and Marshal Zhang's Mansion belong to the National Historical Preservation Program. For the center of the historical preservation district, the government has a relatively large investment and perfect management system. Thus, the street quality in this core area is evidently higher than that in other areas. The main commercial area is Shenyang Zhong Street, formerly known as Siping Street, which is a commercial area with a long history and has been one of the economic center in Shenyang. It has a history of more than 300 years dating back to the Ming Dynasties. Similar to the other ancient capital cities in China, the Fangcheng district was also built according to the planning concept of "the imperial court in front, the market behind, the ancestral shrine on the left and the community on the right". The northern part of the Fangcheng district was originally Siping Street formed by some historical establishment. With the expansion of Siping Street and the change of some old tile-roofed shops into two- or three-story buildings, a commercial concentration area has gradually formed, and the "Siping Night Market" has become one of the eight scenic spots in Shenyang. After years of development, Zhong Street has become one of the most prosperous street in the city of Shenyang, and even in the Northeast part of the country. The surrounding amenities are abundant, and the street environment is relatively pleasing. In this case, the density of high-quality streets is higher and concentrated in the shape of strips in Zhong Street.

As shown in Figure 6, we discovered that the medium-quality streets mostly concentrated in the residential areas surrounding the center of historical preservation areas. The

Fangcheng district is located in the central area of the city, and its favorable geographical location and well-developed supporting facilities attract a large number of people to live in the Fangcheng district. The high population and building density has brought enormous pressure to the street spatial quality in the Fangcheng district. Meanwhile, during the old district renovation campaign in the 1980s, a large number of traditional residential buildings in Fangcheng district were gradually demolished under the pretext of shantytown renovation and replaced by identical multistorey residential buildings. As a result, this led to the residential communities with varying heights and spatial forms that fail to meet the requirements for historical architecture preservation. Moreover, the street facades also lack harmony and coherence. Due to these factors, many medium-quality streets have emerged in the residential neighborhoods surrounding the historic and cultural conservation zone in the center of the Fangcheng district.

Comparatively, the spatial distribution of low-quality streets in the Fangcheng district is quite dispersed. According to onsite investigations, most low-quality streets turn out to be streets with poor (transport) accessibility, located around some open parking lots in Fangcheng district. The street layout of Fangcheng district was formed during the Kyoto Castle period spanning over 300 years of history. Many urban side streets are narrow (as compared to other main road today), and underground space development is inadequate, making it difficult to adapt to the traffic pattern dominated by motor vehicles in modern society.

3.3. Section Line Analysis of Street Spatial Quality

Section line analysis is employed in this section to explore the relationship between changes in the details of spatial street quality and the corresponding street spaces in the Fangcheng district. The locations traversed by the section line can reflect certain areas where such details undergo changes. Therefore, section line analysis is adopted to examine the changes in the specifics of street space quality in the Fangcheng district. Based on the spatial distribution characteristics of street spatial quality in the Fangcheng district, we used the 3D analysis module in ArcGIS to exam the spatial quality distribution in the Fangcheng district. Zhengyang Street, Chaoyang Street, and the central line were selected as section lines in the north-south direction, while Zhong Street, Shenyang Road, and the central line were selected as the section lines in the east-west direction. The location diagram of the section lines is shown in Figure 7. By referring to the street spatial quality contour map of the Fangcheng district, the quality evaluation values of the sections were extracted from ArcGIS based on the section line positions depicted in Figure 7. Ultimately, six profile curves of quality evaluation data were obtained, as shown in Figure 8.

As shown in Figure 8, the area intersected by which the six streets spatial quality section lines pass exhibit numerous fluctuations. Judging from the north–south street space quality profiles, the three positions generally manifest the same value distribution. The street spatial quality from Beishuncheng Road to Zhong Street displays an upward trend, peaking at Zhong Street. The street spatial quality from Zhong Street to the Shenyang Imperial Palace presents a downward trend and then rises again, and peaks at the Shenyang Imperial Palace, surpassing that of Zhong Street. From the Shenyang Imperial Palace to Nanshuncheng Road, the street spatial quality continues to decline. Overall, the Shenyang Imperial Palace has a greater radiation effect on the street spatial quality in the north-south direction, and the section lines of the three positions are all affected by the radiation effect of the Shenyang Imperial Palace.

Judging from the east–west street space quality profiles, the latter two positions generally exhibit the same value distribution. The street space quality from Xishuncheng Street to the Shenyang Imperial Palace keeps increasing, peaking at the Shenyang Imperial Palace, whereas that from the Shenyang Imperial Palace to Dongshuncheng Street continues decreasing. However, the section line at the first position displays a “trough” at the Shenyang Imperial Palace, signifying that the Shenyang Imperial Palace exerts little impact on the street space quality of this cross section.

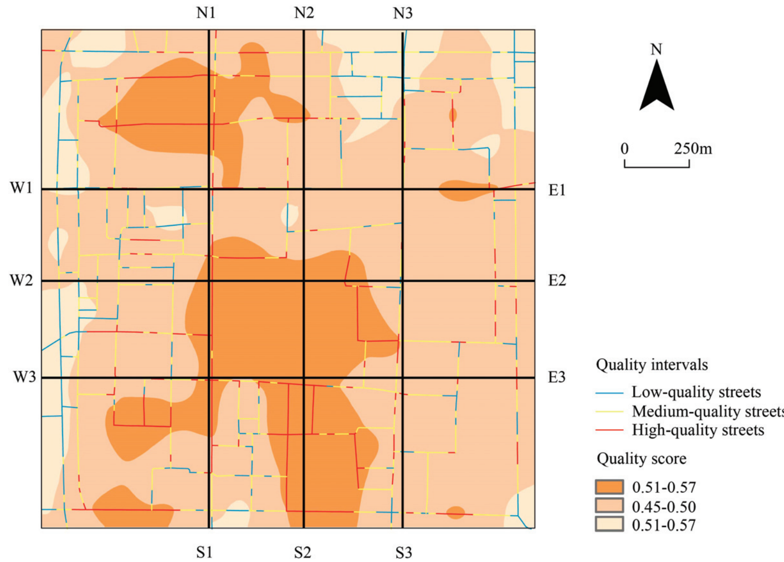

Figure 7. Section line location diagram.

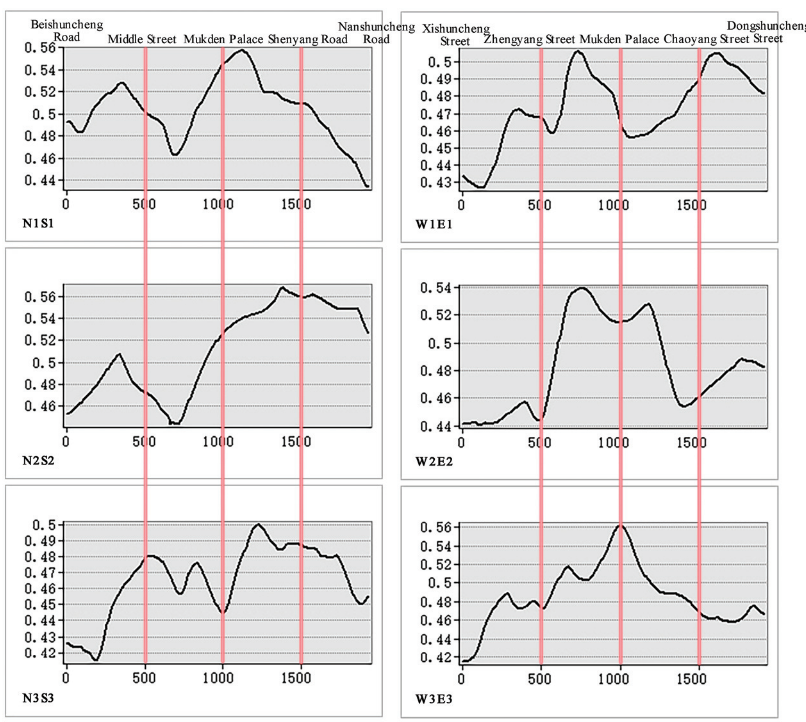

Figure 8. Section diagram of street spatial quality in the NS and WE directions of the main streets.

In summary, based on a comparative analysis of the horizontal and vertical section line analysis, it can be concluded that the Shenyang Imperial Palace has a greater stimulating effect on the street spatial quality in the north–south direction in the Fangcheng district.

4. Discussion

In order to improve the spatial quality of historical districts, it is necessary to propose accurate improvement policy suggestions for streets of different spatial quality: (1) For high-quality streets, we should further enhance spatial vitality on the basis of existing well-functioning spatial carriers of the streets and optimize the layout of supporting facilities to optimize high-quality streets. (2) For medium-quality streets, we should solve the problems existing in the street space one by one through supervision and guidance to achieve a leap from medium-quality streets to high-quality streets. (3) For low-quality streets, we should take more effective control, standardization, and other measures to comprehensively improve the current situation of low-quality streets.

4.1. Policies Suggestions for High-Quality Street Improvement

First, revitalization of the historical district, especially the cultural symbols and characteristics, are critically important. The over-development of modern commerce has had a strong impact on traditional commerce. The disappearance of traditional "street craftsmanship" such as washing and dyeing, darning, and various kinds of maintenance in the heart of the historical district have lead to the loss of traditional cultural traits in the heart of residents. We believe decision makers should consider restoring those so that it would help recoup cultural foundation within the city and further pursue economic benefits in the high-quality streets.

Secondly, we should tap into cultural resources to create a vibrant Fangcheng district. The Fangcheng district has witness socioeconomic changes since the Qing Dynasty; from the stories of Nurhaci occupying Shenyang, Huang Taiji establishing Shengjing in Shenyang, the Qing government's construction of Shengjing, to the Republic of China's transformation of Shengjing they are all related to the Fangcheng district. In this case, the cultural resources of the Fangcheng district, historical sites, Manchu culture, and traditional folk arts of Northeast China can all be used as vessels for inheriting its culture. Therefore, by increasing facilities such as small theaters and museums, new norms of development would incorporate both industrial and cultural development, enrich the function of the space, and improve its quality.

4.2. Policies Suggestions for Medium-Quality Street Improvement

First, the buildings on both sides of medium-quality streets should be gradually improved. Some of the previous renovation attempts have inappropriately addressed the existing issues in the Fangcheng district; specifically, some multi-storey buildings and a few high-rise buildings have been built, causing inconsistency in the spatial form (especially in terms of the skyline of the buildings). For future renovations, rebuilds, and expanded buildings, reasonable control measures should be exercised. Decision makers should create guidelines and standards for building revitalization in the historical district. For instance, policies should ensure that the height, exterior decoration, and color of buildings surrounding the historical and cultural protection area are consistent and harmonious within the district.

Second, the population of the Fangcheng district should be appropriately reduced. For a long time, the high population and building density in the Fangcheng district has had a negative impact on the overall quality of street spatial construction. In order to foster the street quality, it is necessary to gradually reduce the population in the Fangcheng district, and one of the possible approach could be to provide some economic control. For example, maintain the high real estate prices and increase the cost of living inside the Fangcheng district. With the reduced population, the floor–area ratio will also decrease. We should try to increase the vegetation coverage in the extra area by planting more trees, flower stands, and shrubs to increase the green visibility of the streets. In terms of the existing buildings, the rebuilt land of multi-storey residential buildings can be restored to the traditional courtyard form of the Fangcheng district, such as "Liu Xiejiang's Courtyard" and “Huangjia Dayuan”. This will not only improve the quality of street space in the Fangcheng district but also inherit the original texture of the blocks.

4.3. Policies Suggestions for Low-Quality Street Improvement

First, temporary buildings and illegal buildings on both sides of low-quality streets should be demolished. The basic road network of the Fangcheng district was formed during the prosperous period of Shengjing City and, thus, some of the roads are narrow in width by today’s standards. In addition, the maintenance and management of those roads were insufficient. Therefore, the roads and buildings should be the priority in order to improve the street quality in the Fangcheng district. Additionally, the internal branch road system should be organized on the basis of maintaining the original urban space texture to strengthen the traffic capacity of the streets in the Fangcheng district.

Second, we could collaborate with various interest groups and policy-makers to reroute the traffic within the Fangcheng district. As the commercial center of the city, Zhong Street has attracted incalculable numbers of vehicles, resulting in the escalation of congestion. In this case, we should take east-west Shuncheng Street and south-north Shuncheng Road as links to coordinate the urban traffic system and reduce the flow of automobiles entering the Fangcheng district by means of channeling traffic, restricting one-way traffic, limiting traffic at specific times of a day, and implementing sections to ensure the smooth passage of internal vehicles. At the same time, based on urban subways, underground space can be used more efficiently in order to accommodate the flow of people.

5. Conclusions

This paper examines street spatial quality by constructing a street-scale evaluation system for historical districts based on overall quantification and spatial distribution using street view images. Specifically, we focus on the vitality, safety, and landscape. The overall street spatial quality of the Fangcheng district presents a pyramidal structure in its numerical distribution; most streets are medium-quality. In terms of the spatial distribution, high-quality streets are mainly distributed in the core area of historical protection, medium-quality streets are mainly distributed in residential areas close to the historical district and its cultural protection areas, and low-quality streets are associated with poor traffic accessibility. Based on these findings, this paper proposes corresponding spatial quality improvement recommendations for high-, medium- and low-quality streets.

There are several directions for further research. Firstly, there are some limitations with the Baidu Image datasets; they are not up to time, which would potentially affect the results. In future studies, Microsoft images, Weibo data, or Xiaohong Shu image datasets can reflect the streets more accurately. Second, in terms of the research methods, this study used machine learning to identify the semantic elements of street view image data and finally identified only 18 elements. However, the characteristics and identity of urban space refer to not only the physical conditions of the settings but also the social, cultural, artistic, historical, and ecological qualities of space [46]. In follow-up research, relevant street view image element identification can be achieved through continuous dataset training, and the specific disorder of urban street space can be further studied. Third, although the presented method has been able to measure the quality of streets scientifically and effectively, there are still some deviations in the measurement results of streets. For example, the hutongs with high-quality in the traditional sense may be low-quality when measured using the presented method. In follow-up research, a more scientific and perfect street space quality evaluation system can be built by combining street view image data and traditional data.

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buildings

Article

Preferences of Young Polish Renters: Findings from the Mediation Analysis

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Abstract: The worsening housing problems of young adults in many countries have become a worldwide problem. Researchers point to a number of factors that influence young people's decisions to own or rent their own apartments or houses. The term generation of renters or the lost generation has appeared in the literature in relation to the young adult generation. This article offers insights into the housing preferences of young adults aged 18 to 45 in Poland, with a particular focus on the renter cohort. Conclusions are drawn about whether young adults who are already renting prefer to buy an apartment or house rather than maintain their status quo, and what determines their decisions in this regard. The study identifies a number of socioeconomic factors that influence the housing decisions of young renters in Poland. It addresses some of the problems and challenges of today's housing market and, in particular, examines what leads young Polish renters to switch from renting to buying their first home or, alternatively, to live in a rented apartment for years (thus showing indifference to homeownership). Some of the reasons for the change in attitude toward this issue are highlighted. The study is quantitative in nature, relying on an online survey and a mediation analysis that is particularly well suited to explaining the relationship between many different variables. Of the eight hypotheses tested in the study (using mediation analysis), only three could be proven, namely that the amount of rent payments and other costs for economic reasons influences the willingness to buy an apartment or a house, and also that the length of the rental period has a negative influence on the willingness to buy a house. Finally, the mediation model provides evidence that the higher a young renter's tolerance threshold for mortgage interest compared to "rent payments", the more inclined they are to buy an apartment or house. The study suggests that the housing finance subsystem has some shortcomings as far as financing young people is concerned. Strategically, there are two complementary solutions that could be implemented: (1) a long-term home savings plan or program and (2) innovative housing loan options tailored to the financial situation of young people.

Keywords: housing tenure; housing preferences; renting vs. home ownership; young adults; mediation model

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1. Introduction

Finding a place to live is one of the biggest and most important decisions in life. People who are faced with the choice of owning or renting a home do not find the decision easy [1]. This is because they have to choose between alternatives with very different costs/characteristics; essentially, it is a routine decision made under uncertain conditions. Before such decisions are made, several scenarios are usually run, in which appropriate assumptions are made about the elements affecting the value of the property in the future (e.g., the risk of depreciation, etc.), and its financing (i.e., the creditworthiness of the buyer), as well as the living situation of the parties involved [2]. In summary, individuals or entire households face an extremely serious problem, which from their point of view consists of making important decisions under uncertain conditions. While renting an apartment or house involves recurring low costs in the form of rent payments and offers some decision flexibility due to low barriers to entry and exit, owning requires a high one-time initial investment that comes with much less decision flexibility. Aside from the financial aspects (i.e., whether or not one can afford to own a home), preference in this regard may depend on the expected duration of use of the home itself. Home ownership may be preferable for long-term use, while for short-term use, renting a house is usually considered the better option for obvious reasons. For example, Hargreaves [3] has shown that people generally prefer homeownership to renting when the assumed useful life is more than 3 years. However, there is a caveat: this applies when the rate of appreciation of real estate is higher than the rate of inflation. A higher interest rate on the borrowed capital increases the time needed to break even [3]. This topic gains importance against the backdrop of the current cycle of significant interest rate hikes and the politics of dear money. More importantly, the problem is that the duration of housing use is usually not known in advance and may depend on a whole range of different factors [2]. In our daily lives, there are events that can completely change our previous decisions, including those related to owning or renting an apartment or house. One example is the coronavirus pandemic. Another example is the current, very disturbing, and unexpected increase in inflation and the deterioration of living conditions.

There is a general view that renting is a reasonable alternative to homeownership. Erbel [4], for example, discourages young adults from buying a house, arguing that homeownership usually hinders mobility (i.e., geographic and occupational mobility), even though globalization has opened up the world and one can now work anywhere on the globe. Beugnot et al. [5] argue that homeownership impedes mobility because it limits job searches in the economy and imposes additional costs associated with relocation (when a job is far away). However, it is worth considering whether renting from the perspective of young adults is a trend resulting from new trends and preferences that are unique to them, or whether it is an economic necessity that is a consequence of the low incomes of young people who cannot afford homeownership and therefore opt for affordable rental housing. Data show that 45.1% of young adults aged 25–34 still live with their parents, which is probably not their preferred situation and is an undesirable phenomenon from a sociological perspective [6]. Thus, it is worth looking for a rationale for this phenomenon, i.e., for the fact that a large group of young people do not rent an apartment, but continue to live with their parents. It is quite possible that the total cost of rent is too high for them. On the other hand, if rent payments are almost as high as the cost of a mortgage, the renters might consider owning their own apartment or house. So why do they not? To understand the behavior of young adults in the housing market in its complex socioeconomic context, both now and in the future, it will be extremely important to examine many similar issues and answer a whole series of questions. These questions should address the following areas: housing preferences in the context of economic and socio-cultural conditions, lifestyle, utility analysis, etc. It is also worth seeking answers to the question of whether the existing 30-year mortgage annuity (i.e., a repayment mortgage) is attractive enough to the cohort of renters expressing a need for homeownership to encourage them to purchase a home. Perhaps, from the banking sector's perspective, it is possible to offer borrowers a more attractive loan package that is tailored to their income level, occupational status, etc.

The aim of this study is to analyze the main factors influencing the housing preferences of young adults in Poland, focusing on the analysis of the preferences of those who have already rented an apartment or a house. Using a customized questionnaire survey and a mediation model, the study provides insights into the Polish housing market and analyzes the motivations of young Polish renters. It identifies a range of factors that influence their decisions and choices. The study targets young adults between the ages of 25 and 45. It analyzes their attitudes and their ability and willingness to buy an apartment or house financed with a mortgage loan. Housing is a popular topic of public debate in Poland, but most of it is conducted online or as a commercial initiative of the private sector (mostly developers) [7,8]. On the other hand, there is a lack of solid academic research on the cognitions of young renters in Poland. The present study is an attempt to fill this gap.

The structure of the study is very simple. Section 2 discusses previous empirical findings and relevant theoretical concepts. Section 3 outlines the analytical framework, data collection methods and mediation model, including descriptive statistics and methodology. Section 4 provides a detailed presentation of the results, followed by a discussion in Section 5. Finally, conclusions from the conducted research are drawn and presented in Section 6.

2. Empirical Evidence

The importance of home ownership and housing studies has been repeatedly addressed in the literature, and there are numerous studies on the subject [9–15]. Problems have been increasing for years, but in recent years, housing problems among young adults have increased particularly markedly in many countries [14,16]. A wide range of factors have been found to influence young people's housing decisions [17,18]. There are studies that show that among the various factors that influence this market, economic factors are the most important [19]; they have a greater influence on housing choices than, for example, social, or cultural factors. Economic factors include factors such as housing prices, income and wealth, and interest rates, but also factors such as tax regulations influenced by state governments [20,21]. In turn, other studies point to the significant influence of inflation factors and, in particular, the relevance of the relationship between homeownership and inflation [22]. There are also quite a number of studies that point to the significant social [11] and economic benefits of homeownership compared to renting [9,12,13,15,23,24]. Among the benefits, researchers list better social outcomes [11,12], greater civic awareness [9,13,15], less crime and fewer so-called pathological incidents [23], and better cognitive and behavioral performance and learning outcomes [12]. Homeownership creates the right conditions to support and encourage families [24]. In addition, easy access to homeownership leads to higher birth rates [25]. Moreover, homeownership leads to significantly higher life satisfaction [24,26]. Higher homeownership rates are also generally associated with higher housing prices [11].

People's attitudes toward housing choice are also influenced by certain economic, political, and cultural dimensions of consumption, where countries differ [27]. Nevertheless, positive or negative attitudes toward homeownership are also significantly influenced by the socialization process [1], which is why some researchers point out the urgent need for numerous debates and information campaigns on this topic [27]. It is obvious that there is a significant relationship between socialization and public information campaigns. Such campaigns are later reflected in appropriate public housing policies and form the basis for public debates [27]. It is important to note when considering the preferred form of housing that ownership has generally been preferred to renting so far, unless there are financial constraints (i.e., assuming that a person facing this type of choice can afford both) [16]. For example, one study showed that Americans prefer homeownership [15]. More specifically, 86% of respondents clearly preferred homeownership to renting. Only 26% of respondents said they chose to rent their apartments due to pure conviction rather than for financial reasons.

As for the topic of housing preferences, one cannot avoid addressing housing markets (since these issues are inextricably linked). In this issue, speculation and occasional collapses of housing bubbles play an important role, reflected in market conditions and, in particular, in economic uncertainties and difficulties in accessing mortgage financing [8]. This is exactly how the situation looked for a while after the sub-crisis more than a decade ago, and most importantly, the general uncertainty spilled over to the whole world, including Poland [10,28]. This is important because in the post-crisis period, people are generally less likely to opt for home ownership [10]. It is important to note that the crisis hit mainly the countries where the share of the construction sector in GDP is the highest [29], such as Spain [30]. Consequently, the shock of the crisis hit young Spaniards the hardest and led to a significant increase in their interest in renting compared to homeownership [30]. This is a dangerous phenomenon, since it affects socioeconomic aspects and issues of human identity and subjectivity, as well as the tendency of young people to start a family and their emancipation [31]. If such a situation persists over the long term and is accompanied by changes in young people's norms and aspirations (and this is often the case), the social impact of such cohabitation could be difficult to manage. The countries most vulnerable to severe social changes are those where the crisis could not be contained relatively quickly, disrupting previously prevalent living arrangements, and where the living conditions and lifestyles of young adults have been forced in some way, intentionally or unintentionally.

A number of studies also point to another phenomenon: namely that for many young adults the alternative to buying their own home is no longer renting, but having to share housing with their parents, which significantly deteriorates their emancipatory abilities [7,20,32] and also affects the quality of their social life [30,31,33]. Thus, young people today start their own families much later, which is of course significantly influenced by the lack of their own housing [16,32]. Unfortunately, the truth is that no previous generation has lived with their parents as long as today's [16,32]. In this context, it is worth considering the example of Spain, which is traditionally considered a pro-ownership society when it comes to the choice of housing. The great financial crisis in the first decade of this century completely disrupted social expectations and aspirations regarding choices in this area. The difficult situation of young adults means that their parents play a greater role [20,30,31,33,34], whether through financial transfers (donations) and loans or in-kind contributions. Housing preferences are therefore increasingly determined by the social and socioeconomic class of young adults' parents. In this context, it should also be mentioned that parents of young adults exercise a kind of control over their children who are recipients of housing capital, which manifests itself in influencing their standardized social and economic choices [35]. It is also important to point out that the importance of parents' material status increases as housing prices continue to rise and affordability decreases [33,34]. In particular, the problem of the importance of parental support factors is beginning to affect women more [34].

Precisely because of the pervasive market and social uncertainty [16,36], the perspective changes when it comes to financial burdens of any kind. The way rent is viewed is also changing. Increasing uncertainty and more frequent black swan events lead to increased risk aversion, which leads to increasing interest in rent [16]. It is certainly the case that the option to rent gives people a greater sense of flexibility, as it offers the possibility of moving out at any time, which in the context of many economic uncertainties (binary events such as the COVID-19 pandemic, the potential collapse of many businesses, and the possibility of losing one's job) provides a sense of greater security. The lack of access to housing for young adults leads to unequal housing conditions, lower social participation, and an increasingly visible wealth gap between generations. According to Willetts, the older generations have benefited from an exceptional situation, but it has and will burden the welfare of the younger generations, which is unfair [37]. According to the author, the demographic boomers not only dominate culturally through their power as an extremely large consumer market, but have also amassed huge amounts of wealth and real estate, all at the expense of younger generations. The phenomenon of the wealth gap between generations is most likely to be observed in the markets with the highest prices and the lowest prices, where the opportunities to buy a house are rather limited [34]. The housing status of young adults is also strongly influenced by government social policies [20], as evidenced by relevant research showing a negative impact of government benefits on attitudes toward homeownership [20]. Cultural differences also play an important role. Where these values are closer to family values, and where the household is seen as a certain symbol of security and refuge, the level of homeownership tends to be higher (see Figure 1). Figure 1 shows some structural and systemic differences between countries that are not directly related to the economy and that are reflected in the popularity of homeownership.

In Hungary, Slovakia, or Spain, for example, home ownership is generally considered better than in Germany or Austria, which are richer in terms of GDP per capita [22].

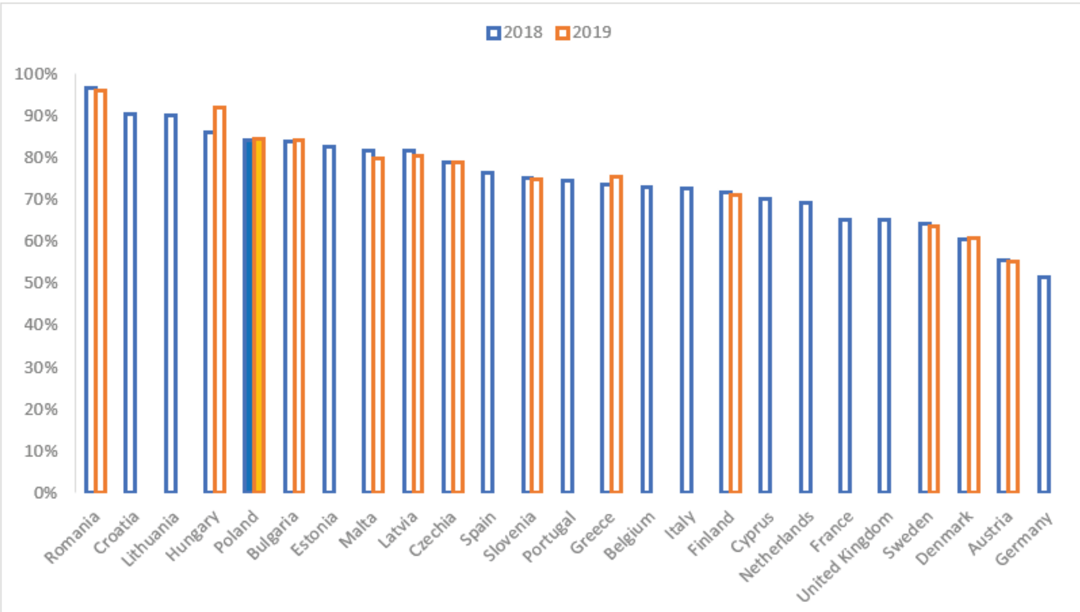

Figure 1. Home ownership rate in selected European countries 2018–2019. Source: own elaboration based on the data from Eurostat (July 2020).

The differences in attitudes among people in different countries are due to non-price aspects, which include demographic factors, institutional conditions, government housing policies [20], cultural differences, etc., in addition to purely economic factors related to prices and supply [2,22]. Decisions about the preferred housing type may be related to lifestyle [16] or, for example, to a particular cultural background and heritage. From a purely economic perspective, housing type is determined by housing prices themselves (so-called affordability) [38], inflation [22], uncertainty about future income [2], risk factors related to job and employment stability, and potential financial support from a life partner [2]. In this context, the increasing number of one-person households is pointed out [2]. As for housing prices, they have risen sharply in many countries in recent decades. Figure 2 shows the percentage change in average apartment/house prices over 2010–2021 in various European countries. In Poland, prices have increased by 39.92% in this period (i.e., in these 11 years). However, as Figure 2 shows, in many countries, prices have increased even more (in Estonia, Latvia, Hungary, and the Czech Republic, for example). The above data are consistent with the data in the study by Sobieraj and Metelski [39].

There is scientific evidence of episodes of price exuberance in many countries, e.g., the U.S. and the U.K. [40], New Zealand [41], and Australia (especially with respect to rental prices) [42]. For years, residential real estate speculation and buying frenzy were fueled by excessive liquidity in the monetary system (lax monetary policy), which naturally led to some of this liquidity spilling over into residential real estate markets [39,43]. Part of the blame for this situation can be laid at the feet of the U.S. monetary authorities, whose imprudent policy of quantitative easing (in contrast to the Austrian school of economics) set a certain new standard in economics. The truth is that credit-driven economies are prone to the spread of housing booms [43,44]. The policies of national governments and central banks contribute to putting homeownership out of reach for young people for purely economic reasons. In turn, those who bought their home with a mortgage must expect that the cycle of interest rate increasing in various countries (which is currently the case) may lead to a decline in home prices, and many will face the problem of interest and principal repayments that they may not be able to afford. It should also be emphasized that government policies (after public consultations) should be prudent and judicious, as studies show that excessive governmental social assistance does not necessarily have a positive impact on homeownership rates [20]. Still further studies point in particular to the need for well-structured [45,46] and developed mortgage markets [7], which significantly accelerate the emancipation process of young adults, as they succeed more quickly in leaving their parental home and starting an independent adult life. There is scientific evidence of a strong correlation between mortgage credit availability and homeownership. This phenomenon is particularly pronounced in the group of young adults who have the greatest problems with access to capital (which could be used for down payments) at a relatively early stage of their adult life and career development [45].

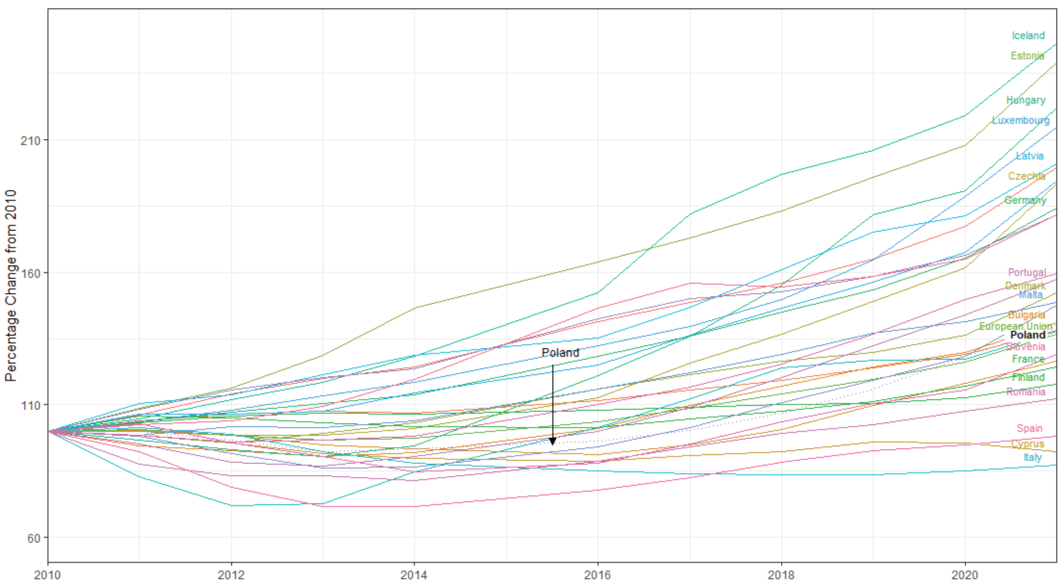

Figure 2. Change in average apartment/house prices over the period 2010–2021 in various European countries (percentage change from 2010, source: own elaboration based on Eurostat—https://ec.europa.eu/eurostat/cache/digpub/housing/bloc-2a.html?lang=en (accessed on 23 March 2023)).

To improve the outlook for the housing market as a whole in the mortgage finance system, flexibility in mortgage repayment is particularly important [46]. Due to the increasing economic turbulence in the markets, some financial engineering mechanisms are desirable to appropriately mitigate the risk so that young people are not exposed to excessive risk [46]. In this area, research has already been conducted that has shown that loans with adjustable interest rates (adjustable-rate mortgages) are the most appropriate form of financing.

Another important point is that it is becoming increasingly difficult for young people to actually identify their housing preferences [7], regardless of the level of economic development of the country from which these young people come. The point is that this phenomenon cannot be explained by the economic situation, nor by the level of development, liquidity or stability of the housing markets themselves [7]. Other studies have shown a relationship between financial strain and outstanding financial debt of young adults (mainly in the form of student loans) and the lack of desire for homeownership [47].

In other words, financial strain is a factor that does not positively influence the desire for homeownership, but rather discourages potential buyers. The increasing credit and financial burden of societies has a negative impact on young adults, which has socioeconomic consequences and demonstrably worsens their chances of homeownership [47].

Economists predict that the current processes will continue in the current decade, leading to a general decline in the relative level of home ownership [10,48]. More specifically, although there will be a net increase in the number of new homes and new households (i.e., the absolute number of homeowners will increase), overall renting will dominate as the absolute number of renters will increase by a larger proportion [10]. In general, rising housing prices and the lack of an adequate financing system mean that more and more young people will be excluded from owning a home and will become part of a generation of renters [49]. Therefore, it is likely that the housing market will be a renter's market in the future [10]. Additionally, it is the lack of access to home ownership and the strong need of young adults to create some kind of housing for themselves that leads to a rapidly growing rental sector [16]. On the other hand, the proportion of young adults still living with their parents is also rapidly increasing [31]. These are now two strongly dominant trends that are setting the direction in which housing markets are developing worldwide [31]. It is also worth highlighting the increasing degree of financialization of housing markets themselves [31], which in many cases even makes it impossible for young adults to become homeowners [16,50]. There is also a body of research that argues for the advantage of renting over owning [17], especially when considering the average duration of homeownership. This perception of choice of housing form is justified, for example, for the US market, as pointed out by Beracha and Johnson [17]. Regarding the choice of housing form, these authors adopted the position of indifference, assuming that it is reasonable to consider the appropriate relationship between the rent and the housing price, taking into account the indicators of volatility of housing prices [17]. However, this type of evaluation should pay special attention to the specifics of the market in question, i.e., demographics, cultural factors, social habits, and so on. In other words, it is difficult to make a similar assessment for other markets, e.g., European or Polish, based on the experience of the American market, which is simply different [10,48]. It should also be emphasized that homeownership has a number of positive aspects from both macro- and micro perspectives [51]. Regarding the latter aspect, homeownership leads to greater social participation and, at the same time, to more savings in households. As for the first aspect, ownership promotes consumption and investment and has a positive impact on public finances. Additionally, it is worth noting that homeownership rates are affected by appropriate government policies, especially tax distortions [51,52]. In the case of unfavorable tax laws, the cost of owner-occupied housing increases [52]. Therefore, it is difficult to imagine a stable housing sector without government action to reduce marginal tax rates [16,52,53]. Important issues for policymakers and decision makers to consider include taxes on tangible property (cadastral), taxes on the transfer of residential property, rent-related taxes, capital gains taxes, cost of owner-occupied housing, imputed income from rental housing [53], and mortgage tax credits [16]. One proposed solution that works well is the possibility of mortgage interest deductions [53] or property tax deductions, as well as mechanisms that interact with capital gains from homeownership [16].

It is important to emphasize that, in addition to typical factors, such as location and price, certain building characteristics (e.g., energy consumption or whether the building has been modernized in this regard) may also play a role in housing preferences [54]. The energy efficiency of new buildings compared to older buildings can influence preferences when renting or buying a new home. Newer buildings designed with energy efficiency in mind may be more attractive to renters and buyers who value lower energy bills and carbon footprints [55,56]. It is important to keep this in mind. Indeed, research has shown that rental properties with higher energy scores are more likely to attract tenants [57]. In addition, government stimulus programs often target building retrofits and efficient new construction [56].

In summary, there are many aspects that influence young people's adequate decisions about their preferred form of housing. In particular, individual decisions depend on the economic situation of a particular country, its background, and cultural values. Additionally important are appropriate programs and policies implemented at both central and local levels, i.e., different types of housing programs, adequate tax regimes, and the existence of a well-developed mortgage finance system with appropriate tools to mitigate financial risk.

3. Materials and Methods

3.1. Research Method

The study is based on a questionnaire survey, which has become a popular means of obtaining information in the information society [58]. This method is effective in the sense that it allows designing customized questionnaires that correspond to the predefined research hypotheses. Data are collected from respondents who are as representative as possible, so that the sample and its parameters correspond to the entire population under study in order to obtain reliable results. Moreover, the development of Internet technologies facilitates access to various communication channels, which makes this form of data collection and knowledge building about various economic and social phenomena attractive and relatively quick to conduct [59]. Surveys provide useful information on various topics related to economic and social life and are widely used in scientific research. Furthermore, the choice of a research method such as a questionnaire survey usually results from the specificity of the phenomenon under study and the research problems that are the subject of investigation. The respondents' answers included in the survey are used as a basis to test the predefined research hypotheses and to confirm or reject them. A mediation model was used to test the hypotheses established in the study.

The study followed several steps to reach its conclusions and recommendations. It begins with a review of the literature to identify potential research problems. Then, a powerful survey database (CAWI) was used to construct variables based on the data. The data were cleaned to ensure accuracy and reliability. The next step was to establish some research hypotheses and choose an analysis method to test them. Briefly, a path mediation/SEM/model was used using the AMOS AxB estimator approach. After the results were analyzed, three of the eight hypotheses were confirmed. Then, the results are discussed in relation to the hypotheses raised and critically analyzed in light of previous empirical findings. Finally, some conclusions are drawn and some recommendations are made based on the findings. Overall, the study demonstrates a comprehensive and systematic approach to conducting research, from problem identification and data collection to analysis and interpretation. It draws on advanced statistical tools and critical thinking skills to make a meaningful contribution to the field. To make the procedures of the study clearer and easier to understand, the flowchart of the study is shown in Figure 3.

3.2. Data Collection

The survey was conducted in early 2021 using the Computer-Assisted Web Interview (CAWI) method on a sample of 983 respondents (n = 983), consisting of young adults between the ages of 18 and 45. CAWI is a survey method in which interviews are conducted with respondents via the Internet. This technique allows researchers to reach large numbers of people quickly and efficiently. Typically, respondents are sent a link to a website where they can complete the survey. The method requires careful sampling to ensure that respondents are representative of the population being studied, and various techniques such as stratification and weighting are used to ensure the accuracy of the results. CAWI is used in quantitative research projects in many fields, including market research, social sciences, and public opinion research.

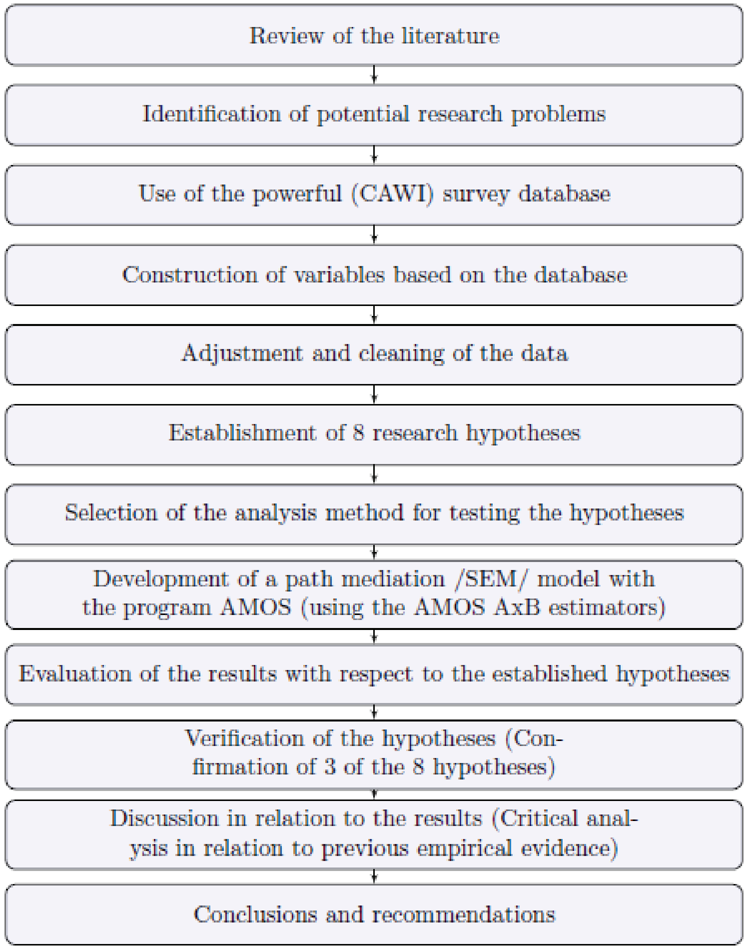

Figure 3. Flowchart of the study.

3.3. Mediation Analysis: Hypotheses of the Study

Mediation analysis has been used in a variety of studies to identify and evaluate the mechanisms by which treatments affect an outcome by revealing intermediate variables that transfer the effect of an independent variable to a dependent variable [60]. This research method has become very popular in medical sciences, but there are also socioeconomic studies in which it has been used. Examples include studying BMI as a mediator of the relationship between smoking and insulin levels [61], evaluating the relative size of different pathways in production functions [62], and determining the sources of output effects [62]. Other applications include promoting and increasing the use of causal mediation analysis in applied education research [63], identifying mediators of health outcomes [64], exploring and assessing biological or social mechanisms to support policy making [65], and causal mediation analysis in clinical research contexts [66].

A mediation model is a particular type of analysis that examines the relationship between an independent variable and a dependent variable and assumes that a third, mediating variable (also called an intervening variable or intermediate variable or mediator) plays some role in that relationship. The entire model aims to better understand and explain this relationship. Traditional regression models examine direct changes in an endogenous variable in response to changes in a set of exogenous variables. A mediation model assumes that an explanatory variable influences an intermediate variable, which in turn influences the endogenous variable. In other words, a mediation model considers indirect causal relationships and compares them to direct relationships. It can also be considered a special case of path analysis, which assumes the inclusion of a mediating variable (mediator) when studying the relationship between two or more variables. When hypothesizing a causal sequence X $\rightarrow$ M $\rightarrow$ Y, mediating models actually attempt to illustrate the mechanisms by which X and Y are connected in some way [67]. The inclusion of a mediating variable in a model facilitates the understanding of the relationship between response and explanatory variables [68,69]. Cohen et al. [70] point out that a mediating variable can be particularly useful when direct relationships between exogenous variables and an endogenous variable are not obvious, or when there are a number of additional contextual mechanisms that significantly complicate the understanding of the relationships under study. MacKinnon [69] noted that mediation models can steer the context of the mechanisms and processes under study in previously unexplored directions through a whole range of mediating variables [69]. In general, mediation explains causal relationships that are somewhat more complex than a relationship that can be expressed as "X influences Y". Viewing the phenomenon under study through the lens of the available literature on the subject, it can be assumed that the relationship between X and Y requires a deeper explanation than simply relying on a simple direct causal effect emanating from the independent variable (IV) on the dependent variable (DV). Since the housing market and the forces influencing it are an extremely complex system composed of many different subsystems [71], many of its relationships are the result of contextual determinants, the mediation of which can lead to a transformation of the entire system. In other words, the relationships that prevail in this market are very complex and a function of decisions made at the microeconomic and macroeconomic levels, which can be influenced, for example, by economic and housing policies.

Mediation was popularized by the work of Baron and Kenny [72], who applied it to psychological studies. They point out that several conditions (prerequisites) must be met in order to model a mediation relationship [72]. MacKinnon [68] points out that mediation analysis considers the following 3 approaches: (a) causal steps, (b) difference of coefficients, and (c) product of coefficients [68], which can be described by the following three equations:

$$Y = i_1 + cX + e_1 \tag{1}$$

$$Y = i_2 + c'X + bM + e_2 \tag{2}$$

$$M = i_3 + aX + e_3 \tag{3}$$

Figure 4 illustrates a simple representation of the mediation model, which reflects the relationships between two variables via a mediator.

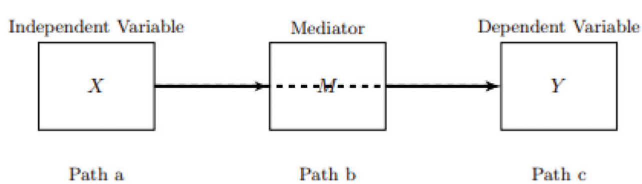

Figure 4. Simple mediation model (source: own elaboration).

Equations (1)–(3) can also be illustrated in a graphical form (Figure 5).

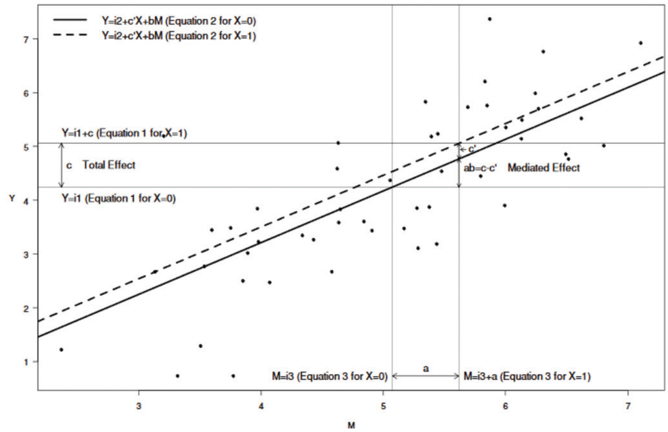

Figure 5. Mediation effect (for simplicity, hats are not included in the coefficient estimates).

In addition, it must first be determined whether we are dealing with a mediator and not a moderator. However, there is an important rule to consider in this question, namely: (1) the mediator must be an accidental result of the IVs and an accidental antecedent of the DVs; (2) the moderator must not be the accidental result of IV. First, we need to check whether the explanatory variable is a significant predictor of the response variable (explanatory variable → response variable). This can be expressed as follows:

$$Y = \beta_{10} + \beta_{11}X + \varepsilon_1 \tag{4}$$

and the β_{11}—coefficient has to be significant.

For the same reason, the intermediate variables are regressed on the explanatory variables to test whether the latter are significant predictors of the mediating variable, which must be associated with the independent variable because otherwise it does not mediate anything (independent variable → mediator):

$$Me = \beta_{20} + \beta_{21}X + \varepsilon_2 \tag{5}$$

and the β_{21}—coefficient has to be significant.

Last but not least, the response variable is regressed on both the mediating and explanatory variables to check whether the mediating variable significantly explains (predicts) the dependent variable:

$$Y = \beta_{30} + \beta_{31}X + \beta_{32}Me + \varepsilon_3 \tag{6}$$

and the β_{32}—coefficient must be significant and β_{31} must be smaller in absolute value than the β_{11}—coefficient (i.e., the coefficient of the independent variable reflecting the original effect).

In the case of the present study, all of the above criteria were met for each of the mediating variables considered. Finally, mediating effects can be tested using the approach of Baron and Kenny [72], bootstrapping, or AMOS AxB estimators [73]. For the purposes of this study, the latter method was used. The AMOS AxB estimator approach is a type of structural equation modeling that allows the estimation of indirect effects in mediation models. It relies on a maximum-likelihood estimation method to estimate the model parameters. The assumptions that must be satisfied for this approach are: normality, linearity, no multicollinearity, homoscedasticity, and no outliers. Violations of these assumptions can lead to biased estimates and erroneous conclusions. However, it is worth noting that the AMOS AxB estimator approach is relatively more robust to violations of the normality assumption than other methods, such as the Baron and Kenny [72] approach. Advantages of the AMOS AxB estimator approach include: (1) simultaneous testing of multiple mediator variables in a single model; (2) estimates of direct, indirect, and total effects of independent variables on dependent variables; and (3) a variety of fit indices and goodness-of-fit measures to assess the overall fit of the model. The software AMOS uses estimation options to fit a model to the data and provide estimates of freely varying parameters based on minimizing a function that indicates how well the model fits [74]. In addition, the AMOS AxB estimator allows user-defined estimates that can include various quantities, such as standardized regression weights and covariances between variables in the model [74].

3.4. Characteristics of the Study Sample: Variables and Data Analysis

A number of variables were selected for the study that seem relevant to this particular type of analysis (see Table 1). The questions and answers in the questionnaire form the basis for an in-depth analysis of young adults' housing preferences. The items of the questionnaire consisted of single-choice questions. A summary of the questions and their underlying variables can be found in Table 1. Subsequently, these variables were used to develop a mediation model that accurately describes the phenomenon under study and, in particular, the relationships between different observable variables.

Table 1. Questionnaire questions and the observable variables behind them.

Var	Variable	Description
ev1	I/we rent an apartment or house	0 = no; 1 = yes
m1	employed	0 = no; 1 = yes, I am employed or self-employed
m2	rising children	0 = no; 1 = yes
m3	amount of rent and all related fees	0 = no payment; 1 = less than PLN 500; 2 = between PLN 500 and 1000; 3 = between PLN 1000 and 2000; 4 = between PLN 2000 and 3000; 5 = over PLN 3000
m4	one's own share of all housing-related payments	0 = I/we do not pay; 1 = less than half; 2 = half; 3 = more than half; 4 = all payments
m5	length of rental period	0 = I/we do not rent a home; 1 = not longer than 1 year; 2 = 1 to 3 years; 3 = 3 to 5 years; 4 = 5 to 10 years; 5 = over 10 years
m6	number of dependents	0 = only myself; 1 = myself/ourselves + 1 more; 2 = myself/ourselves + 2 more; 3 = myself/ourselves + 3 more; 4 = myself/ourselves + 4 and more;
m7	family or relationship status	0 = no; 1 = yes (currently in a relationship, or either marital or family status)
m8	mortgage compared to rentals	0 = I/we do not need/want to buy; 1 = same amount as rental payments; 2 = less than PLN 200 more than rental payments; 3 = PLN 200 to 500 more than rental payments; 4 = from PLN 500 to 1000 more than rental payments
dv1	I/we want to buy an apartment or house	0 = I/we are not interested; 1 = yes, we want to purchase an apartment or house
dv2	renting preference	0 = no; 1 = yes, we prefer to rent a home (instead of purchasing one)
c1	age bracket	1 = 18–25 years of age; 2 = 26–35; 3 = 36–45
c2	gender	1 = male; 2 = female
c3	education	1 = primary education; 2 = lower secondary education; 3 = vocational education; 4 = secondary education; 5 = post-secondary education; 6 = bachelor degree; 7 = MSc/Engineer; 8 = academic degree
c4	hometown population size	1 = rural area; 2 = suburb area; 3 = small town; 4 = medium city; 5 = large city

Note: ev = exogenous variable; dv = dependent variable; m = mediation variable; c = control variable (covariates).

From a theoretical point of view, economic security is expected to be directly related to the preference to purchase an apartment or house [16,26]. Respondents who are financially secure (i.e., have a stable income) are more likely to consider buying a home. Similarly, perceptions of the level of acceptable mortgage rates are likely to affect the willingness to purchase a home. For example, Oliveira [75] points out that, in general, when mortgage rates increase, the overall cost of owning a home also increases, thus decreasing the affordability of real estate [75]. As noted by Altschaeffel et al. [76], an increase or decrease in mortgage rates affects housing price trends and should be taken into account when analyzing and evaluating the housing market and housing preferences. Similar relationships for the Belgian market were described in the work of Hoebeeck and Inghelbrecht [77]. The purpose of this study is not to evaluate the mortgage rate itself, but rather the perception and acceptable tolerance of mortgage rates that are believed to influence purchase decisions in the housing market. It is also known that housing preferences (whether owning or renting) are not only the result of the macroeconomic conditions prevailing in a given country, but are also related to sociocultural anthropology, which leads to the perception of housing as a place of refuge and a certain value base. Therefore, the model includes variables representing the social status of the respondent. They indicate either that the respondent has a family of their own (e.g., marital status, child-rearing, number of dependents) or that they intend to start a family (relationship status). Vidal et al. [78] point out that the rising costs of both raising children and housing have created an endemic resource conflict that prevents many households from achieving their desired housing outcomes. That is, in those countries where the family still holds a strong position as a social unit, home ownership tends to be higher, e.g., in Poland, but also in Spain or Hungary. The situation is different in countries that deviate from the traditional family model, e.g., Germany or Austria, where the social model is no longer so much based on family ties. As shown in Table 1, there are 8 mediating variables (binary or categorical) and 4 control variables included in the model. The independent variable and dependent variables are binary (respondents indicate certain binary preferences). The mediating variables are divided into economic variables, i.e., employment status, rent and related fees, own contribution to housing costs, and mortgage interest compared to rent, which explain, on the one hand, financial security; on the other hand, there are variables that are more social in nature, i.e., that explain the respondent's social situation, such as whether they are single or have a partner and/or children (i.e., marital status/relationship status, number of dependents, length of tenancy). Our objective is to examine how the mediation variables influence respondents' attitudes toward their personal housing preferences. The research hypotheses, based on logical premises as well as evidence from the literature, are listed in Table 2.

3.5. Characteristics of the Study Sample: Descriptive Statistics

A total of 981 people participated in the study, most of whom were in the 18–25 and 26–35 age groups. Study participants were divided into three age groups according to life stage and social development. The first group consisted of 18-to-25-year-olds who typically enter adulthood and begin university studies, post-secondary education, or work. This stage is associated with renting an apartment and moving out of the parental home. The second group includes the 26–35-year-olds who are established in the workforce and are looking to separate from their parents, often starting their own families. Finally, the third group includes the 36–45-year-olds who are expected to have stabilized their job and housing situation, with many already owning their own home at this point.

More specifically, 425 respondents were in the 26–35 age group, while 310 were in the 18–25 age group. The older age group of 36–45 years old was represented by 248 respondents. Of the respondents, 69.2% or 678 were women, while 30.8% or 303 were men. Previous studies have confirmed that women are more likely to be involved in the process of buying a home and more likely to make the final decision about where they want to live. Women are also more interested in the details and emotional aspects of the buying process. Men, on the other hand, tend to focus more on the financial value–price ratio of a home and its functionality. There is also a growing trend of singles interested in buying a home, with women making up the majority of this group. Women are willing to bear the additional cost of buying a home with higher standards. As a result, real estate marketing strategies are now specifically targeting women, as they tend to have the final say in the purchase decision. These findings are consistent with research conducted by Ale et al. [36] and Infor [79].

Table 2. Research hypotheses based on the literature and existing knowledge.

Hypothesis	Description of the Hypothesis	Logical Reasoning and Justification of the Hypothesis
H1	Employment (financial security) mediates the positive effect of the variable "I/We rent an apartment or house" on "I/We want to buy an apartment or house."	It is very likely that someone who is financially secure will consider buying a home.
H2	Raising children mediates the positive effect of the variable "I/We rent an apartment or house" on "I/We prefer to rent".	Young adults raising children are more likely to buy their own home. A home of one's own can be seen as a refuge for the family and a unifying element for the family, providing the children with a space of their own where they can develop better. On the other hand, people who are already renting a home and raising their own children may prefer to maintain their status quo, as they do not want to expose themselves to additional financial burdens.
H3	The level of rent payments and other costs mediates the positive effect of the variable "I/We rent an apartment or house " on "I/We want to buy an apartment or house".	Typically, the amount of rent payments and other costs for economic reasons influences the willingness to buy an apartment or house.
H4	The amount of one's share of housing costs mediates the positive effect of the variable "I/We rent an apartment or house" on "I/We want to buy an apartment or house".	When a young renter's share of rent payments is high, they are less likely to rent and more likely to consider buying a home. This suggests that individuals who have higher expenses for rent payments are more likely to be aware of available housing options, such as using the same amount they pay for rent (or slightly more) for mortgage payments and owning a home.
H5	The length of time spent renting mediates the positive effect of the variable "I/We rent an apartment or house" on "I/We prefer to rent".	The length of the rental period has a negative effect on the willingness to buy a home. In other words, the longer someone has rented an apartment, the less inclined they are to buy a home of their own. This may be due to a reluctance to change, convenience, or habit (an aversion to change).
H6	The number of dependents mediates the positive effect of the variable " I/We rent an apartment or house" on "I/We prefer to buy an apartment or house".	Typically, the number of dependents influences young adults' willingness to buy a home because they want to provide more space for all of their dependents.
H7	Marital/relationship status mediates the positive effect of the variable " I/We rent an apartment or house" on "I/We prefer to rent".	A young adult who is in a marital or non-marital relationship is more likely to be willing to buy a house. Typically, a young, newly married couple wants to build their future, which requires a new home that provides some sort of refuge and security.
H8	The level of mortgage interest compared to rent payments mediates the positive effect of the variable "I/We rent an apartment or house " on "I/We want to buy an apartment or house" and mediates the negative effect on "I/We prefer to rent".	The higher a young adult's „tolerance level for mortgage interest compared to rent payments", the more inclined they are to buy an apartment or house.

3.5.1. Characteristics of the Study Sample: Education and Residential Area (Hometown Population)

The survey results show that a significant majority of respondents, nearly two-thirds (643), had either a university degree, including a master's or engineering degree, or a bachelor's degree. In addition, individuals with secondary education completed 95 questionnaires. There were also respondents with lower levels of education, such as elementary education (3), secondary education (6), lower secondary education (6), vocational education (4), and academic degrees (44). Most respondents resided in Mazowieckie Voivodeship, which accounted for almost two-thirds of completed questionnaires. The other Voivodeships were represented to varying degrees, ranging from one response in Opole Voivodeship to over 40 responses in Lesser Poland and Pomerania Voivodeships. The regional distribution of respondents' places of residence is shown in Figure 6.

More than 75.5% of respondents lived in large cities (with more than 100 thousand inhabitants), which means that their living conditions and views strongly influenced the results of the survey. Medium-sized cities were represented by 113 respondents, while rural areas and suburban regions accounted for 63 and 24 participants, respectively. Unfortunately, interest in participating in the survey was low among residents of small towns, with only 41 respondents. Better representation of this group of respondents would provide greater insight into their opinions, potentially highlight housing needs in such towns, and pave the way for practical measures to address any housing gaps. It should be noted that small towns are not among the beneficiaries of developers' activities due to their low economic potential. However, they are subject to significant market-related pressures and suffer from a continuous population outflow due to various factors primarily related to the market [80].

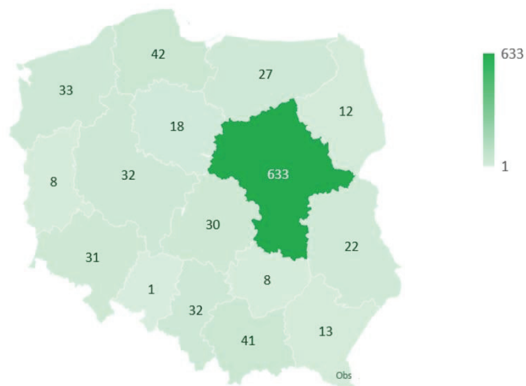

Figure 6. Regional distribution of the respondents' residence among the different voivodeships in Poland. (source: own elaboration with the use of GeoNames).

The survey questionnaire included a question on occupational activity aimed at determining the respondent's current occupational status. It was closely related to other questions concerning the source of income, housing situation, age of the respondent, etc. The question about the respondent's permanent residence seems to have some significance, as it is generally easier to find a job in larger cities (i.e., the answer can be considered a proxy for the respondent's financial situation).

In the survey, the occupational situation of the respondents was as follows: Approximately 83% of participants (819 individuals) reported being employed, while nearly 26% (254 individuals) reported being students. Raising children was reported as the current occupation of 122 respondents, and 53 individuals were actively seeking employment. In addition, 23 respondents indicated that they were attending school. The survey allowed respondents to select several options when answering the question about their occupation, which resulted in some individuals indicating a combination of studying and/or working and raising children, and so on. Therefore, the group of students and learners is reported separately. In addition, there were 156 participants who were students and had a job. Respondents could give multiple answers to the question about their sources of income. The results show that 63.8% of respondents (624 individuals) were employed and that an employment contract was their primary source of income. Task-specific contracts or mandate contracts proved to be the main source of income for 9.8% of respondents (96 people). In turn, self-employment was the main source of income for 102 respondents (10.4%). Table 3 provides an overview of the respondents' sources of income, divided into primary and secondary income.

In terms of changes in income across age groups, as people move to the next age group, their main source of income also changes. Understandably, most dependents were from the 18-to-25-year-old age group; they also had the highest number of "casual contracts" (i.e., task-specific or mandated contracts). Employment contracts were mainly the domain of the middle age group, while business activities were mainly carried out by people in the second and third age groups. Of the respondents, 399 individuals, or 40.6%, reported owning their own home, while 247 respondents (25.1%) reported living with their parents. The remaining participants, representing more than one-third of all respondents (34.3%), reported living in rental housing, of which 270 individuals (27.5%) rented from a non-relative.

Table 3. Summary of respondents' sources of income, categorized into primary and secondary income.

Source of Income	Primary Source	Additional Source	Not Applicable
dependent	17.1%	10.1%	72.8%
employment contract	63.8%	2.8%	33.4%
task-specific contract	2.1%	0.6%	97.2%
mandate contract	9.8%	14.7%	75.5%
allowances	1.8%	2.9%	95.3%
scholarship	1.2%	5.2%	93.6%
self-employment	10.4%	3.3%	86.3%
royalties	0.8%	5.5%	93.7%
various sources	1.7%	8.4%	89.9%

3.5.2. Characteristics of the Study Sample: Home Ownership Structure and Housing Quality

One of the questions aimed to determine the current housing status of the respondents. The purpose was to determine the extent to which respondents had already satisfied their need to "stand on their own two feet". Responses to this question correlated with other survey responses and reflect the potential of the housing market and the problems faced by those interested in homeownership, in addition to respondents' individual housing situations. Another question asked about the "number of people living under one roof". The results show that most respondents lived with a partner/husband/wife—34.6%, followed by married couples or domestic partnerships with a child/children—23.5%, and single people—13.9%. For more details, see Table 4.

Table 4. A structure showing with whom young adults share a house/apartment.

With Whom Do Young Adults Share Their Apartment or House?	Share of Reponses
living alone	13.9%
husband or wife (or a partner)	34.6%
parents	7.4%
parents and/or siblings	7.0%
friends/colleagues	7.3%
husband or wife and/or children	23.5%
husband or wife and/or children and parents	2.6%
various reasons	3.6%

Respondents also had the opportunity to provide their own answers. There were 35 responses classified as "other reasons", which mainly referred to single persons, i.e., widows/widowers, divorced persons, or persons living with their parents. Another question aimed to find out the number of occupants per room in the occupied housing units. Almost $\frac{3}{4}$ (72.8%) indicated that there was no more than 1 person per room in the place where they lived. More than $\frac{1}{4}$ of respondents said they had no more than 2 people per room, and only 15 people (1.5%) said there were between 2 and 3 people per room.

3.5.3. Housing Preferences of Young Adults Living with Their Families

When asked why they lived with their parents/siblings or friends, 74.4 percent of all respondents indicated that this question was not relevant to them. Of those respondents who did provide an answer, 252 provided various explanations, with the majority citing financial challenges as the primary reason. For example, 146 respondents indicated that financial constraints prevented them from renting or buying an apartment, with responses such as "I/We can not afford to rent", "I/We can not afford to buy an apartment or house", and "I/We are afraid of credit loans". Meanwhile, 67 respondents said that they chose this housing option for convenience. In addition, 15.5% of those living with their parents and 4% of all survey respondents gave "other reasons" as their answer. Since there were quite a lot of answers of this type in total, it was decided to take a closer look at them. It turned out that 38.5% of those who stated "other reasons" fell into the "financial difficulties" group. They explained that they had to live together in order to accumulate enough savings to buy a house, or they reported that they could not afford to live alone due to a low income. A number of people were assigned to the "convenience reasons" group (e.g., grandparents taking care of their grandchildren, but also children taking care of their parents), i.e., such a living situation proves convenient for both parties—parents and adult children. There was still a group of young adults who indicated that they lived with their parents while waiting for their own apartment, which they had already bought, and that they were saving for its completion and furnishing. Overall, the responses found under the label of "other reasons" were substantially revised in light of the objective of the entire survey, and eventually a number of responses were moved to the group of financial insecurity or lack of sufficient funds, while the group indicating commonly understood reasons of convenience and/or temporary necessities, advantages, and benefits was increased (the group of respondents who fell under the heading of "other reasons" was reduced). This adjustment resulted in 241 respondents being classified as "living with their parents" for a variety of reasons, namely, financial difficulties (ongoing financial insecurity/fear for future financial security)—161 persons; convenience (ease of living/feeling obligated to other family members)—74 persons; other reasons—6 persons.

3.5.4. Attractiveness of Renting an Apartment among Young Adults

The survey also examines how attractive renting an apartment or house was in the eyes of young adults. With current challenges in mind, the following research question was considered: at what stage does the desire for stability and home ownership outweigh the convenience and attractiveness of rental housing for young adults? The above question was answered based on respondents' answers to one of the survey questions, which was: If you live with your parents/siblings or friends, please indicate why? When analyzing each age group, the survey data showed a remarkable discrepancy between those who lived with their parents or others and those who did not (because they already had their own apartment or house). The results show that it was primarily young adults in the lowest age group, i.e., ages 18–25, commonly referred to as "student age", who lived with their parents or siblings. However, even in this age group, there were people who wanted to have their own apartment.

3.5.5. Is Renting More of a Lifestyle and an Underestimation of the Benefits of Ownership?

The question of whether the respondents would like to acquire their own apartment or house as a basis for their future was answered positively by 553 people (56.3 percent of the respondents). Of these people, 320 (32.6 percent) said they wanted to buy a house because they did not currently own one, while 180 people (18.3 percent) wanted to buy a larger house, and 53 people (5.4 percent) wanted a house in a different location. In addition, 221 respondents were not interested in purchasing a home, and 89 people had no opinion on the subject. Finally, 120 people gave "other reasons" and provided more detailed justifications. A large number of responses categorized under the "other reasons" label (12.2%) needed clarification to explain interest in housing preference. Responses were classified as follows: (1) 71 respondents indicated that they were not interested in purchasing a home because they either already owned a home, were awaiting commissioning, or were already in the process of completing a home they had already purchased; (2) 2 respondents indicated that they would inherit a home from their parents; (3) 10 respondents indicated that they intended to buy a house for investment purposes; (4) 22 respondents were "fresh in the process" of buying/building an apartment or house; (5) 2 respondents did not intend to buy a house, although they could not specify the exact reason, e.g., lack of money or other reasons; (6) 8 people planned to buy a home (1 indicated she did not qualify for a mortgage loan—a widow with 2 children; 7 planned to buy a smaller home to move away from their parents); and (7) 4 people responded that the question did not apply to them.

The above analysis shows that of the 120 survey respondents who gave an open-ended response, 105 respondents had to be assigned to the "I/We do not want to buy a home" group, which was justified in detail by these respondents (e.g., I/We inherit a home, already own one, or are finishing one, etc.). In turn, the responses of 8 people from another group were merged with the group: "I/We want to buy a home because I/We do not have one". The reasons for willingness to buy a house are shown in Table 5.

Table 5. Reviewed answers about the reasons for buying an apartment or house.

Would You Like to Buy a Home to Live in?	Responses	Share
I/we want to buy because I/we do not have my/our own home	328	33.30
I/we want to buy bigger apartment or house	180	18.30
I/we want to buy an apartment or house in a different location	53	5.40
I/we do not want to buy an apartment or house	326	33.20
I/we do not know	89	9.10
various reasons	7	0.70
Total	983	100

As shown in Table 5, about one-third of survey respondents, or 328 people, expressed interest in buying an apartment or house for their own use because they did not currently own one. This figure coincides with the number of people who rent an apartment or a room—327. From the survey, it can be concluded that the desire to buy a home was widespread among the participants of the survey. In addition, it is noteworthy that 22.7% of respondents wanted to buy a larger apartment or one located in a different place. Examination of the responses shows that renting an apartment was not a matter of preference for young adults, but rather a constraint. Moreover, young adults' decision to rent an apartment should not be taken as a disregard for the importance of homeownership. On the contrary, those who were forced to rent expressed a desire to own their own home.

3.5.6. Expected Shifts in Mortgage Financing among Younger Generations

Young adults' need or desire to own a home did not match their financial capabilities. When asked, "Why are you hesitant or unable to buy a home?", 290 people responded, "I/We do not have enough funds for my/our own share (mortgage prepayment)"; 117 people responded, "I/We cannot afford to repay the mortgage loan"; and 192 people provided the response, "I/We do not want to expose myself/ourself to financial hardship for the rest of my/our life". It is important to highlight that a large number of respondents (599 people, or 61%) considered the mortgage system unaffordable. The responses—"I/We cannot afford to repay the mortgage loan" and "I/We do not want to expose myself/ourself to financial hardship in my/our lifetime"—do not have the same meaning. In fact, the reasons given by the respondents are different from each other. However, it should be noted that each respondent had the opportunity to provide multiple answers, resulting in non-aggregated responses (the number of responses exceeded the number of respondents). Therefore, to facilitate further analysis, it was assumed that people who gave two or three reasons considered them to be equivalent. For example, responses such as "I/we cannot afford to repay the mortgage loan" and "I/we do not have the funds for my/our own share (mortgage payment)" were considered equivalent. When these responses were weighted by 1/2 and 1/3, respectively, and added together, the total number of respondents was 44 (out of 983 respondents), or 44.9% of all survey respondents. Financial difficulty (reported by 440 respondents) as a reason for inability to buy a home is shown separately in Table 6.

Table 6. Reasons behind financial difficulties in purchasing a home.

Reasons behind Financial Difficulties in Purchasing a Home	All	18–25 y.o.	26–35 y.o.	36–45 y.o.
I/we do not have the funds for my/our own contribution	226	113	90	23
Insufficient funds for the repayment of the mortgage	67	35	23	9
I/we do not want to be in financial hardship for the rest of my/our life	147	46	65	36
Sum total	440	194	178	68

It should be emphasized that among the reasons for people's inability to buy an apartment or house, insufficient funds for a down payment was cited as the main reason (51%) in all age groups. Another reason was "high credit risk", while the lowest number of respondents cited "insufficient funds for mortgage repayment". However, the importance of each reason varied from one age group to another. For the youngest group, insufficient funds to pay their own way was the most problematic aspect (58%), followed by unwillingness to take out a long-term mortgage loan (24%). The survey results show the importance of considering these factors when promoting homeownership, especially for younger people who face significant financial constraints. In contrast, the question of funds to repay the loan proved least problematic (18%). Fewer people in the "middle" age group were concerned about their own contribution (51%), while reluctance to take out a long-term loan increased (36%). Only 13 percent of participants indicated that they were likely to experience financial difficulties in repaying loans. The significant increase in pessimistic attitudes about repaying long-term loans suggests inherent economic and social changes that occur later in people's lives. In addition, 54% of respondents did not want to be exposed to financial difficulties throughout their life. Finally, it was found that one-third of the participants, or 33 percent, reported that they did not have sufficient resources to contribute themselves. Similarly, 13 percent of respondents from the same age group lacked the financial means to repay loans.

3.6. Objectives, the Model, and Formal Results

It is important to emphasize that the questionnaire used in this study went through a long process of development and modification prior to its elaboration. It is based on interviews with young adults, especially students and graduates of Polish universities. A pilot study followed, during which the scope of the questions and answers, their logical structure, and the most appropriate response formula were finally determined. For the purposes of the pilot study, the questionnaire was developed using a Google form. Finally, the survey was adapted to the requirements of the Survio platform, which was set up specifically for this purpose. The survey was distributed online and targeted a wide range of respondents who met the established age criteria. The final version of the questionnaire was distributed among college students in the largest cities in Poland, as well as among members of scientific circles and alumni, including the alumni network of one of the faculties of the Warsaw College of Technology. In addition, the survey was published on some social networks, private and public social media, as well as on the websites of real estate agencies in various cities in Poland. The survey was accessed through an attached link. The questionnaire was titled: Home Ownership or Rental Housing? Housing Preferences of Young Adults in Poland (a questionnaire for people aged 18–45). The study not only tried to find an answer to the question whether renting an apartment or a house is more of a lifestyle or an existential necessity for young people, but also to find out what prevents young adults from buying an apartment. Intuitively, several reasons for this can be found. However, the focus of the survey was to test general perceptions by analyzing the responses of respondents in the age groups described. Part of the survey was used to find out whether respondents who rent an apartment are aware that the rental costs they incur are actually equal to the mortgage interest they would pay if they decided to buy their own apartment of similar size (and finance it with a mortgage loan). In addition, the survey aimed to determine the extent of young people's interest in mortgages and their willingness and ability to buy an apartment or house. It is important to highlight that 1893 people participated in the survey, of which 983 answered all the questions in the questionnaire completely. Overall, the 52% response rate achieved can be considered a success in terms of the number of entries on the designed survey website.

In line with the above considerations on young adults' housing preferences, a theoretical mediation model was developed to test the original hypotheses. The theoretical mediation model, which relates to the hypotheses (presented in Table 2), in the form of a system of equations for estimation, takes into account two endogenous observed variables, namely the propensity to own an apartment or house (the variable referred to as dv1) and the preference for renting (the dv2 variable). Figure 7 shows a schematic diagram of the mediation (path) model that illustrates the interdependencies established in the initial hypotheses presented earlier.

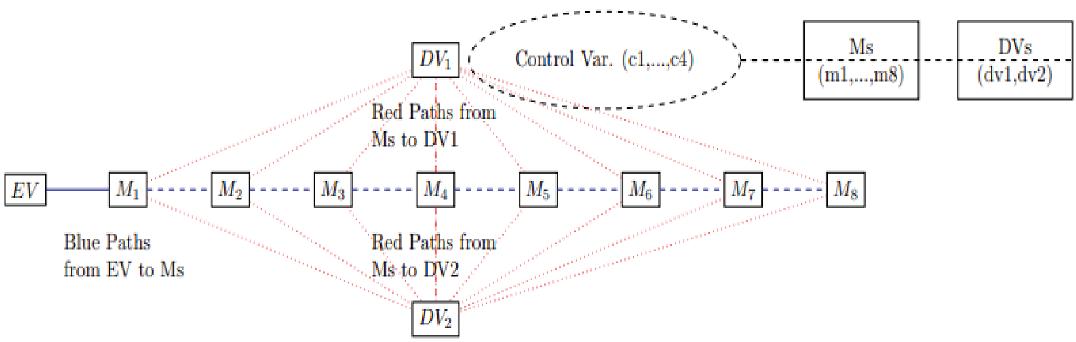

Figure 7. Mediation (path) model. A schematic diagram of the mediation structural equations model (SEM) which illustrates the hypotheses (source: own elaboration).

The upper right corner of the diagram explains the role of control variables and shows that paths in a mediation model can lead from all control variables to both the independent (EV1) and dependent variables (DV1, DV2), and even to the mediator variables (Ms). Confirmation of this can be found in the Results section, where all paths are shown (and the directions of the relationships, $\hat{\beta}$ coefficients, and p-values are given). It is important to emphasize that the inclusion of control variables in a mediation model is important because it helps to account for the effects of other variables that may affect the relationship between the independent variable, the mediator variable, and the dependent variable. This means that control variables can have direct effects on the outcome variable, independent of their influence on the mediator variable [81]. Control variables are variables that are not of primary interest in the analysis but are included to control for their potential confounding effects. In the mediation analysis conducted in this article, control variables included age, education, gender, and hometown population size, which means that they can be related to all variables of interest. Fundamentally, the role of control variables is to reduce the potential for spurious relationships among variables in the model [82]. Spurious relationships occur when two variables appear to be related, but their relationship is actually due to the influence of a third variable. By including control variables in the model, the effects of these potential confounding variables can be statistically removed. This ensures that the relationship between the independent variable, the mediator variable, and the dependent variable is not due to other extraneous factors [82].

The estimation of the structural equation models (SEM) themselves was carried out using the maximum likelihood method (ML), the least squares method (LS), or the asymptotic distribution method (ADF). The way such models are calibrated should depend largely on issues such as the nature of the data themselves (with particular reference to their distributions) and the sample size. For multidimensional normal distributions, it is advisable to use the ML method. On the other hand, if a distribution does not meet this condition, either the LS (for a sample with more than 2500 observations) or the ADF method (for a sample with more than 100 observations) are considered most appropriate, depending on the sample size [83]. Each estimated model should also be evaluated in terms of its goodness-of-fit (GoF) and the significance of the parameters obtained. In addition, there are some specific guidelines on the criteria for the evaluation of mediation models [84]. Moreover, there are quite a number of different benchmarks to evaluate the estimates and the degree of goodness-of-fit of the models. Their evaluation can be determined, for example, by comparing their estimates with two other extreme models, i.e., the baseline model and the saturated model. Such comparisons are performed using specific SEM software packages. In the present study, both STATA16 and AMOS software were used because they have built-in interfaces specifically designed for estimating mediation path models. In general, the main SEM fit measures are those that compare the estimated model with the baseline model, e.g., the Root Mean Squared Error of Approximation (RMSEA) and Comparative Fit Index (CFI), Tucker–Lewis Index (TFI), or Standardized Root Mean Squared Residual (SRMR) [see Table 7] [85,86].

Table 7. Assessment of the goodness-of-fit (*GoF*).

Goodness-of-Fit (GoF)	Source
$p > 0.05$	Awang [87]
RMSEA < 0.05 good fit	Hair et al. [88], Awang [87]
RMSEA < 0.08 acceptable fit	Awang [87]
Value greater than 0.80 suggests a good fit	Forza and Filippini [89]
CFI > 0.9 means satisfactory fit	Hair et al. [88], Awang [87]
TLI > 0.9 means satisfactory fit	Forza and Filippini [89], Awang [87]

For models with an RMSEA, fit measures of less than 0.08 are considered satisfactory [86,87]. The computation and interpretation of other goodness-of-fit measures, i.e., CFI and TLI, are explained in [90]. The model SEM can be evaluated using the *RMSEA* indicator [86]. Unlike most measures of fit, the *RMSEA* calculation does not compare the estimated model with the baseline model. It follows the formula: $RMSEA = \sqrt{\frac{T_h - df_h}{(N-1)df_h}}$ where T_h—chi-square statistic of the estimated model, df_h—number of degrees of freedom of the estimated model, and N— number of observations. In general, the lower the *RMSEA* value calculated based on the estimated model, the better its goodness-of-fit. The model is considered to be well fitted to the data if the *RMSEA* value is between 0.05 and 0.08 [91,92]. The values of RMSE, CFI, TLI, and SRMR also indicate a good fit of the two models to the data.

4. Results

First, several important criteria for fitting the model were reviewed to further test the proposed hypotheses. These criteria take the form of global and local tests [64,93]. The strength of the local test alone is not important if the global tests are not met. Local tests assess the significance of individual paths in the model, while global tests assess the overall fit of the model [94]. The latter are the starting point for validating the obtained results and evaluating the overall fit of the model. A model that is well fitted provides more credible results. If it passes these global tests, the *p*-values for the hypothesized relationships are considered. On the other hand, if the *p*-values support the relationships under investigation, but the model itself has a poor fit, these results cannot be taken seriously [93]. Figure 8 shows the global and local test criteria that must be met to assess the reliability of the results.

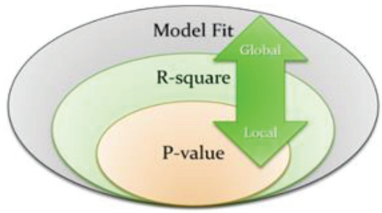

Figure 8. Evaluation criteria for hypothesis testing.

The next step was to evaluate the r-squared values (i.e., the percentage of variance explained). These values must not be too low, because then the results are considered unreliable, since the variability of the explanatory variable does not explain an acceptable and satisfactory percentage of the variability of the endogenous variable [95,96]. In the case of the model developed for the purpose of this study, the r-squared value is 0.27, indicating moderately sufficient explanatory power [97,98]. It should be emphasized that the r-squared values in the mediation model (path model) are not generally accepted as a measure of effect size, and thus there is no specific threshold for what constitutes a low value [95]. Therefore, the accepted r-squared values for a mediation model depend on the context and the specific research question [98].

The last important point for evaluating the results and testing the proposed research hypotheses is the direction of the regression, indicated by the standardized and unstandardized estimates of the coefficients and, in particular, by their sign. For example, assuming that the number of dependents affects the propensity to purchase a home, and the actual results show that it has a negative effect (reducing the propensity to purchase a home), provides some sort of counterevidence. The detailed results are presented in Tables 8 and 9.

Table 9, in turn, shows the relationships between the different variables specifically with respect to the hypotheses tested. It proves that hypotheses H3, H5, and H8 were positively verified. In the other cases, namely H1, H2, H4, H6, and H7, the hypotheses were disproved, with some contrary evidence found in two cases (H2 and H7).

First, it was found that there is a relationship between the variables EV and DV. Baron and Kenny [72] argue that in order to test a mediation model, there should be a significant relationship between EV and DV. The development of a mediation model describing the relationship between variables X and Y, which requires the inclusion of some type of intermediate variable, assumes that the relationship between EV and DV is statistically significant. This is indeed the case for the EV and both DVs used in the model under study.

Among other things, the study shows that gender has a statistically significant relationship with rental preferences. That is, women show less interest in renting an apartment or a house and are more likely to own a home (although the latter relationship is not statistically significant). The same is true for the "age group" variable. The higher the age group, the lower the propensity to buy a house. This may be due to habit or convenience. In other words, those who have rented for long enough have become accustomed to it and do not want to change their preferences. This is supported by the evidence for hypothesis H5. Similarly, the size of the resident population in the hometown leads to a higher willingness to buy a house. This can be implicitly deduced from the study of Wessel and Lunke [99]. Overall, the results show that some individuals who already live for rent consider buying an apartment or house, while others stick to the renting option, i.e., want to maintain the status quo. The beta coefficients for direct correlations are positive in both cases. This is precisely the reason that justifies that, in order to better understand the phenomenon under study, some kind of mediation model was needed to better explain these relationships by considering mediating variables. Table 10 again shows the goodness-of-fit of the obtained mediation (path) model.

Table 8. Estimated parameters of the mediation (path) model.

Variable	Direction	Variable	$\hat{\beta}$	$\hat{s.e.}$	C.R.	*p*-Value
ev1	—>	m7	−0.089	0.030	−2.98	0.003
ev1	—>	m6	−0.477	0.061	−7.78	***
ev1	—>	m3	2.756	0.051	53.74	***
ev1	—>	m4	0.597	0.108	5.51	***
ev1	—>	m5	2.708	0.052	51.72	***
ev1	—>	m2	−0.107	0.021	−5.05	***
ev1	—>	m1	0.017	0.025	0.678	0.498
ev1	—>	m8	2.108	0.283	7.43	***
m1	—>	dv1	0.006	0.040	0.153	0.878
m1	—>	dv2	−0.110	0.032	−3.45	***
m2	—>	dv1	0.077	0.047	1.62	0.104
m2	—>	dv2	−0.050	0.037	−1.32	0.184
m7	—>	dv1	−0.038	0.031	−1.24	0.212
m7	—>	dv2	−0.085	0.024	−3.49	***
m6	—>	dv1	−0.030	0.017	−1.76	0.077
m6	—>	dv2	−0.003	0.013	−0.25	0.798
m3	—>	dv1	0.047	0.018	2.66	0.008
m4	—>	dv1	−0.006	0.009	−0.72	0.471
m4	—>	dv2	−0.011	0.007	−1.63	0.103
m5	—>	dv2	0.083	0.014	6.11	***
m5	—>	dv1	−0.009	0.017	−0.529	0.597
m3	—>	dv2	0.022	0.014	1.57	0.116
c1	—>	dv2	−0.008	0.019	−0.43	0.667
c2	—>	dv2	−0.051	0.023	−2.21	0.027
c3	—>	dv2	−0.005	0.010	−0.45	0.651
c4	—>	dv2	−0.003	0.010	−0.27	0.788
c4	—>	dv1	0.025	0.012	1.99	0.047
c3	—>	dv1	−0.008	0.013	−0.58	0.561
c2	—>	dv1	0.033	0.029	1.14	0.253
c1	—>	dv1	−0.076	0.023	−3.23	0.001
ev1	—>	dv1	0.072	0.068	1.06	0.049
ev1	—>	dv2	0.095	0.054	1.77	0.037
m8	—>	dv2	−0.037	0.008	−4.50	***
m8	—>	dv1	0.128	0.010	12.42	***

Note: *** means that the *p*-value is smaller than 0.001.

Table 9. Verification of the hypotheses tested in the study.

Relationship	Indirect Effect				Hypothesis
	Estimate	Lower	Upper		*p*-Value
Renting (ev1) -> Employed (m1) -> Ownership Preference (dv1)	0.000	−0.002	0.004	0.649	H1: failed
Renting (ev1) -> Employed (m1) -> Renting Preference (dv2)	−0.002	−0.008	0.004	0.480	
Renting (ev1) -> Children (m2) -> Ownership Preference (dv1)	−0.008	−0.019	0.001	0.075	H2: failed
Renting (ev1) -> Children (m2) -> Renting Preference (dv2)	0.005	0.000	0.012	0.045	H2: counter-evidence
Renting (ev1) -> Rental Paym. (m3) -> Ownership Preference (dv1)	0.129	0.037	0.233	0.007	H3: confirmed
Renting -(ev1) -> Rental Paym. (m3) -> Renting Preference (dv2)	0.060	−0.031	0.154	0.195	
Renting-(ev1) -> One's share in hous.paym(m4) -> Ownership preference (dv1)	−0.004	−0.016	0.005	0.416	H4: failed
Renting (ev1) -> One's share in hous.paym.(m4) -> Renting Preference(dv2)	−0.007	−0.016	0.001	0.096	
Renting (ev1) -> Length of renting (m5) -> Ownership Preference (dv1)	−0.025	−0.111	0.068	0.621	
Renting (ev1) -> Length of renting (m5) -> Renting Preference (dv2)	0.225	0.121	0.322	0.003	H5: confirmed
Renting (ev1) -> Dependents (m6) -> Ownership Preference (dv1)	0.014	−0.003	0.031	0.100	H6: failed
Renting (ev1) -> Dependents (m6) -> Renting Preference (dv2)	0.002	−0.011	0.013	0.812	
Renting (ev1) -> Family/Relationship (m7) -> Ownership Preference (dv1)	0.003	−0.002	0.011	0.177	H7: failed
Renting (ev1) -> Family/Relationship (m7) -> Renting Preference (dv2)	0.008	0.002	0.017	0.006	H7: counter-evidence
Renting (ev1) -> Mortgage comp. to rent (m8) -> Ownership Preference (dv1)	0.270	0.194	0.365	0.002	H8: confirmed
Renting (ev1) -> Mortgage comp. to rent (m8) -> Renting Preference (dv2)	−0.077	−0.121	−0.044	0.001	H8: confirmed

Source: own elaboration.

Table 10. A variety of fit indices and goodness-of-fit measures to assess the overall fit of the model.

Fit Statistic	Value	Description
Discrepancy		
chi2_ms(0)	211.054	model vs. saturated
p > chi2	0.000	
chi2_bs(41)	4040.622	baseline vs. saturated
p > chi2	0.000	
NPAR	94	
CMIN/DF	4.744	
Population error		
RMSEA	0.06	Root mean squared error of approximation
90% CI, lower bound	0.052	
upper bound	0.069	
pclose	0.000	Probability RMSEA $\leq$ 0.05
Baseline comparison		
NFI	0.961	
RFI	0.901	
IFI	0.969	
CFI	0.969	Comparative fit index
TLI	0.920	Tucker–Lewis index
Size of residuals		
SRMR	0.0421	Standardized root mean squared residual
CD	0.993	Coefficient of determination

5. Discussion

Rapidly deteriorating housing conditions for young adults around the world pose a serious policy challenge. This paper draws on a survey of young Polish renters aged 18 to 45 to examine their preferences for homeownership over renting. The study investigates how young Polish renters perceive renting an apartment and, in this context, formulates eight research hypotheses, of which only three could be confirmed: H3, H5, and H8. In two cases (H2 and H7), counter-evidence to the hypotheses was provided. Therefore, the following conclusions can be drawn. Length of tenancy is an important mediating variable affecting young adults' housing preferences. The longer a person rents an apartment, the less willing they are to change their status quo. The results of the mediation analysis are consistent with findings from Zillow's [100] report on consumer housing trends that the longer someone rents, the less desire there is for homeownership. More than half of renters who do not want to move have lived in rental housing for five or more years, the report found. Similar results were found in California, as reported by the California Department of Real Estate [101]. Therefore, it is critical for housing policy to promote homeownership awareness and encourage young people to consider homeownership at a young age. In addition, individuals who pay a higher rent are more inclined to shift their preference to homeownership. They have a better understanding of existing housing alternatives that could offer them the opportunity to pay off their mortgage at rent-like rates. The study also showed that relationship status is not a significant mediating variable (as it could not be confirmed that the variable m7 mediates the positive effect of ev1 on dv1). However, counter-evidence was found. A relationship with a partner encourages young adults already renting to maintain their status quo (and stay with the rental option). One might have expected the marital or relationship status of young adults to be a factor encouraging them to strengthen their family ties, which, according to the conventional view, requires owning a home. Moreover, previous research has shown that children who grow up in households with home ownership tend to perform better at school [17]. In addition, there is scientific evidence that homeownership is associated with better health outcomes than renting [102] and that homeowners are more likely to be satisfied with their homes, have higher self-esteem, and suffer less from economic strain, depression, and problematic alcohol use than renters [15]. Homeownership also allows families to build assets and serves as a measure of financial security [48]. However, for the cohort of Polish renters studied, the results do not support the hypothesis that individuals who live with their partner in any form (whether marital or nonmarital) also have an increased need for homeownership. Understanding this requires a deeper analysis of the nature of modern relationships and a clear understanding of the erosion of the traditional family model as it has been understood in the past. Along these lines, Simpson and Overall [103] have found that families have recently become less integrated on a global scale than in the past. This is evident from statistical data on marriage breakdown, cohabitation dissolution, and the rising number of one-person households. The authors argue that the growing insecurity associated with modern relationships can lead to a paradoxical sense of insecurity and instability among those living in such relationships. For example, individuals who declare that they are in a marriage or cohabiting relationship may not wish to risk the additional financial burdens that would result from the dissolution of such a relationship (because they are uncertain whether the relationship can be sustained in the long term). The termination of such a relationship would undoubtedly significantly complicate the borrowers' legal situation and deprive them of their freedom and flexibility in life. In many cases, this would mean that people who have separated would have to continue to make joint loan repayments or live (with their ex-partner) in a shared apartment or house after their separation. In other words, young adults may be aware that the duration of loan repayments does not necessarily correspond to the duration of the relationship (whether marriage or cohabitation). A young couple unsure about the dissolution of their relationship may not want to buy shared housing units [104]. Instead, they might opt for a living-apart-together relationship (LAT), which involves fewer public expressions of commitment such as a shared apartment or house [105]. Renting is also an option, as it carries less risk of partnership dissolution than home ownership [106].

The variables "raising children" and "dependents" also do not prove to be statistically significant mediators of tenants' willingness to change their preferences towards home ownership. In the case of the variable "raising children", the opposite is the case. Young adults raising children may be afraid of the additional financial burdens that might be associated with buying a house. Raising children is already a major financial challenge by nature, so the reluctance to face additional financial risk factors should not surprise anyone. After all, buying a house and then paying off the mortgage puts borrowers at risk. To tackle this problem, the government should launch appropriate housing programs specifically targeting these people, because family policy and the fight against negative demographic trends are part of every government's policy. According to Sobieraj and Metelski [39], programs to support young people in Poland were implemented earlier and should be adapted to the changed circumstances. Scientific research suggests that young adults raising children are fearful of the additional financial burdens associated with buying a home [107,108]. Low-income families in particular may be further burdened by expenses such as food, housing, and petrol [108].

Last but not least, the present study proves a positive mediation effect of the variable "mortgage interest compared to rentals" on the association between "I/We rent an apartment or house" and "I/We want to buy an apartment or house", and a negative mediation effect of the same mediation variable on the association between "I/We rent an apartment or house" and "renting preference". The above mediation effect implies that an appropriate housing policy should include an information campaign that—firstly—makes young people aware that an alternative to renting is to finance one's own apartment or house with a mortgage and that the amount of the mortgage payment itself need not necessarily be significantly higher than the amount of the payments associated with renting. Considering the evidence for hypothesis H8, it appears that mortgage loan plans could be structured more appropriately; for example, spread over a longer time horizon.

6. Conclusions

This article offers insights into the housing preferences of young renters in Poland. The study is based on a survey targeting young people aged 18–45 and on the mediation model, which is particularly well suited to explaining the relationship between a variety of different variables. Inferences are drawn about whether young renters in Poland prefer buying an apartment or house to renting and what determines their decisions in this regard. The study is quantitative in nature and is based on a survey and mediation model, which is particularly well suited to explaining the relationship between many different variables. Of the eight hypotheses tested in the study, only three could be proven, namely that the amount of rent payments and other costs for economic reasons influences the willingness to buy an apartment or a house, and also that the length of the rental period has a negative influence on the willingness to buy a house. Finally, the mediation model provides evidence that the higher their tolerance threshold for mortgage interest relative to "rent payments", the more willing young renters are to buy an apartment or house.

First, in contrast to previous research, the survey results show that the prevailing belief that young people prefer renting to owning a home is wrong. The survey found that the vast majority of young renters actually aspire to become homeowners and plan to achieve that goal through the financial resources they accumulate over the course of their careers and the availability of mortgages. The survey data show a trend in which the number of respondents who rent decreases with each age group, while the number of homeowners increases. This means that younger people, especially in the first age group of 18 to 25, tend to rent rather than own a home. For the majority of respondents, over 90 percent, homeownership is important because it provides a sense of security and stability and creates good living conditions. This new research contrasts with previous studies that suggested young people prefer to rent rather than own a home. The authors of this study argue that this misconception may have been fueled by the high number of young people who currently rent as opposed to those who aspire to homeownership in the future. In summary, the survey shows that homeownership is highly valued by young people because it gives them a sense of security and stability and is an important goal they want to achieve over time. Second, the path to homeownership is not straightforward, and the difficulties in pursuing this goal are mainly due to two reasons: (1) insufficient funds to raise the minimum amount of equity required to purchase an apartment or house; and (2) the lack of creditworthiness for many individuals seeking to obtain a loan from a bank. This can be due to the respondent's own estimation of their creditworthiness, or the bank's evaluation of their financial situation. This suggests that the housing finance subsystem has some shortcomings as far as financing young people is concerned. Strategically, there are two complementary solutions that could be implemented: (1) a long-term home savings plan or home savings program [this type of plan would help young people save for their first home by offering incentives and special savings accounts] and (2) innovative home loans tailored to the financial situation of young people that would take into account the specific financial situations of young people. The first solution would require cooperation between banks and the Polish government, while the second solution could be developed independently by banks, as long as they adhere to the housing loan evaluation criteria set and monitored by the Polish Financial Supervision Authority. There are already successful models, such as the extensive offer of housing loans for U.S. citizens. It is possible that banks in Poland will offer similar loan products. One of the key findings of the study is that there is a gap in home financing for young adults [71]. Fourth, the accumulation of savings in the form of building savings contracts (especially with a term of several years, but also contractual) stabilizes the banking system, and the accumulated savings can be used as personal contributions for the purchase of housing (i.e., home ownership), increasing the opportunities for young renters to purchase an apartment or house for their needs. Implementing such a system is preferable to seeking complex solutions using mortgage bonds to finance the purchase of housing.

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Investigating the Synergistic Evolution Mechanism of Multi-Scale Cities: A Case Study of Three Urban Agglomerations in Eastern China

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Abstract: Urban growth has evolved from cities to metropolitan areas and urban agglomerations, exhibiting a multi-scale pattern. Urban scaling law can reflect the nonlinear relationship between urban indicators and population size, which is very important for urban planning through analyzing the evolution of urban system characteristics. However, existing studies mainly focused on scalar law within countries, neglecting the multi-scale synergistic evolution of complex urban systems. The purpose of this study is to investigate the scalar relationship between urban indicators and population size at multiple scales from the perspective of individual cities, metropolitan areas, and urban agglomerations, using data from 45 cities in three urban agglomerations in eastern China. Based on the urban scaling law, local spatial autocorrelation model is used to analyze and explore the collaborative evolution of multiple scales. Results show that from the perspective of time evolution, the three urban agglomerations exhibit greater scaling effects than metropolitan areas, with a scaling exponent (β) greater than 1 for urban indicators including economy, land, infrastructure, ecological pressure, and innovation. From the perspective of spatial differences, the spatial development gap between the metropolitan area scale and the urban agglomeration scale is relatively small compared with the city scale. In addition, the Beijing–Tianjin–Hebei urban agglomeration (BTH) mainly displays the synergistic development of the dual-core structure of Beijing and Tianjin. The Yangtze River Delta (YRD) exhibits significant disparities between its cities, resulting in a low degree of overall synergy. In contrast, the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) leads in terms of synergistic evolution. This study is crucial to help understand the development of urban systems at different scales and to support regional planning and the achievement of coordinated development.

Keywords: scaling law; multi-scale; co-evolution; metropolitan area; urban agglomeration

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1. Introduction

Since the 20th century, rapid urbanization and globalization have given rise to mega-cities and megacities worldwide, with metropolitan areas, urban agglomerations, and contiguous areas of large cities emerging in various locations. These developments have brought about significant changes to the urban landscape, resulting in the formation of a complex multi-level spatial structure [1–4]. Over the past 40 years of reform and opening up, China's city scale has continued to increase, and urbanization rates have risen, with three of China's representative urban agglomerations forming in the eastern region, the Beijing-Tianjin-Hebei urban agglomeration (BTH), the Yangtze River Delta (YRD), and the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) [5]. Understanding how different scales of cities can synergistically evolve in time, space, and organization during rapid urbanization is crucial for regional sustainable development.

Cities are complex systems with characteristics such as self-organization and nonlinearity [6,7]. Metropolitan areas and urban agglomerations established by numerous cities aggregate a significant quantity of resources in a restricted space, such as population, capital, technology, and innovation, and have a high economic volume and radiation capacity, as well as the same qualities as complex systems [8–10]. The first stage of the urban development system is characterized by substantial agglomeration in the center city, a high degree of industrial and population agglomeration in the first city, and a siphon effect throughout the region [11]. During the second stage, the regional center gradually spreads and becomes polycentric, leading to the development of urban systems in subsidiary cities within the region, eventually establishing metropolitan areas within a commuting circle of one hour [12]. In the third stage, the region's first metropolitan area will continue to grow, while the second metropolitan area's population growth rate will outstrip it, increasing the population of the region's small and medium-sized cities which are smaller in population and area compared to major cities. Relying on a well-developed infrastructure network, an urban agglomeration with one megacity as the core and at least three metropolitan areas or large cities as the basic units is gradually formed, which is characterized by a relatively compact space and a highly integrated economy. In summary, cities transition from urban areas to metropolitan areas and urban agglomerations through the tangible material exchange, connected transportation infrastructure networks, and intangible flow spaces intertwined between cities [13,14]. The evolution of urban space reflects the multidimensional, multilevel, and multifactorial structure of the urban system [15]. Analyzing the evolution process of urban systems to summarize the laws and patterns of urban development is the foundation for achieving sustainable cities.

At present, the research content and methods of the evolution process of cities, metropolitan areas, and urban agglomerations are constantly enriched. From a research perspective, studies on cities tend to focus more on changes in spatial relationships among elements and the evolution of geographical space. In contrast, research on metropolitan areas and urban agglomerations tends to be more concerned with centralization, networking, and the structure of different layers within the regions [16–21]. Wang et al. calculated the centrality indices of six major urban agglomerations in China based on population and economic use of the ordinal scale rule [22]. In terms of indicators and research methods, indicators have diversified from population and economic indicators to land, innovative technology, and ecological environment indicators, and network analysis methods, GIS-based spatial analysis, remote sensing, and landscape indices are useful for studying the evolution of urban agglomerations [23–27]. Although there have been many studies on spatial evolution, there is still a lack of research on the synergetic evolution of cities at multiple scales.

In recent years, the theory of urban scaling laws has provided new insights into the evolution of urban systems, based on common approaches to the evolution of urban systems [28,29]. Scaling laws can help reflect the characteristics of urban functions and the development status of urban systems [30–33], which is used to assess the balance of development of urban indicators and urban sustainability [34–36]. The basic formula of urban scaling law is $Y = Y_0 N^{\beta}$, where Y is an urban index, N is population size, and β is scaling exponent. The scaling exponent represents the nonlinear relationship between urban index and urban population size [37,38]. Scholars have conducted extensive research on urban scaling laws, which have been supported by a wealth of empirical evidence covering various urban indicators in many countries, including GDP, land use efficiency, urban crime, environmental pollution, social interactions, and urban form (Table 1). Most scaling law studies have focused on short-term data and city scales, and have lacked exploration of the multi-scale coordinated evolution of complex urban systems, which hinders the investigation of the dynamic changes in complex urban systems [39,40].

Table 1. Studies related to urban scalar laws.

Authors	Country	Sample Size	Urban Features
Bettencourt, L.M.A., et al. [29]	US, European Union, China	MSAs, LUZs, UAUs	New patents, inventors, private R&D employment, total wages, total electrical consumption, total housing, GDP, total employment, gasoline stations, and road surface
Arcaute, E., et al. [41]	UK	8850 wards of England and Wales	Patents
Fragkias, M., et al. [42]	US	942 urban 'core based statistical areas'	CO_2 emissions
Schläpfer, M., et al. [43]	Portugal, UK	nationwide communication records	social connectivity
Bettencourt, L.M.A. and Lobo, J. [44]	Europe	102 cities	GDP, urbanized area, employment, patents
Jiao, L., et al. [45]	China	289 prefecture-level cities	Urban land use efficiency
Prieto-Curiel, R., et al. [46]	Africa	Nearly 6000 urban agglomerations	Urban form
Cottineau, C., et al. [47]	France	Urban units and Metropolitan areas	Land use, commuting flows, commuting flows, jobs by sector, infrastructures, hospitals, and length of roads
Keuschnigg, M., et al. [48]	Sweden	Sweden's 75 labor market areas	Wage income
Arvidsson, M., et al. [49]	Europe and the US	cities in Sweden, Russia, and the United States	interconnectivity, productivity, and innovation

Thus, this study establishes a multi-scale perspective based on the urban scaling law, and explores the co-evolution of urban systems in the BTH, YRD, and GBA. The main objectives include: (1) To verify multi-scale urban scaling law, and to reveal the temporal changes and spatial differences of the scaling exponents of urban indicators at different scales; (2) to comparatively analyze the evolution process of multi-scale urban scaling law; (3) to analyze the process of regional co-evolution through spatial autocorrelation analysis of scaling exponents for urban indicators in three urban agglomerations. The BTH, YRD, and GBA are of great strategic significance to national economic development. This study innovatively deepens the dynamic analysis of urban system evolution from a multi-scale perspective based on the urban scaling law, and examines the balance and efficiency of the development of these three important urban agglomerations, which serves as a theoretical basis for proposing development suggestions.

2. Materials and Methods

2.1. Study Area and Data

BTH, TRD, and GBA are the most economically developed regions in China, known for their high-density and high-urbanization areas with well-established urban systems, including 10 metropolitan areas and 45 cities (Figure 1). Due to the differences in the definition of the concept and spatial scope of metropolitan areas and urban agglomerations in relevant studies at home and abroad, this study relies upon China Metropolitan Area Development Report 2018, Yangtze River Delta Urban Agglomeration Development Plan and Outline of the Guangdong-Hong Kong-Macao Greater Bay Area Development Plan.

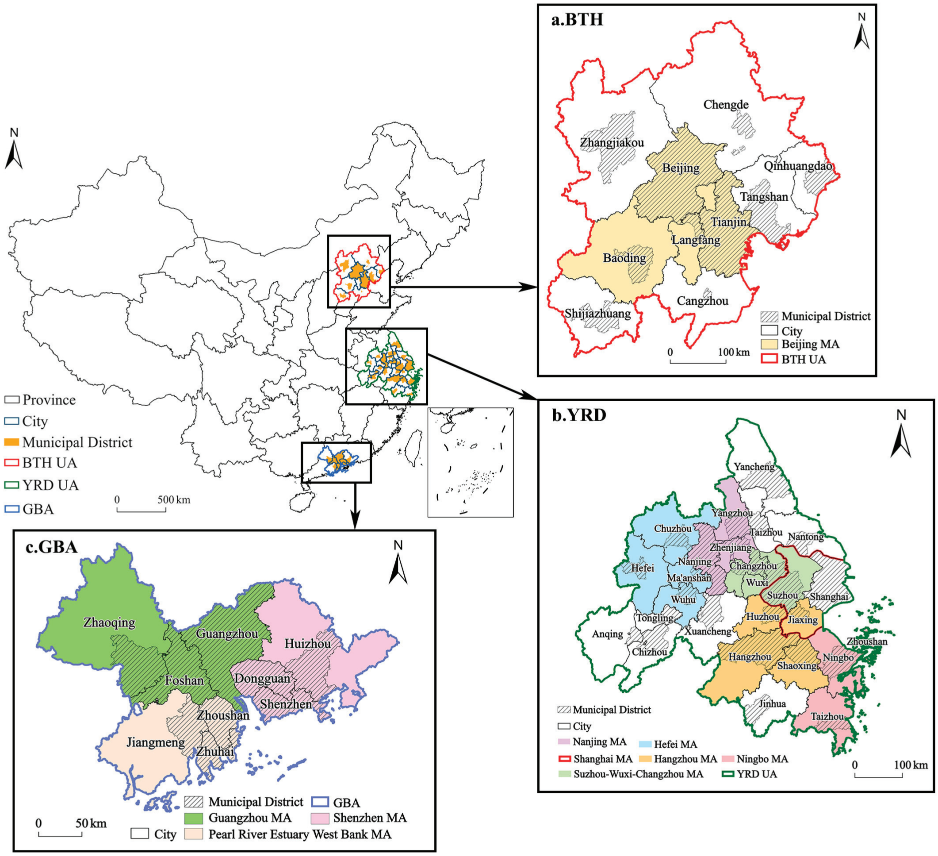

Figure 1. Study Area.

Due to the high urbanization rate in municipal districts, they are more representative of the "urbanized areas". Therefore, the statistical scope of urban indicators is defined as municipal districts. This study collects data on population and urban indicators for urban areas above prefecture level contained in the three major urban agglomerations from China Urban Construction Statistical Yearbook (1999–2018) and China Urban Statistical Yearbook (2000–2019). Considering that urban indicators need to represent the urban development dimension, we selected 12 urban indicators, including economic development (GDP), land use (built-up area, green coverage area of built-up area, area of green space), infrastructure (length of urban roads, area of urban roads, length of water supply pipelines, total collections of public libraries, number of beds in hospitals and health centers), environmental pressure (annual quantity of wastewater discharged, house garbage collected and transported), technological innovation (number of invention patent applications). We chose these specific indicators because they are widely used in urban studies and provide a comprehensive understanding of different aspects of urban development. For instance, the GDP is an important economic indicator that reflects the overall economic performance of a city or region. The built-up area, green coverage area of built-up area, and area of green space provide insights into the land use pattern and the extent of urbanization. The length of urban roads, area of urban roads, and length of water supply pipelines are indicators of infrastructure development. The total collections of public libraries and number of beds in hospitals and health centers can reflect the level of development of public infrastructure and social welfare. The annual quantity of wastewater discharged, house garbage collected, and transported are important indicators of the environmental pressure caused by urban development. As cities grow and populations increase, there is often a corresponding increase in the production of waste and wastewater, which can have negative environmental impacts if not properly managed. Therefore, monitoring the amount of wastewater and waste produced by a city is crucial in assessing its environmental sustainability. Technological innovation is a key driver of economic growth and social progress, and cities with higher levels of technological innovation tend to be more competitive and attractive to businesses and skilled workers. Therefore, measuring the number of invention patent applications is a useful indicator for evaluating a city's innovative capacity and potential for future growth. China's regional statistics are based on administrative divisions, and GDP is deflated using GDP data from China Urban Statistical Yearbook for municipal districts, with 2000 as the base year. We removed data that had changed abruptly due to administrative division changes and corrected data using local statistics yearbooks, resulting in a sample of 45 cities in three major metropolitan agglomerations. Due to missing data, Hong Kong and Macau are excluded from the scope of this study.

2.2. Urban Scaling Law

Bettencourt et al. introduced Kleber's law into urban research and proposed the urban scaling law, which represents the nonlinear relationship between urban indicators and urban population [38]. Urban scaling law has been widely used in geography and sociology. For example, some scholars have compared the differences in regional development and provided development suggestions by analyzing the geographical spatial differentiation characteristics of scaling exponents for urban indicators [45]. In sociology, some scholars have found that human networks and productivity exhibit a heavy-tailed distributions in the urban scaling law, revealing the inequalities that urban residents benefit from during the process of urban expansion [49]. The formula is as follows:

$$Y_i(t) = Y_0 N_i(t)^{\beta} \tag{1}$$

where $Y(t)$ represents the measurement of various indicators (GDP, built-up area, etc.) within the city; i represents different cities within the whole urban system; $N(t)$ is the urban population size at time t; Y_0 is the normalized constant; β is the scaling exponent.

We take logarithms on both sides of Equation (1) and get:

$$logY_i(t) = logY_0 + \beta logN_i(t) \tag{2}$$

Urban indicators can be classified into three categories according to the scaling exponent β: (1) sublinear indicators ($\beta \approx 0.85 < 1$) show a sublinear relationship with urban population size, mainly including urban indicators related to infrastructure construction (length of roads, etc.), where the rate of increase of indicators is smaller than the rate of increase of the population; (2) linear indicators ($\beta \approx 1$) show a linear relationship with the urban population, mainly including indicators related to individual demand (number of houses, household water consumption, etc.); (3) super linear indicators ($\beta \approx 1.15 > 1$) show a superliner relationship with the urban population, mainly including urban indicators related to economy and social interaction (GDP, knowledge output, etc.), reflecting the increasing return to scale effect of urban indicators [29].

2.3. Research Method of Multi-Scale Co-Evolution

Spatial autocorrelation models include global spatial autocorrelation and local spatial autocorrelation, which measure and test patterns of spatial association. Global spatial autocorrelation explores the average degree of association of an attribute value across the study area, while local spatial autocorrelation reflects the degree of association and distribution pattern of an attribute value in one regional unit with the same attribute value in neighboring regional units. From city to metropolitan area and then to urban agglomeration, evolution is a complex process, which is influenced by many factors such as economy, politics, and technology. Urban scaling law provides a simplified method to understand multi-scale co-evolution by analyzing the impact of city size on urban indicators at city, metropolitan, and urban agglomeration scales. Based on the urban scaling law, this study discusses the co-evolution of city-metropolitan circle-urban agglomeration and pays attention to the correlation between the development level of urban indicators and the development level of urban indicators in neighboring cities. Therefore, the local Moran's I index is used for analysis. The formula is as follows:

$$Local\ Moran's\ I_{ij} = \frac{n(\beta_{ik} - \overline{\beta_k})\sum_{j=1}^{n}\omega_{ij}(\beta_{jk} - \overline{\beta_k})}{\sum_{j=1}^{n}(\beta_{jk} - \overline{\beta_k})^2} \tag{3}$$

where β_{ik} represents the scaling exponent of urban indicator k for city i, n represents the number of cities, ω_{ij} is the spatial weight, and the spatial weight matrix is created by K-nearest neighbors. Through the Moran scatter plot to achieve a more intuitive LISA plot on the map, spatial association mode of local autocorrelation can be divided into four types, HH(LL) indicates that the high-value (low-value) unit is also clustered around the high-value (low-value) unit; HL indicates that the high-value unit is surrounded by low-value cells; LH indicates that the low-value cell is clustered around the high-value unit.

3. Results

3.1. Multi-Scale Urban Scaling Law

3.1.1. City Scale

Figure 2 showed that the relationship between urban GDP and population from 2000 to 2018 was super-linear ($\beta > 1$), which was in line with the theoretical expectation. From 2000 to 2009, β value of GDP increased from 1.07 to 1.14, indicating the effect of urban economic agglomeration increased. After 2009, β value of GDP began to decline to decrease until 1.05 in 2018, with the stable play of the economic agglomeration effect. City economic development did not rely on innovation-driven. From 2000 to 2014, the number of patent applications for inventions showed a super-linear relationship with population, but the number of patent applications for inventions showed a nearly linear relationship with the population since 2015, indicating a weakening of the urban talent agglomeration effect and a stable rate of technological innovation in cities.

The scale economy of land use has been more significant because built-up area has been always sub-linearly related to the population ($\beta < 1$). β value of the built-up area increased from 0.88 to 0.90 from 2000 to 2009, and the comparative advantages of land use economies of scale in large cities gradually weakened. Since then, β value of the built-up area decreased, falling to the lowest value of 0.82 in 2018, indicating a strengthening trend of land use scaling. In terms of ecological green space, β value of green coverage area of built-up area was stable between 0.84 and 0.98, while β value of green space area is between 0.94 and 1.10. β value related to green space was generally greater than β value of built-up area, indicating that although land resources are in short supply in urban construction and the trend of land use intensification is strengthened, greening work has been still paid attention to and implemented in place.

The supply of urban infrastructure such as roads, water supply, and medical treatment lagged behind the population growth, resulting in significant pressure on public service provision and management. In recent years, urban road occupancy per capita has decreased and traffic congestion has intensified. From 2000 to 2011, owing to the long-term construction of water supply pipelines by the government, the water supply system realized the full coverage of the urban system, and the length of water supply pipelines was approximately linear with urban population ($\beta \approx 1$). However, with urban expansion, construction of water supply pipeline gradually lagged behind the growth rate of population from 2012 to 2018, which was manifested in the sublinear relationship between the length of water supply pipes and the population ($\beta < 1$). From 2001 to 2018, β value of the number of beds in medical and health institutions decreased from 1.00 to 0.79, the relationship with urban population changed from linear to sublinear, reflecting the current situation of the overall shortage of urban medical resources. In response to this situation, the investment of urban public resources and medical resources should be increased in the future.

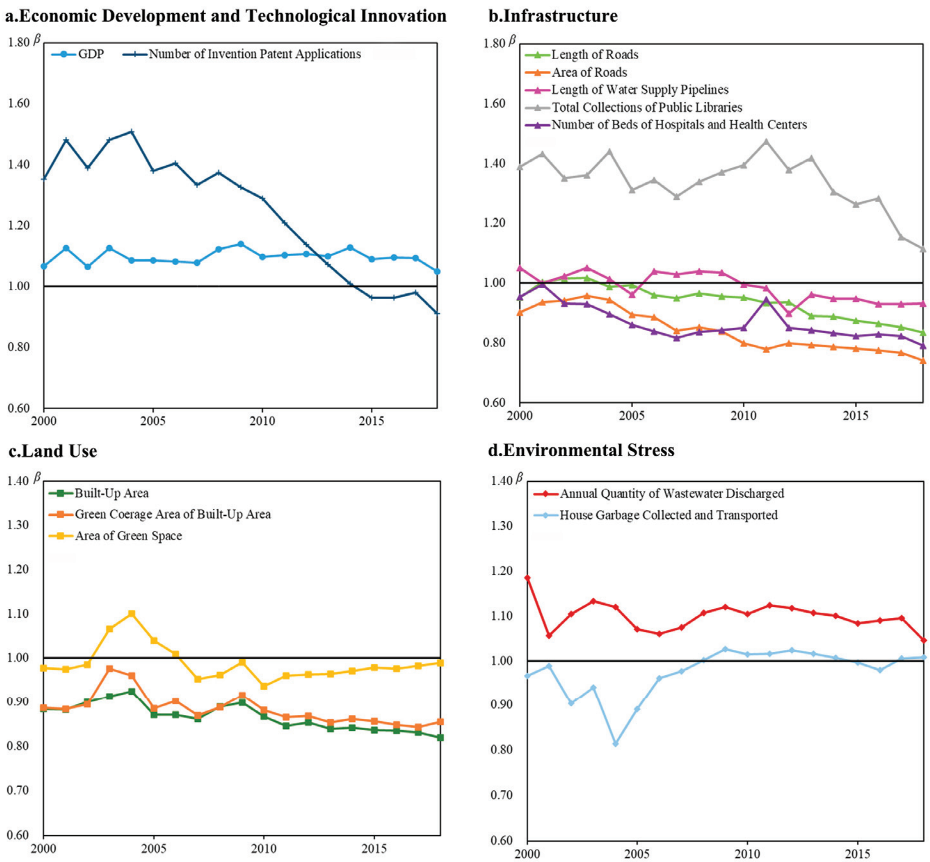

Figure 2. Changes in scaling exponents of city-scale elements from 2000 to 2018.

In the horizontal comparison of cities, the GDP scaling exponent of 43 cities was greater than 1, indicating that most cities showed strong agglomeration effect of economic output (Figure 3). The exception was that the GDP of Dongguan and Xuancheng was sublinearly related to population. The reason was that Dongguan's labor-intensive industries developed and its population attraction increased. However, its current industrial structure restricts the city's economic development and scientific and technological innovation; Dongguan's number of invention patent applications scaling exponent was the smallest ($\beta = 1.63$). Based on labor force gathering, Dongguan should drive industrial upgrading by innovation and highlight the advantage of industrial cluster. The huge population has also brought problems such as traffic jams, insufficient education, and medical resources, β value of urban infrastructure indicators in Dongguan was all at a low level. Unlike Dongguan, Xuancheng's economic development had a poor foundation, its urbanization was lagging and its GDP growth was stunted.

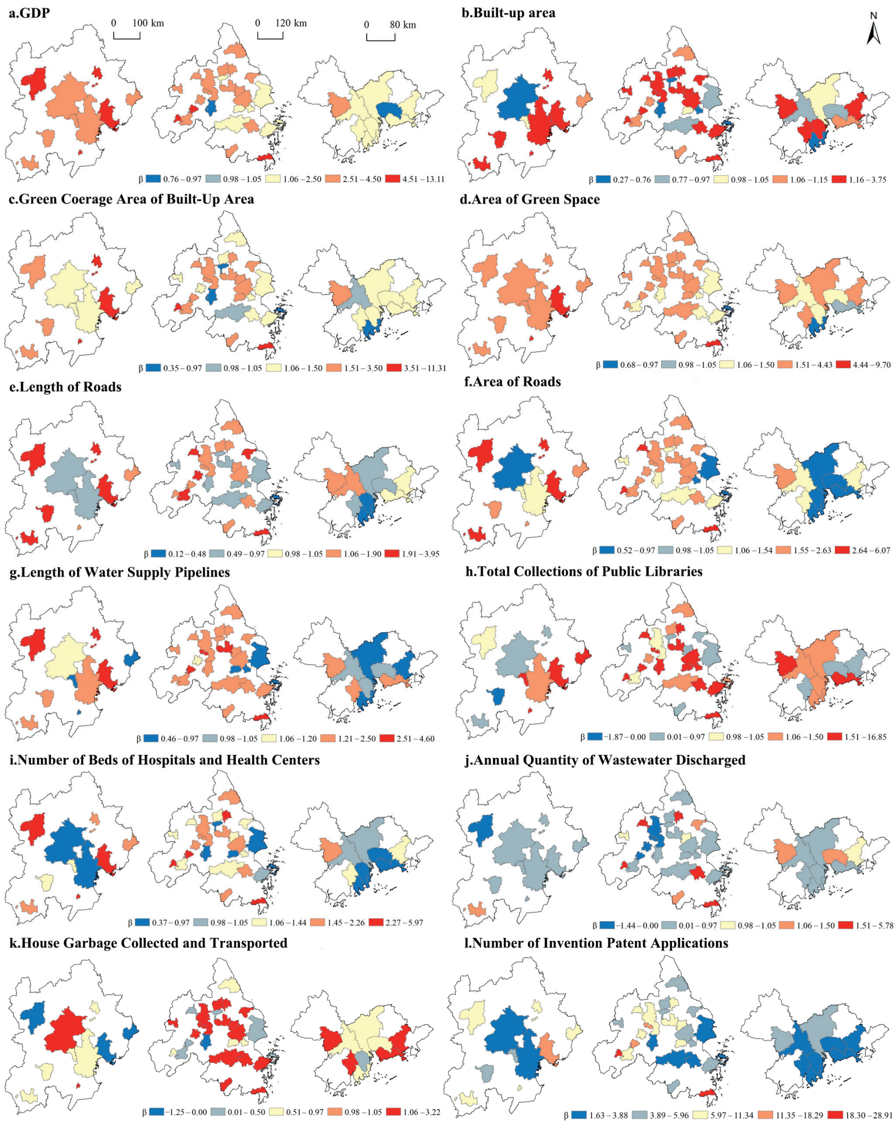

Figure 3. Spatial distribution of scaling exponents of city scale elements.

We found that land use in large cities tended to be more intensive, as shown by the sublinear relationship between built-up area and population ($\beta < 1$) in Beijing, Shanghai, Hangzhou, and Guangzhou, and the approximately linear relationship between built-up area and population ($\beta \approx 1$) in Dongguan and Shenzhen. The greening level of 43 cities has been greatly improved with super-linear relationship between green area and population in the built-up areas, which indicates that cities have been paying more and more attention to the construction of ecological civilization. Due to its good foundation of ecological environment, there was little pressure on green space construction. There was a sublinear relationship between green area in built-up areas and population of Zhuhai (β = 0.52) and Zhoushan (β = 0.35). Meanwhile, we found that β value of roads area and length, beds in medical institutions are generally low in large cities. Therefore, traffic jams and medical resource shortages have been more likely to occur in large cities, such as Beijing, Zhuhai, Shenzhen, Shanghai, Guangzhou, and Dongguan. The number of invention patent applications and population in 45 cities showed a super-linear relationship, which fully demonstrated the effect of talent aggregation.

3.1.2. Metropolitan Area Scale

To summarize the temporal change pattern at the metropolitan area scale, we calculated the scaling exponent of each urban indicator from 2000 to 2018 (Figure 4). We found that GDP of metropolitan areas had a sublinear relationship with population, with β value increasing from 0.82 to 0.93. It showed that the metropolitan area as a whole was gradually mature, but it was still in a state of diseconomy of scale.

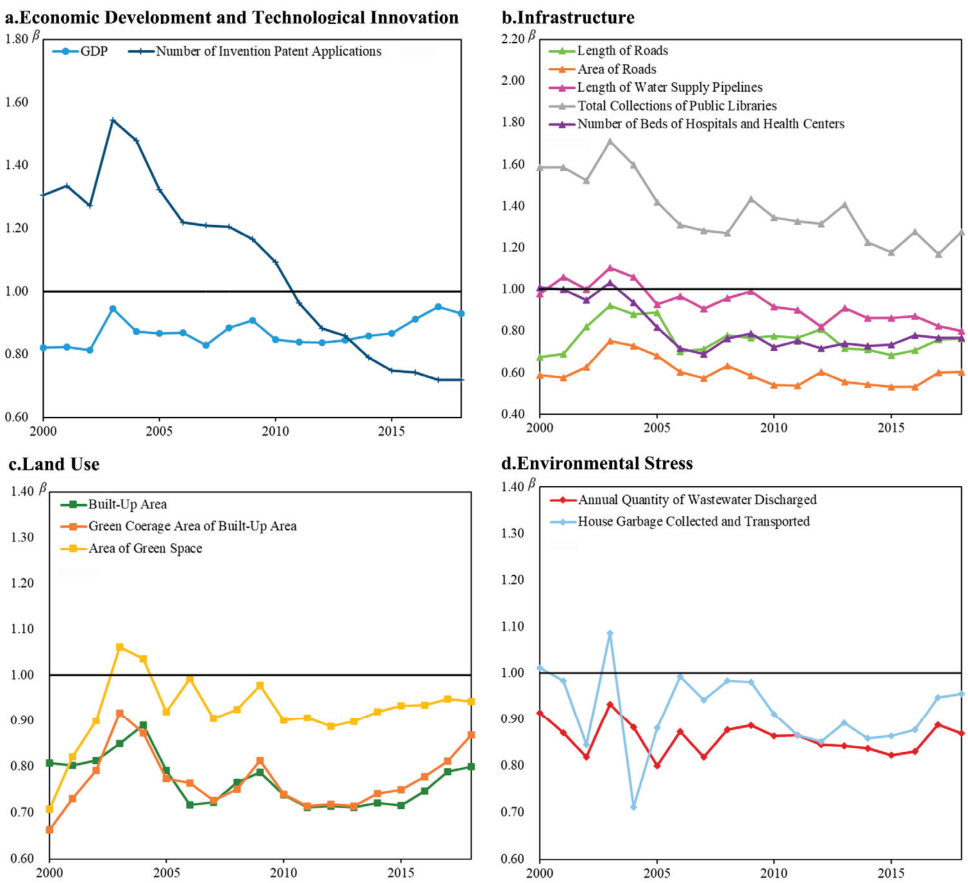

Figure 4. Changes in scaling exponents of metropolitan scale elements from 2000 to 2018.

Similar to economic trends, various infrastructure has gradually improved, but in recent years it has fallen behind the population growth. β value of road length increased from 0.67 in 2000 to 0.77 in 2018, indicating that the road construction has been gradually strengthened and the road network structure has been improved at metropolitan area scale. From 2000 to 2004, β value of water supply pipeline length increased from 0.98 to 1.06, which showed the construction speed of urban water supply pipelines was approximately equal to the population growth speed in metropolitan areas. However, the relationship between the length of water supply pipeline and population became sublinear after 2005 (β = 0.93). Continuously, β value of water supply pipeline length decreased to 0.80 in 2018, and the pressure of water supply increased in metropolitan areas. β value of the number of beds in medical institutions fluctuated between 0.94 and 1.03 from 2000 to 2004, which showed an investment of medical resources matched the population growth. But it showed the same trend as the water pipeline, β value of number of beds in medical institutions decreased from 0.82 to 0.77 from 2005 to 2018. The investment of medical services lagged behind the population growth, and medical resources was increasingly strained.

By horizontally comparing scaling exponents of urban indicators at metropolitan area scale (Table 2), we found that the strength of the economic agglomeration effect of metropolitan areas has been strongly correlated with transportation. Ten metropolitan areas, with β value of GDP ranging from 1.22 to 4.04, while the length of roads, area of roads, and population in most metropolitan areas have a linear or super-linear relationship. Scaling exponents of GDP (β = 4.04), road length (β = 1.80), and road area (β = 2.40) of Nanjing metropolitan area were the largest, while scaling exponents of GDP (β = 1.22) and road area (β = 1.86) of Shenzhen metropolitan area were the smallest. Innovation plays an important role in the economic development of metropolitan areas, the relationship between the number of patent applications and population in all metropolitan areas was super-linear. Scaling exponent in Suzhou-Wuxi-Changzhou metropolitan area was the largest (β = 7.32). The main reason is that Suzhou, Wuxi, and Changzhou had a solid industrial base and carried out more collaborative innovation cooperation in the fields of equipment manufacturing, electronic information, high-end textiles, and biomedicine, which ensured the quality and quantity of innovative inventions.

Table 2. Scaling exponents of urban indicators at metropolitan area scale.

Metropolitan Area (MA)	Economic Development	Land Use			Environmental Stress	
	GDP	Built-Up Area	Green Coverage Area of Built-Up Area	Area of Green Space	Annual Quantity of Wastewater Discharged	House Garbage Collected and Transported
Beijing MA	3.48	1.02	1.59	2.00	0.82	1.09
Pearl River Estuary West Bank MA	1.74	0.98	1.00	1.22	0.58	0.77
Shenzhen MA	1.22	1.06	1.26	1.15	0.78	0.80
Guangzhou MA	2.53	1.02	1.29	1.99	0.71	0.71
Shanghai MA	2.47	1.09	1.62	1.61	0.39	0.69
Suzhou-Wuxi-Changzhou MA	3.59	1.71	2.06	2.19	1.06	1.91
Hangzhou MA	2.35	1.02	1.26	1.77	0.74	1.24
Hefei MA	2.98	1.27	1.54	1.86	0.53	1.36
Nanjing MA	4.04	1.75	1.93	2.07	−0.03	1.52
Ningbo MA	2.74	1.14	1.74	1.97	1.13	1.37

Metropolitan Area (MA)	Infrastructure					Technological Innovation
	Length of Water Supply Pipelines	Length of Roads	Area of Roads	Total Collections of Public Libraries	Number of Beds of Hospitals and Health Centers	Number of Invention Patent Applications
Beijing MA	1.41	0.94	1.43	0.99	0.84	4.65
Pearl River Estuary West Bank MA	1.2	0.58	0.86	1.29	1.02	3.35
Shenzhen MA	1.12	0.96	0.96	1.36	0.64	2.09
Guangzhou MA	1.02	1	1.09	1.32	1.09	4.23
Shanghai MA	1.08	1.02	1.3	0.55	0.85	4.28
Suzhou-Wuxi-Changzhou MA	2.06	1.39	2.1	2.09	1.78	7.32
Hangzhou MA	1.54	1.04	1.43	1.4	1.29	4.29
Hefei MA	1.93	1.19	1.85	0.91	1.39	6.72
Nanjing MA	1.84	1.8	2.4	1.18	1.6	7.25
Ningbo MA	1.81	0.96	1.39	2.92	1.4	6.1

We found that land use was relatively less tense at the metropolitan scale compared to the city scale. The built-up area of metropolitan areas in the northern YRD grew faster than population growth rates, such as Nanjing metropolitan area (β = 1.75), Suzhou-Wuxi-Changzhou metropolitan area (β = 1.71), and Hefei metropolitan area (β = 1.27). The built-up area of other metropolitan areas had a linear relationship with population in general ($\beta \approx 1$). However, the medical resources at the metropolitan area level are affected by the core cities. For example, the number of medical beds in Shanghai metropolitan area, Shenzhen metropolitan area, and Beijing metropolitan area was sub-linearly related to population ($\beta < 1$), mainly because the medical resources in the core cities (Shanghai, Shenzhen, and Beijing) were too tight.

Water-rich and industrially developed metropolitan areas have greater pressure for wastewater treatment. Only annual quantity of wastewater discharged and population of Ningbo metropolitan area (β = 1.13) and Suzhou-Wuxi-Changzhou metropolitan area (β = 1.06) showed a super-linear relationship. Two regions had abundant water resources and developed industries, resulting in more wastewater discharged. In contrast, scaling exponent of wastewater discharged in other metropolitan areas shows a sub-linear relationship with population with less pressure on sewage treatment.

3.1.3. Urban Agglomeration Scale

Table 3 showed that the scaling exponents of GDP, built-up area, green space, length and area of roads, length of water supply pipelines, beds of hospitals, and invention patent applications in GBA are all lower than those of BTH and YRD. In terms of economic development, β value of GDP in GBA is the smallest (β = 1.74), and the agglomeration effect of economic output is relatively weak. Meanwhile, β value of GDP in BTH is the largest (β = 3.88) with a strong economic output agglomeration effect. Thanks to strong education, technological innovation resources, and industrial economy and education foundation, β values of invention patent applications in BTH (β = 5.34) and YRD (β = 5.59) were significantly higher than β value of GBA (β = 2.95) with rich innovation.

Table 3. Scaling exponents of urban indicators at urban agglomeration scale.

Urban Agglomeration (UA)	Economic Development	Land Use			Environmental Stress	
	GDP	Built-Up Area	Green Coverage Area of Built-Up Area	Area of Green Space	Annual Quantity of Wastewater Discharged	House Garbage Collected and Transported
BTH UA	3.88	1.17	1.76	2.30	0.82	0.85
GBA	1.74	1.05	1.28	1.43	0.70	0.80
YRD UA	3.22	1.41	1.82	2.02	0.53	1.18

Urban Agglomeration (UA)	Infrastructure					Technological Innovation
	Length of Water Supply Pipelines	Length of Roads	Area of Roads	Total Collections of Public Libraries	Number of Beds of Hospitals and Health Centers	Number of Invention Patent Applications
BTH UA	1.52	1.11	1.73	1.12	1.07	5.34
GBA	1.09	0.93	1.02	1.37	0.82	2.95
YRD UA	1.64	1.19	1.87	1.01	1.40	5.98

In terms of land use, built-up area and population of BTH (β = 1.17) and YRD (β = 1.41) showed a super-linear relationship, with the built-up area expanding faster than population growth. The built-up area of GBA had an approximately linear relationship with population (β = 1.05), and the land urbanization matched the population urbanization. Meanwhile, sufficient land resources guaranteed greening construction, as evidenced by β value of green coverage area of built-up area and area of green space in BTH and YRD being greater than GBA.

The length and area of roads in BTH and YRD had a super-linear relationship with population. However, β values of length and area of roads in GBA were 0.93 and 1.02, respectively. The per capita road occupancy was relatively low, and residents' transportation is relatively congested in GBA. β value of water supply pipelines length in GBA (β = 1.09) is better in water saving than that in BTH (β = 1.52) and YRD (β = 1.64). In terms of medical infrastructure, β value of beds of hospitals and health centers in GBA was the smallest (β = 0.82), and the scale economy of medical resources in GBA was the most significant, which indicated that the medical resources in GBA were relatively tight.

3.2. Comparative Analysis of Evolution Process of Multi-Scale Urban Scaling Law

By comparing and analyzing the changes in scaling exponents of urban indicators at urban agglomeration, metropolitan area, and city scale from 2000 to 2018 (Figure 5), we found that β value of all urban indicators in metropolitan areas was basically smaller than β value of cities, indicating that urban agglomeration failed to exert strong scale effects and metropolitan area system was still in the cultivation and formation stage without reaching maturity. Especially in terms of economic development, β value of GDP at city scale was stable between 1.05 and 1.13, but β value of GDP is less than 1 at metropolitan area scale. However, β value of GDP at urban agglomeration scale increased overall and changed from sublinear to linear and super-linear with population. Through these years of development, urban agglomerations realized the role of urban resource agglomerates and achieved greater economies of scale.

The built-up area of city scale and metropolitan area scale had a sublinear relationship with population. The coordination between land expansion and population growth of city and metropolitan area was weak. Scaling exponent of urban agglomerations exceeded that of cities and metropolitan areas, and the rate of land expansion gradually caught up with the rate of population growth after 2011.

The scaling exponent of road length and road area in urban agglomerations was greater than that of cities and metropolitan areas, and it had a super-linear relationship with population. Transportation and infrastructure, for example, can enable physical connectivity, accelerate the circulation of factor resources among cities, and form a unified factor and product market. A single city faced the dilemma of medical resource scarcity and unbalanced distribution, and the integration of many cities into a unified service network by urban agglomerations was conducive to improving resource linkage efficiency and distribution rationality. As a result, the scaling exponent of the number of beds in medical and health institutions in urban agglomerations was greater than in cities and immature metropolitan areas, and it had a super-linear relationship with population.

Innovation in science and technology is the endogenous driving force for the synergistic development of urban agglomerations. From 2000 to 2018, the relationship between invention patent applications and population of cities and metropolitan areas shifted from super-linear to linear and sub-linear, respectively, which proves that the isolation and isolation of cities are not conducive to the development of science and technology [50]. However, on a larger spatial scale, the number of invention patent applications in urban agglomerations had a super-linear relationship with the population, and technology exchanged between cities became increasingly common. Cities in the region gradually evolved from fighting alone to collaborative innovation, indicating the maturity of urban agglomerations.

Figure 5. 2000–2018 changes of scaling exponents of urban agglomerations, megalopolises, and urban scaling exponents.

The scaling exponents of GDP, built-up area, green area, road area, road length, number of innovations and inventions, total collections of public libraries, and beds in hospitals and health centers in the BTH were all greater than those of the Beijing metropolitan area (Figure 6), indicating that the scale agglomeration effect of the BTH was stronger than that of the capital metropolitan area. The scaling exponent of wastewater discharged in the BTH was the same as that of the Beijing metropolitan area (β = 0.82), and the scaling exponent of house garbage collected and transported was smaller than that of the Beijing metropolitan area. The ecological pressure of the BTH was less than that of the Beijing metropolitan area, and the ecological collaborative governance has achieved remarkable results. Except for house garbage collected and transported, the scaling exponents of other urban indicators in Beijing were smaller than those of the Beijing metropolitan area, indicating that the scale agglomeration effect of the Beijing metropolitan area was stronger than that of Beijing. Since the BTH only included the Beijing metropolitan area, and the scaling exponents of most urban indicators were larger than the Beijing metropolitan area, it can be concluded that for an urban agglomeration that only included a single metropolitan area, the scale effect became stronger as the scale expanded.

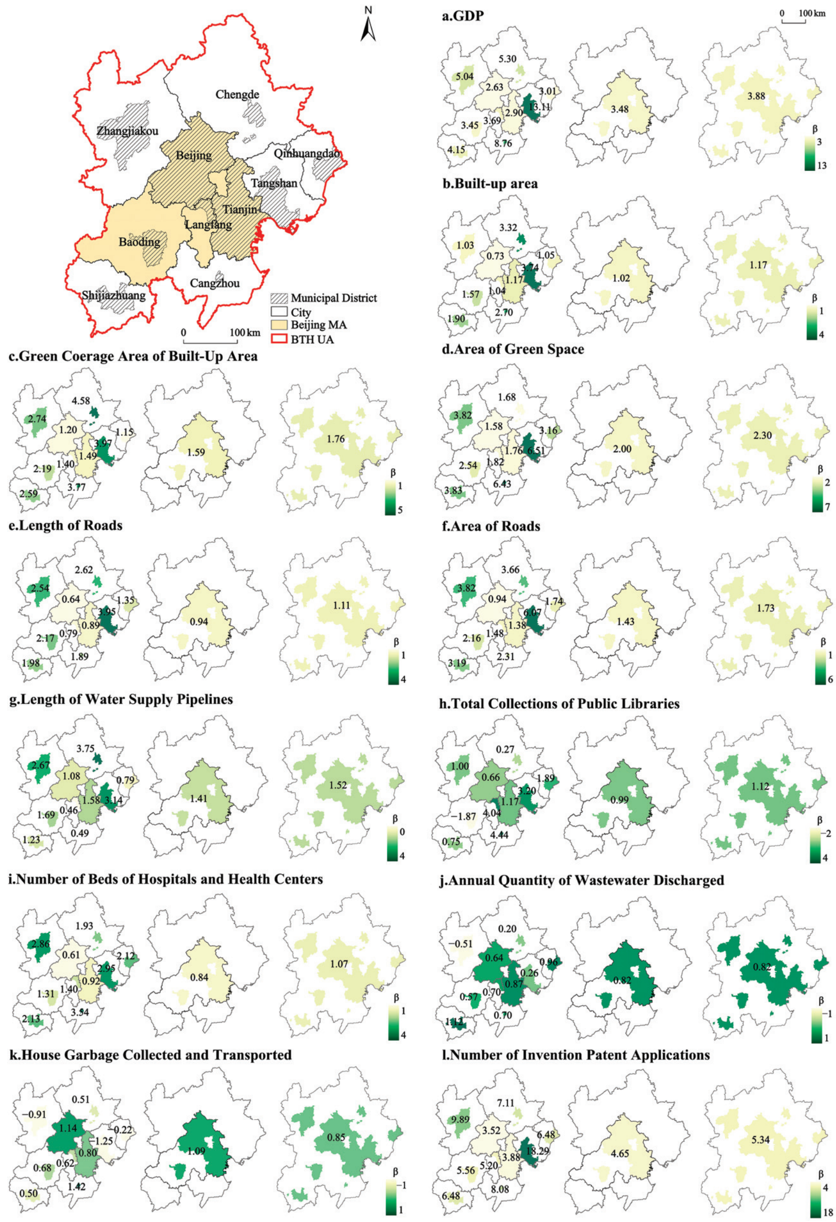

Figure 6. Spatial distribution of scaling exponents in urban agglomeration, metropolitan area, and city scales in BTH.

The YRD contained six metropolitan areas, and the evolution of the metropolitan areas showed obvious spatial differences (Figure 7). In addition to the volume of household garbage collected and transported, the scaling exponents of GDP, built-up area, green area, length of water supply pipelines, length of roads, area of roads, beds of hospitals and health centers, collections of public libraries, and number of invention patent applications in the YRD were all less than Nanjing metropolitan area and Suzhou-Wuxi-Changzhou metropolitan area. The scale effect of the Nanjing metropolitan area and the Suzhou-Wuxi-

Changzhou metropolitan area were stronger than that of the YRD. The scale effect of the YRD in terms of economic development, land use, road construction, and technological innovation was stronger than that of the Shanghai metropolitan area, Ningbo metropolitan area, Hangzhou metropolitan area, and Hefei metropolitan area.

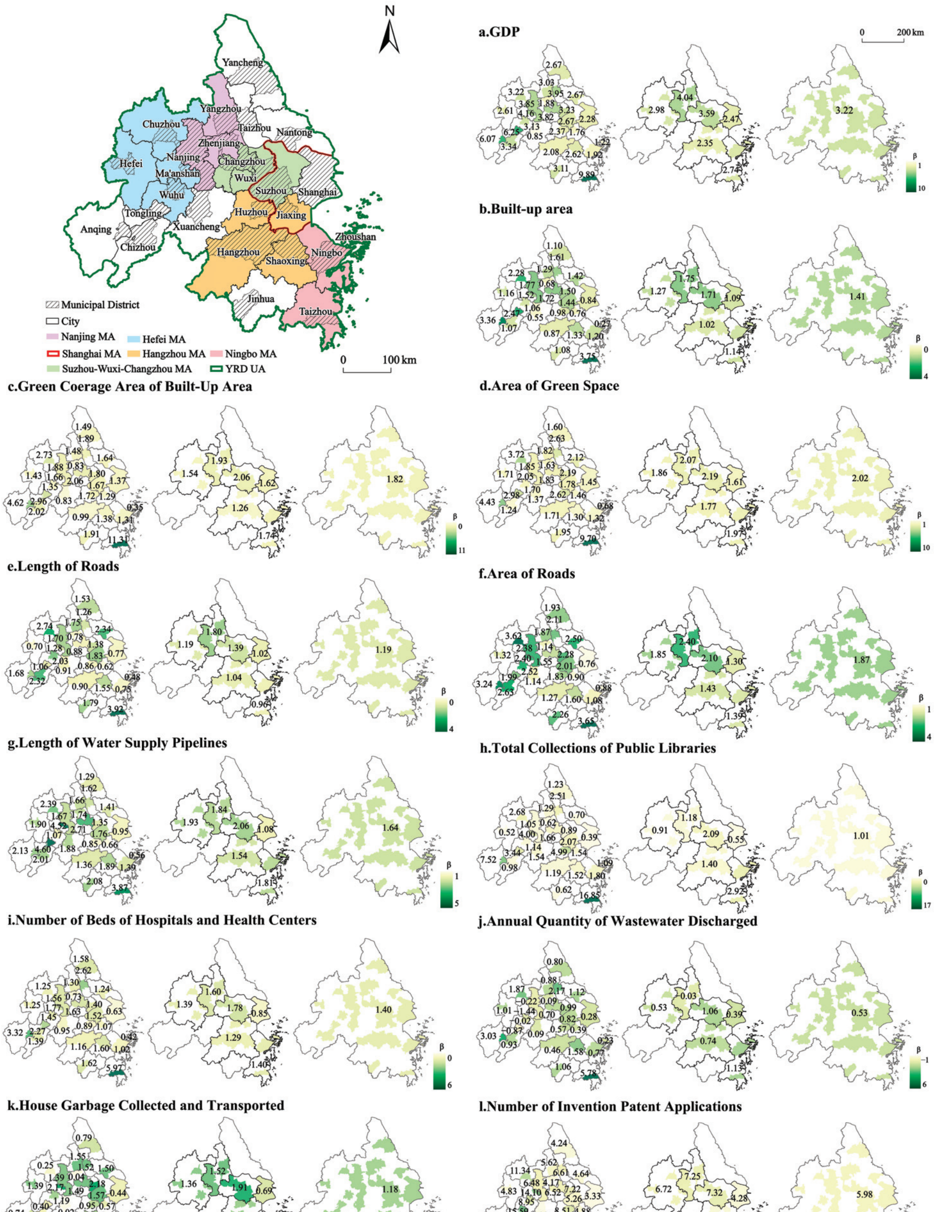

Figure 7. Spatial distribution of scaling exponents in urban agglomeration, metropolitan area, and city scales in YRD.

The GBA includes three metropolitan areas, and each metropolitan area presented different characteristics in the evolution of different urban indicators (Figure 8). For example, the scaling exponents of GDP, length of roads, area of roads, green area, number of patent innovation applications, collections of public libraries, and beds of hospitals and health centers in the GBA were smaller than those of the Guangzhou metropolitan area. The economic development, road construction, greening construction, public services, and innovation of the Guangzhou metropolitan area were significantly ahead of the overall level of the GBA. The scaling exponents of water supply pipeline and beds in hospitals and health centers in the GBA were smaller than those of the Pearl River Estuary West Bank metropolitan area, indicating that the construction of water supply pipeline length and the supply of medical resources were stronger than those in the GBA. At the same time, except for GDP, the scaling exponents of various urban indicators in the Shenzhen metropolitan area were very close to those of the GBA. It can be said that the development of the Shenzhen metropolitan area was the epitome of the GBA.

3.3. The Co-Evolution Process of Urban Scaling Law

Urban scaling law is a powerful summary of the change of urban indicators with city scale [39]. Based on the K-nearest neighbor matrix, we calculated the local Moran Index of the scaling exponent of 12 urban indicators, obtained the spatial evolution patterns of different urban indicators (Figure 9), and analyzed the regional co-evolution process. In BTH, the low-high concentrations of the scaling exponent of GDP, road area, and road length were found in Beijing, Tianjin, and Qinhuangdao, while the high-high concentrations were found in other cities. The dual-core structure of Beijing and Tianjin was stable, but it lacked the radiation-driving effect on the economic development of the surrounding cities, which had a certain impact on the coordinated development. At the same time, the production development drove the transportation infrastructure construction and established the convenient transportation connection. The area of built-up and area of green space in Baoding belonged to the low-high concentration, while Tianjin belong to the high-high concentration. This showed that the urban land expansion was co-evolving with a gap. In terms of ecological pressure, house garbage collected and transported in Beijing belonged to the high-low concentration. As the core city of population and economic aggregation, Beijing has always borne greater ecological pressure. The ecological optimization of the BTH urban agglomeration focuses on solving the "big city disease" of Beijing.

In the YDR, scaling exponent of GDP low-low gathered in Shanghai and Shaoxing, most of the city's GDP scaling exponent space was not relevant. As the core city of Shanghai stimulated the development of the surrounding city, the radiation ability weakened. The economic development of YRD was on a large scale. There was less collaboration and exchange between cities, and competition was greater than cooperation. The integrated development of metropolitan areas needs to be strengthened. In addition, the city location difference, imbalance of economic development level, and the construction of infrastructure and other issues also increased the difficulty of co-evolution. The development of the YRD in the future needs to attach great importance to the overall regional linkage, deepen city exchanges and cooperation, and narrow the gap between regions.

In the GBA, Zhaoqing was a high-low β value aggregation area of GDP, built-up area, public green area, road area, road length, water supply pipe length, and number of beds in medical institutions. Zhaoqing, which was originally more backward, has actively integrated into the GBA by initially building a three-dimensional transportation network, optimizing the business environment, introducing enterprises from Guangzhou and Shenzhen, developing green energy industry with ecological advantages, and building a livable and quality living city. Other cities are low-low β value agglomerations of GDP, green area, road area, road length, water pipeline length, number of beds in medical institutions, and invention applications. We found that the development of GBA was holistic and coordinated, and developed in a steady and low state of synergy in terms of economy, ecological green areas, transportation and pipeline infrastructure, and medical services.

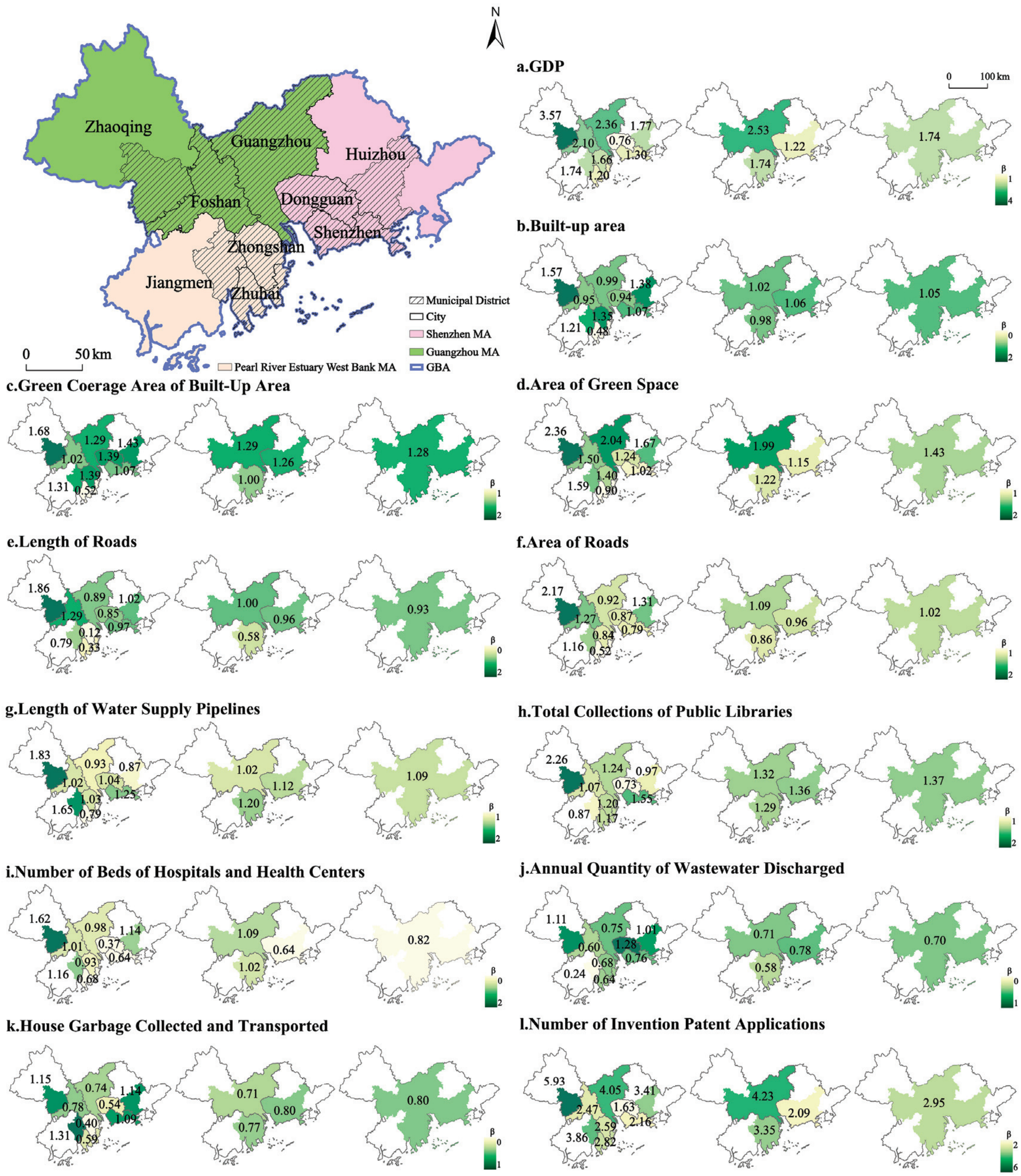

Figure 8. Spatial distribution of scaling exponents in urban agglomeration, metropolitan area, and city scales in GBA.

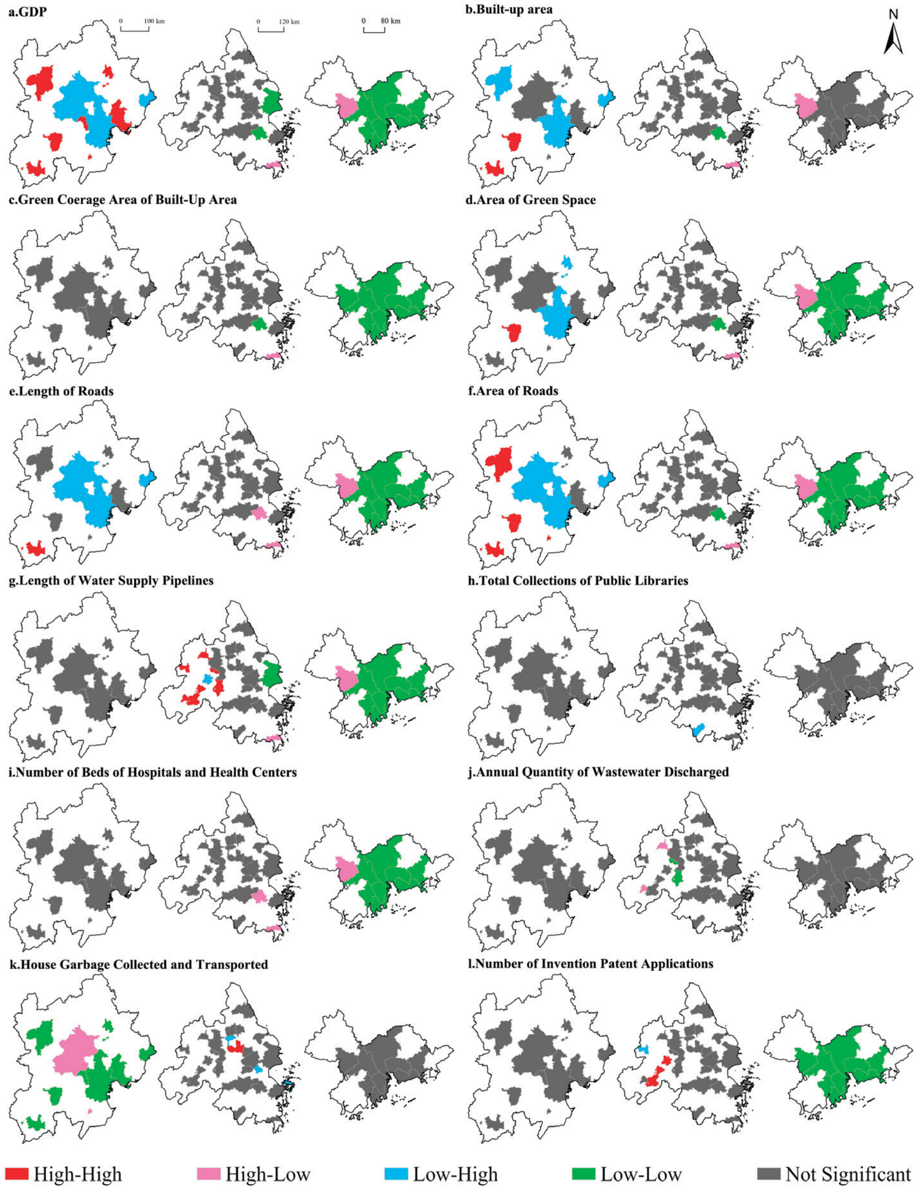

Figure 9. Lisa's aggregation graph of city index scaling exponent.

4. Discussion

Based on the BTH, YRD, and GBA, this study explored the scaling law of urban population and urban indicators from the perspective of city, metropolitan area, and urban agglomeration. The results of previous studies showed that the scaling exponent of urban built-up area, road area, road length, number of beds in medical and health institutions was less than 1, and the scaling exponent of GDP and patents applied for was more than 1 [29]. We found that the scaling exponent of urban indicators in large cities has been more in line with the theoretical expectations. The scaling exponents of urban indicators in metropolitan areas were mainly influenced by the core cities. For example, the number of medical beds in Shanghai metropolitan area, Shenzhen metropolitan area, and Beijing metropolitan area was sub-linearly correlated with the population, because the core cities of metropolitan areas (Shanghai, Shenzhen, and Beijing) were too tight in medical resources ($\beta < 1$). There was an excessive concentration of medical and health resources in municipalities directly under the central government, while resources in lower-level cities, especially prefecture-level cities, were relatively insufficient. This has led to people in lower-level cities frequently traveling to higher-level cities to obtain high-quality medical and health resources, exacerbating the problem of relatively insufficient per capita medical and health resources in higher-level cities [51].

Previous studies have shown that, at the city scale, the same urban indicators exhibit fundamental differences in temporal and spatial scaling [52]. Our research found that this conclusion also applied to the metropolitan and urban agglomeration scales, but as the scale increased, the magnitude of the temporal variation of the scaling exponent increased, while the spatial differences gradually decreased. For example, the scaling exponent of GDP at city scale was stable over time between 1.07 and 1.14, while the inter-city variability ranges from 0.76 (Dongguan) to 13.11 (Jiangmen). The scaling exponent of GDP for metropolitan areas fluctuated between 0.81 and 0.95 over time, and the inter-metropolitan area variability ranged from 1.22 (Shenzhen metropolitan area) to 4.04 (Nanjing metropolitan area). The scaling exponent of GDP at the urban agglomeration scale fluctuated between 0.43 and 1.34 over time, and the inter-urban agglomeration variability ranged from 1.74 (GBA) to 3.88 (BTH). The differences in temporal changes at different scales indicated that metropolitan areas and urban agglomerations were at a high development stage, and the spatial differences at different scales indicated that the economic development of individual cities was relatively unstable, while metropolitan areas and urban agglomerations possess more sharing and coordination of industries, resources, and markets, and their economic development was relatively stable, emphasizing the need for regional synergistic development [15,53].

The temporal change in the scaling exponent described the evolution process of the urban system. From a holistic perspective, the GDP scaling exponent of the metropolitan area was lower than the theoretically expected value, and the economies of scale have not been fully utilized. This may be because the urban hierarchy and division of labor system within the metropolitan area have not been fully established, resulting in a weak circle structure. The competition for urban resources is greater than cooperation, and the ability of metropolitan areas to resist risks is weak, and high-quality development of metropolitan areas has not been fully promoted. The planning and construction focus of many metropolitan areas is on the core city, resulting in a low degree of integrated development of the metropolitan area and a fragmented development between the central city and the peripheral regions. The urban system is currently in the stage of cultivation and formation and has not reached a mature state. At the same time, the development speed and maturity level of urban agglomerations were faster. As the connections between cities in urban agglomerations strengthen, the efficiency of resource integration improves, and the economies of scale of the economy, land, transportation, public services, and innovation resources were raised to a higher level. The construction of metropolitan areas should not only pursue a large area and coverage of cities, but should accurately define the scope, concentrate resources to exert economies of scale and promote urbanization and integrated development. The research area in this study was based on the administrative boundaries of the officially designated metropolitan areas and urban clusters, which may not be the most functional and efficient combination of cities. Therefore, for metropolitan areas and urban agglomerations, how to define the most efficient development scale is a question we need to consider in the future.

Although this study analyzes the co-evolution of urban systems from a multi-scale perspective based on existing data, but there are still limitations. First, existing urban statistical data are based on the statistics of administrative units. The lack of statistical data on urban physical space and functional characteristics cannot scientifically and accurately reflect the real situation of the city, which is not conducive to meaningful urban spatial division. In the future, multiple sources of high-resolution spatial data that can reflect urban entities should be used for research. Second, the evolution of metropolitan areas and urban agglomerations needs to consider the interaction between cities, and the co-evolution of urban systems needs to extend to flows and networks, which is also important for exploring the scaling law, further research is needed to consider the flow of elements between urban systems.

5. Conclusions

Urban scaling law, as one of the models for studying urban science, reflected the regularity of urban evolution to a certain extent. This study found that land use tends to be intensive in big cities, and the problems of traffic jams and medical resource supply were more likely to occur ($\beta < 1$). The metropolitan area was in a state of diseconomy in scale, but the development has been gradually maturing. The road factor of urban agglomerations was larger than that of cities and metropolitan areas, and had a super-linear relationship with population, indicating that a perfect transportation network system was an important foundation for the development of urban agglomerations. The synergistic evolution of the GBA was steadily advancing, but medical resources were relatively scarce ($\beta = 0.82$). The degree of synergistic evolution of Beijing and Tianjin in the BTH was high, with Beijing facing greater ecological pressure. The YRD had difficulties in overall synergistic evolution due to the wide area of the region, a large number of internal cities and metropolitan areas, and the large gap in development bases. It is necessary to pay more attention to the construction of road infrastructure, strengthen inter-city exchanges, and promote the synergistic development of the economy, infrastructure, innovation, and other elements.

Author Contributions: Conception and design of study, data acquisition, data analysis, drafting the manuscript, revising the manuscript critically for important intellectual content, X.L. Conception and design of study, supervised and carried out the experimental procedures, revising the manuscript critically for important intellectual content X.M. All authors have read and agreed to the published version of the manuscript.

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buildings

Article

Spatial Distribution and Typological Classification of Heritage Buildings in Southern China

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Abstract: Heritage buildings are a crucial aspect of a country's cultural heritage, serving as a means of preserving and passing down its history and traditions to future generations. The heritage buildings in southern China possess significant conservation, utilization, and research value. However, research is lacking on the spatial distribution characteristics and subdivision types of these buildings in the region. This study aimed to investigate the spatial agglomeration and distribution characteristics of heritage buildings in southern China, as well as the factors contributing to the formation of these spatial distribution patterns. This article focused on the protection of 981 heritage buildings in southern China since the founding of China. The study examined the buildings' spatial agglomeration and distribution characteristics from various dynasties and subdivided types. It utilized the average nearest neighbor analysis, unbalance index, and kernel density estimation to analyze this distribution. Additionally, this study also investigated the primary factors influencing the spatial distribution and differentiation of these buildings. The results demonstrated the following: (1) In general, the spatial distribution of heritage buildings in southern China is characterized by unevenness and clustering, with a concentration in the eastern coastal and Sichuan provinces. (2) In terms of temporal dimension, the spatial distribution of heritage buildings exhibits unique characteristics in various dynastic zones. (3) In the type dimension, the number of different types of heritage buildings varies greatly. (4) Further analysis of the distribution and types of heritage buildings indicates that quantitative differences are primarily influenced by natural, human, and socio-economic factors. This research was unique as it explored the geospatial distribution characteristics and determinants of heritage buildings. It offers a valuable perspective on the spatial distribution of heritage buildings and can serve as a reference for future studies on the preservation and protection of such buildings in China. Additionally, the findings can provide guidance for the management and rational use of heritage buildings in southern China.

Keywords: ancient architecture; heritage building; spatial distribution; heritage building types; building conservation and utilization; southern China

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1. Introduction

Heritage architecture is a valuable heritage left behind by previous generations, representing the crystallization of ancient engineering construction techniques, architectural engineering art, and the creative wisdom of ancient working people. It serves as a witness to ancient historical changes and holds extremely rich historical, cultural, and artistic research values [1]. As protected objects, heritage buildings are a form of material and spiritual wealth of mankind [2]. They possess multi-dimensional research values, including artistic aesthetic value, historical and cultural value, tourism value, and architectural technology reference value [3–8]. The southern region of China boasts a wealth of heritage buildings, encompassing a variety of architectural styles such as Huizhou style architecture [9], Hakka architecture [10,11], and Suzhou-style architecture [12]. Not only are these styles unique and representative of the region, but they also convey rich historical, technical, and cultural information [8]. Therefore, conducting research on heritage buildings in southern China holds great significance.

Current research in the field of heritage buildings is primarily focused on four key areas. First, the conservation and restoration of such buildings have yielded abundant research results. Systemic approach [13], building information models [14], 3D LiDAR, and multi-technology collaboration [15] are among the methods that aid in the conservation of these structures. Materials such as organic–inorganic hybrid sol [16] and lime-based mortars [17] have also proven to be effective in the restoration of heritage buildings. Second, with regard to heritage buildings and tourism development, Nuryanti proposed that heritage buildings are integral to cultural tourism [18], while Martha et al. suggested that combining these structures with cultural activities is key to promoting tourism development [19]. Moreover, Wang et al. analyzed the impact of tourism activities on heritage buildings [20]. Third, various countries and regions have made active attempts to incorporate heritage buildings into their modern urban planning systems. Italy, Britain, France, and Norway are among the countries that have carried out practices in this regard [21–23]. Fourth, the study of architectural models dominates the aspect of the structure of single heritage buildings. For instance, Angelini et al. conducted a 3D modeling of the patriarchal cathedral of the Patriarchal Basilica of Santa Maria Assunta in Aquileia [24] and Jiang et al. conducted a survey to develop an architectural information model of the cultural heritage of the Yingxian Wood Pagoda [25]. Similarly, Vranich reconstructed the building called Pumapunku at the site of the ruins of Tiwanaku (A.D. 500–950), in the modern republic of Bolivia [26]. However, research is lacking on the spatial distribution of heritage buildings at the macroscopic scale and large regional level. The spatial distribution of these buildings is influenced by both natural geography, such as climate change, topography, and river hydrology, and human factors, such as changes in administrative systems, ideological evolution, and socio-economic development [27]. These buildings are often found in clusters. The fertile rivers and plains of the Middle East, India, China, and Europe have historically been the birthplace of some of the world’s greatest civilizations. Today, heritage buildings can be found in Europe, America, Asia, the Pacific, and Arab countries, with a concentration in the eastern and northern coastal areas of Central and Western Europe [28]. The distribution of these heritage buildings offers valuable insights into local geography and historical and cultural systems [29]. Analyzing the distribution characteristics of China’s heritage buildings can provide a macroscopic understanding of their architectural features.

The temporal and spatial characteristics, spatial layout, and functions of heritage buildings undergo gradual changes during different periods of development, influenced by national history, cultural background, and regional characteristics [30,31]. These changes are reflected in the time of completion and building types, which are represented spatially by the number of buildings in different periods and the coupling of the number of different types of buildings with space and time [32]. To achieve a refined and differentiated conservation and use of heritage buildings in southern China, it is important to understand their distribution characteristics based on two perspectives, namely time of completion and building type.

China boasts a wealth of heritage buildings [33]. In October 2019, the National Cultural Heritage Administration of China (NCHA) announced 8 batches of 5060 key cultural relic protection units in China, of which 2169 were heritage buildings accounting for 42.87% of the total. These heritage buildings serve as crucial material foundation for showcasing traditional culture and promoting cultural tourism in various regions. China has implemented several measures to preserve and protect heritage buildings [34]. These measures include involving the community in conservation efforts [35], improving legislation for conservation and management [36], and utilizing modern technology [37]. However, there is a lack of research examining the regional spatial distribution of heritage buildings, which could aid in promoting their conservation.

This study aimed to analyze the differences in the spatial distribution characteristics of cultural relics and buildings from different periods and types and clarify the spatial clustering and distribution characteristics of heritage buildings in southern China. Additionally, this study aimed to identify the factors contributing to the differences in spatial distribution characteristics and the variety of types of heritage buildings. This study examined the spatial differentiation, distribution characteristics, and types of heritage buildings in southern China, based on data from the first eight batches of key cultural relic protection units in China published by the National Cultural Heritage Administration (NCHA) in October 2019. Specifically, this study analyzed the distribution of heritage buildings in general and in different periods and the quantitative differences between different types of heritage buildings. Finally, it analyzed the reasons influencing differences in the distributions and types of heritage buildings. This study analyzed the spatial characteristics of the distribution of heritage buildings and their spatial relationships on a macro scale, in contrast to previous architectural studies that have been dominated by the micro scale of individual buildings, with less attention paid to the macroscopic spatial distribution of heritage buildings. Furthermore, it clarified the basic resources of heritage buildings in terms of their practical value, which was conducive to the rational allocation and arrangement of resources by the conservation and management departments of heritage buildings.

2. Data and Methods

2.1. Study Area and Data Sources

2.1.1. Southern Region Overview

The southern China region comprises 15 provinces and cities, namely, Jiangsu, Anhui, Zhejiang, Hunan, Hubei, Sichuan, Yunnan, Guizhou, Guangdong, Guangxi, Fujian, Jiangxi, Hainan, Shanghai, and Chongqing (Figure 1). Data for Hong Kong, Macau, and Taiwan were not collected in this study. The region is located between 3–35° N latitude and 108–123° E longitude. Most of the provinces and cities in southern China are situated south of the Qinling and Huai Rivers. The region is characterized by a complex and diverse topography, which includes plateaus, mountains, basins, hills, and plains. The Yangtze and Pearl Rivers flow through this area.

2.1.2. Research Data and Sources

The research data on heritage buildings used in this paper were obtained from the National Cultural Heritage Administration (NCHA) of China of the National Key Cultural Relics Protection Units, specifically from the first eight batches of the National Key Cultural Relics Protection Units as of October 2019. The latitude and longitude of the Chinese heritage buildings were obtained by extracting the location information from Baidu Maps. Cultural heritage was classified as follows: monuments (e.g., paintings, sculptures, architectural and archaeological works, inscriptions, etc.); groups of buildings (e.g., separated or connected buildings with a value for architecture, homogeneity, or place in the landscape); "sites" (e.g., works of man or combined works of nature and man, and archaeological sites) [38]. The way in which this cultural heritage was classified provided an important reference for the classification of heritage buildings in this study. In the "Chai Zejun Ancient Architecture Anthology", heritage buildings were classified according to their function. This classification system was combined with the main function and nature of use of southern heritage buildings. As a result, southern heritage buildings were classified into 12 categories (Table 1): palace building, defensive building, monumental building, garden architecture, sacrificial architecture, water building, residential architecture, religious building, civic architecture, mausoleum building, social architecture, and productive building. After data processing, a total of 981 southern heritage buildings were collected. The data were disaggregated and a total of 981 southern heritage buildings were recorded.

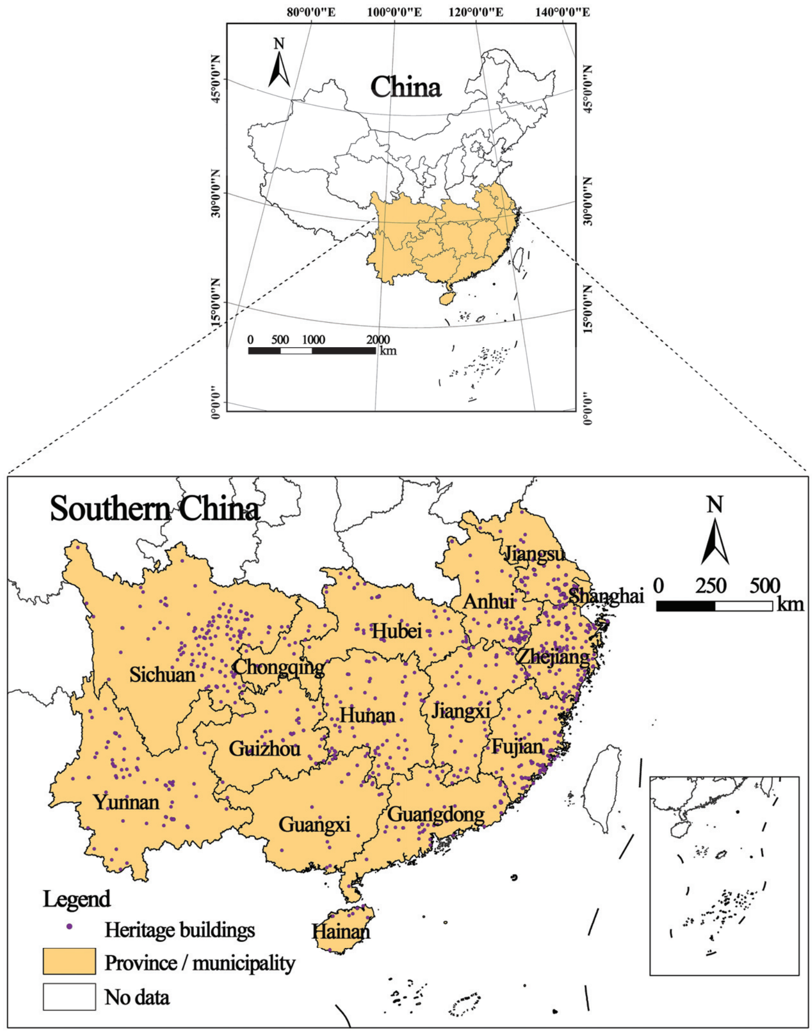


Figure 1. Study area and heritage buildings sites.

Table 1. Heritage building types and components.

Type	Component
Palace building	imperial palace, yamen, temple, mansion house, etc.
Defensive building	battlement, bunker, pass, fire beacon, city hall, the Great Wall, etc.
Monumental building	belfry, drum tower, marble pillar, memorial arch, etc.
Garden architecture	The Royal Park, yard, villa, etc.
Sacrificial architecture	temple of Confucius, martial temple, ancestral hall, altar, etc.
Water building	bridge, dam, ditch, harbor, marina, etc.
Residential architecture	house, hall, courtyard, thatched cottage, etc.
Religious building	Buddhist temple, pagoda, Daoist temple, mosque, church, etc.
Civic architecture	tearoom, drama stage, dance pavilion, etc.
Mausoleum building	stone fault, stone archway, graveyard, stone carving, sacrificial altar, etc.
Social architecture	provincial or county guild hall, post station, etc.
Productive building	workshop, atelier, barn, storeroom, plant, etc.

2.2. Research Methods

2.2.1. Average Nearest Neighbor Analysis

The average nearest neighbor analysis is most suitable for comparing elements of different periods in a fixed study area. It can be used to determine the average distance of heritage building sites of the different periods in southern China and the spatial distribution characteristics of heritage building sites (aggregated distribution, random distribution, and dispersed distribution) based on the ratio R of the average observed nearest neighbor value (di) to the average expected nearest neighbor value (de). Therefore, in this study, the researchers utilized the average nearest neighbor analysis to determine the spatial distribution type of southern heritage buildings. Additionally, the researchers calculated the proximity value of each heritage building point element in the study area. The spatial distribution type of the point elements was classified into three categories: aggregated distribution (R < 1), random distribution (R = 1), and dispersed distribution (R > 1). The nearest neighbor index R was used to calculate the spatial distribution type; its formula is shown below:

$$R = \frac{\overline{r_i}}{r_E} = 2\sqrt{Dr_i} \tag{1}$$

where $\overline{r_i}$ is calculated as the average distance between neighbouring points of the heritage buildings and r_E represents the average distance of the heritage buildings in the random distribution model. The density of the heritage buildings is denoted by D.

Its standard deviation Z value is expressed as [39]:

$$Z = \frac{(d_i - d_e)\sqrt{N^2/A}}{0.26136} \tag{2}$$

In the formula, the significance p-value is smaller when the Z-value is too high (strongly dispersed) or too low (strongly aggregated). When $p > 0.1$, the significance is poor and the heritage building sites are randomly distributed. When $p < 0.01$, the heritage building sites are strongly aggregated (or dispersed); $0.01 < p < 0.05$ is a strong aggregated (dispersed) distribution and $0.05 < p < 0.1$ is a general aggregated (dispersed) distribution.

2.2.2. Kernel Density Estimation

Kernel density estimation is a modern statistical analysis method for non-parametric density estimation commonly used in geography to analyze spatial patterns. The kernel density estimation method based on ArcGIS can be used to assess the spatial density of a certain phenomenon in a certain area and show the distribution pattern of spatial phenomena more intuitively. Therefore, in this study, kernel density estimation can be used to analyze the spatial distribution pattern and aggregation characteristics of southern heritage buildings. The density around the sample points can be estimated based on the density of the heritage buildings in the unit grid and produce a smooth surface [40]. The kernel density value reflects both the overall distribution characteristics of heritage buildings and the distribution characteristics of heritage buildings from different dynasties. A higher kernel density value indicates a denser distribution of heritage building points. The formula for kernel density estimation is as follows [41]:

$$f_n(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - X_i}{h}\right) \tag{3}$$

where $f(x)$ is the estimated kernel density of heritage buildings; $H > 0$ is a preset radius; n is the number of heritage building points, 981 in total; $(x - X_i)$ is the distance from valuation point x to event X_i, where the larger the kernel density value the more clustered the distribution of heritage buildings in the characterized area; h is the bandwidth (i.e., the search radius of the kernel density function); $K(x)$ is the quadratic kernel function of spatial weights, $K > 0$.

2.2.3. Unbalance Index

The unbalance index can reflect the balanced distribution of heritage buildings in southern China and is calculated as follows:

$$S = \frac{\sum_{i=1}^{n} Y_i - 50(n+1)}{100n - 50(n+1)} \tag{4}$$

The formula for calculating the unbalance index of heritage buildings in the southern region takes into account the number of southern provinces and regions (n), the proportion of the number of heritage buildings in each province and city to the total number of heritage buildings in the whole southern region (Y_i), and the cumulative percentage of the i-th place in the ranking from largest to smallest. The resulting value of S ranges from 0 to 1. If $S = 1$, it means that the heritage buildings are concentrated in one province; if $S = 0$, it means that the heritage buildings are evenly distributed in each province [42].

3. Results and Analysis

3.1. Divergent Characteristics of the Spatial Dimension

3.1.1. Overall Spatial Agglomeration Distribution Characteristics

The average nearest neighbor analysis can also be used to determine the average distance and spatial distribution characteristics (aggregated distribution, random distribution, and dispersed distribution) of heritage building sites in southern China. Through the use of the average nearest neighbor analysis in ArcGIS10.7 software (Table 2), heritage buildings in the southern provinces and cities of China were found to exhibit an average observed distance of 17.4 km, an average expected distance r_E of 34.9 km, a nearest neighbor index R value of 0.4993, and a z value of -30.0019. The p value, which was less than 0.01, indicated a strong spatial clustering distribution characteristic of southern heritage buildings.

Table 2. Results of average nearest neighbor analysis of heritage buildings in southern China.

Projects	Results
Nearest Neighbor Index R	0.4993
Observed Distance di/m	17,428.3795
Expected Distance de/m	34,906.1134
Z-score	-30.0019
p-value	0.00
Distribution Characteristics	Strongly clustered

This study utilized the kernel density estimation tool of ArcGIS 10.7 to analyze the spatial clustering of heritage buildings across 15 provinces and regions in southern China (Figure 2). The kernel density value can reflect the overall distribution characteristics of heritage buildings; the higher kernel density value indicates a denser distribution of heritage building points. The results of the kernel density analysis revealed that the distribution of heritage buildings is highly uneven, with a concentration in the middle and lower reaches of the Yangtze River plain, followed by the eastern coastal areas and the Sichuan basin. The kernel density likewise varied significantly between the east and west, with a trend of "more in the east and less in the west". According to the study, the middle and lower plains of the Yangtze River, Fujian, and Sichuan have the highest concentration of heritage buildings.

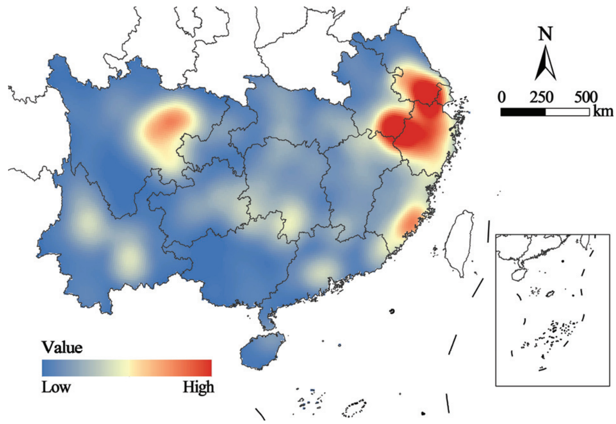


Figure 2. Analysis of the nuclear density of heritage buildings in southern China.

3.1.2. Characteristics of the Distribution of the Number of Heritage Buildings in the Province

Figure 3 illustrates the distribution of heritage buildings in the 15 southern provinces and cities of China. The data indicate a significant variation in the number of heritage buildings across these regions. Zhejiang, Jiangsu, Anhui, Fujian, and Sichuan have a higher number of heritage buildings distributed in their provinces and cities, while Shanghai, Chongqing, Guangxi, and Hainan have a lower number of heritage buildings distributed.

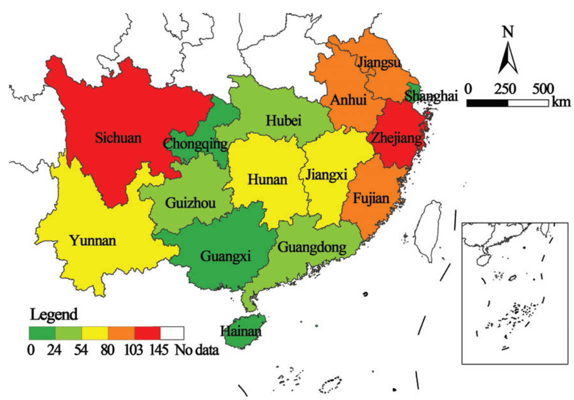


Figure 3. Map of numbers of heritage buildings in southern China.

An imbalance index analysis was conducted on the number of provinces and regions, resulting in an *S*-value of 0.396, which indicates an uneven distribution of heritage buildings in the southern regions of China. The degree of bending of curve (Figure 4) is of great significance because it can intuitively reflect the degree of equilibrium or imbalance in the distribution of heritage building sites in southern China. The greater the degree of bending, the more unequal the distribution of heritage building points and vice versa. As shown in Figure 4, the Lorenz curve is far from the uniform distribution, indicating a significant arc that represents the uneven distribution of heritage buildings in the region. The provinces of Zhejiang, Sichuan, Jiangsu, Fujian, and Anhui account for over 57% of the total number of heritage buildings, while Chongqing, Hainan, and Shanghai have fewer heritage buildings.

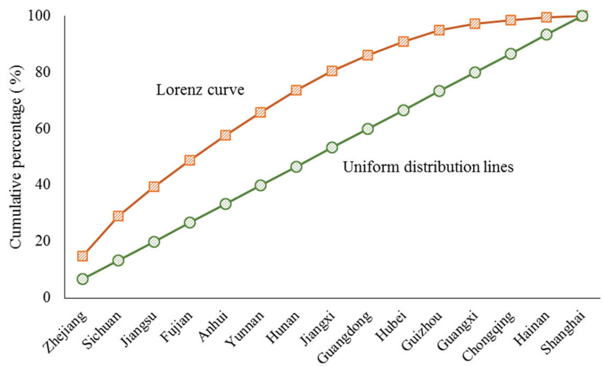


Figure 4. Lorenz curve for heritage buildings in southern China.

3.2. Spatially Differentiated Features of Heritage Buildings from Different Dynasties

In this study, heritage buildings in southern China were categorized into four time periods based on their construction dates. The first period includes the Spring and Autumn period, the Warring States period, the Qin Dynasty, and the Han Dynasty to the Northern and Southern Dynasties. The second period comprises the Tang–Song dynasties, the third period includes the Yuan–Ming dynasties, and the fourth period consists of the Qing dynasty–Republic of China. Figure 5 presents the number of heritage buildings from each period. The largest number of heritage buildings (410) are distributed from the Yuan–Ming Dynasty. Following that, the period from the Qing Dynasty–Republic of China has the second largest number of heritage buildings, with 377. In southern China, a total of 176 heritage buildings from the Tang Dynasty to the Song Dynasty have been preserved. By contrast, the number of heritage buildings from the Spring and Autumn period to the Northern and Southern Dynasties periods in the southern region is only 18.

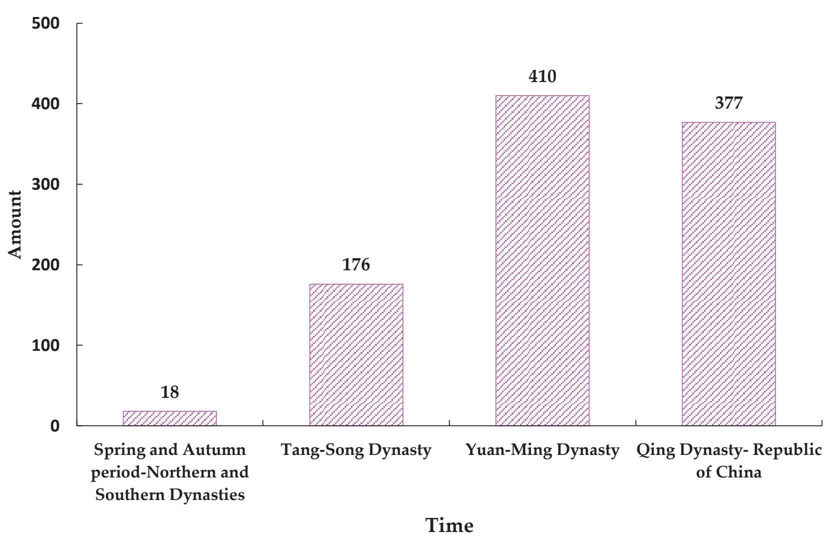


Figure 5. Number of heritage buildings by phase in southern China.

A comparison of the elements of different periods in a fixed study area can be made using the average nearest neighbor analysis method, which can determine the average distance of the same period of heritage building sites in southern China and clarify the spatial distribution of heritage buildings. To explore the spatial characteristics of heritage buildings in each of the four periods, average nearest neighbor analysis was employed and the results are recorded in Table 3. The analysis revealed significant differences in the distribution characteristics of buildings in the four periods. Specifically, the Spring and Autumn period and the Southern and Northern Dynasties period did not exhibit significant clustering, with an R-value of 0.8263, a Z-value of -1.4100, and a p-value of 0.16. During the Tang–Song Dynasty, Yuan–Ming Dynasty, and Qing Dynasty–Republic of China periods, heritage buildings were strongly clustered, as indicated by nearest neighbor index R-values of 0.5858, 0.5869, and 0.5184, respectively. Based on the smallest nearest neighbor index R-value, it can be concluded that the spatial agglomeration of the Qing Dynasty–Republic of China period was the most significant, with an observed distance of approximately 28.5 km. On the other hand, the observed distances for the Tang–Song Dynasty and Yuan–Ming Dynasty periods were farther away, measuring about 41.6 and 50.5 km, respectively.

Table 3. Results of average nearest neighbor analysis of heritage buildings of different periods.

Time	Nearest Neighbor Index R	Observed Distance d_i/m	Expected Distance d_e/m	Z-Score	p-Value	Distribution Characteristics
Spring and Autumn Period–Southern and Northern Dynasties	0.8263	125,535.4925	151,928.8986	-1.4100	0.16	Insignificant
Tang–Song Dynasty	0.5858	41,630.1366	71,063.9755	-10.5120	0.00	Strongly clustered
Yuan–Ming Dynasty	0.5869	50,457.2026	29,613.9577	-16.0017	0.00	Strongly clustered
Qing Dynasty–Republic of China	0.5184	28,494.3869	54,962.2124	-17.8877	0.00	Strongly clustered

In this study, kernel density estimation was utilized to identify the core areas where heritage buildings were clustered during four distinct periods. The default parameters of ArcGIS 10.7 were used to set the search radius and other parameters. The results, as depicted in Figure 6, indicate a significant spatial heterogeneity in the distribution of heritage buildings during the four periods.

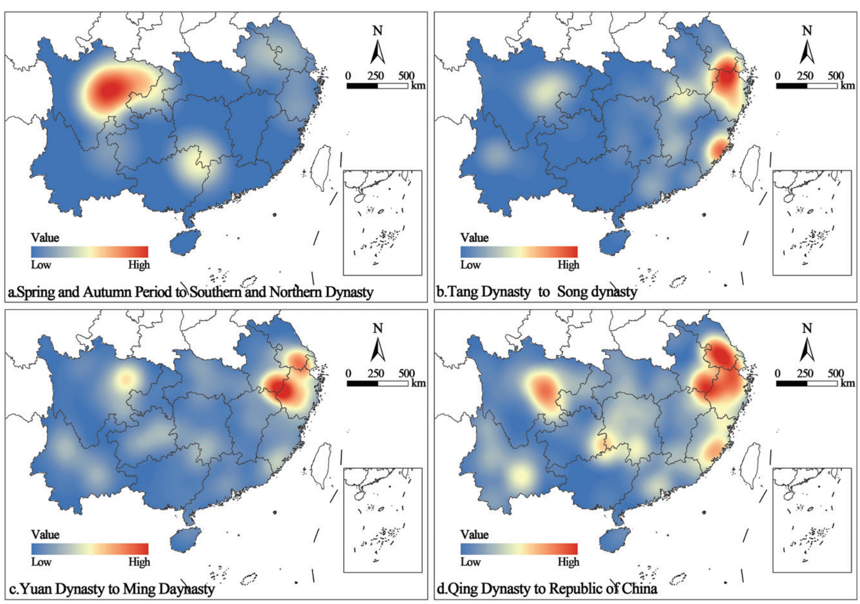


Figure 6. Analysis of the kernel density of heritage buildings in the four periods in southern China.

During the Spring and Autumn and Warring States period to the Northern and Southern Dynasties period, heritage buildings were predominantly clustered in the Sichuan basin, forming a high-density grouping in the region (Figure 6a). The heritage buildings in Sichuan were primarily from the Qin and Han dynasties, with Dujiangyan, Binh Duong Fu Junque, and Shen Fu Junque being the most widely distributed. Since the Han Dynasty, Sichuan has been referred to as the "Land of Heaven" because of its exceptional natural conditions. Additionally, Chengdu held the position of political center during the Shu Han Dynasty.

The Tang–Song Dynasty is distinguished by a "double core" of heritage buildings, primarily located in the Jiangsu and Zhejiang regions of the Yangtze River Delta and the eastern coast of Fujian (Figure 6b). The Yangtze River Delta region has a wider distribution and a higher density of heritage buildings, including notable sites such as Lingyin Temple, Linhu Temple, and Ganlu Temple. During this period, the economic center of the country shifted southwards. The Southern Tang Dynasty had its capital in Nanjing, located in Jiangsu Province. In addition, the capital of the Southern Song Dynasty was moved from Kaifeng in the north to Hangzhou.

The heritage buildings from the Yuan Dynasty to the Ming Dynasty period in Anhui and southern Jiangsu, as well as the northwest of Zhejiang Province, form a "double core" pattern (Figure 6c). This suggests that the main development of heritage buildings during this period occurred in the middle and lower reaches of the Yangtze River region. The Sichuan basin also has a great number and density of heritage buildings. Furthermore, heritage buildings from this period are scattered throughout other provinces and cities. The economic recovery of the Yuan Dynasty, coupled with the establishment of the capital in Nanjing, Jiangsu, at the beginning of the Ming dynasty, and the favorable natural conditions of the middle and lower reaches of the Yangtze River plain, were key factors that led to the population growth and economic prosperity of the region.

During the Qing Dynasty-Republic of China period, heritage buildings were distributed in a "multi-core" manner (Figure 6d). The Yangtze River Delta region was the main core area and had the highest density of buildings. Other core areas included the eastern coastal areas of Fujian Province, the Sichuan basin, and the Guizhou–Hunan border, which also had a significant number of heritage buildings.

From a historical perspective, there appears to be a significant gap in the temporal distribution of cultural heritage buildings in southern China. Specifically, there are no cultural heritage buildings from the pre-Qin and Sui dynasties in this region during the historical period. Furthermore, the number and density of cultural heritage buildings in southern China vary greatly depending on the time period being examined.

3.3. Distribution Characteristics of the Type Dimension

In the "Chai Zejun Ancient Architecture Anthology", heritage buildings in the south are classified based on their functions and appearance characteristics. The classification includes palace building, defensive building, monumental building, garden architecture, sacrificial architecture, water building, residential architecture, religious building, civic architecture, mausoleum building, social architecture, and productive building. The distribution of these different building types is shown in a bar chart (Figure 7). This study revealed that religious architecture was the most prevalent building type in the southern region, followed by residential and ritual architecture. Productive, social, mausoleum, cultural, recreational, and palace buildings are less commonly found. The findings suggest that religious buildings are less susceptible to destruction during dynastic changes and that provinces tend to prioritize a particular type of heritage building when applying for national heritage protection designation. The number and types of heritage buildings vary due to natural, human, socio-economic, and other factors.

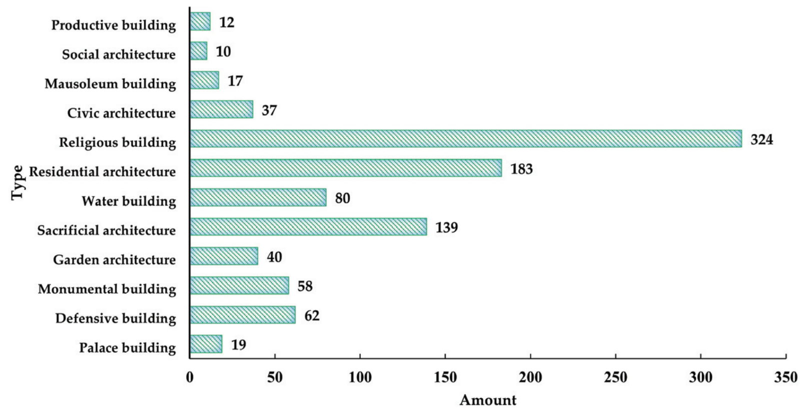


Figure 7. Number of heritage buildings by type in southern China.

Different types of heritage building have unique functions and characteristics (Table 4). Water buildings are constructed on rivers, lakes, and other water bodies, serving as bridges, embankments, canals, and weirs. Examples of water buildings in southern China include Dujiangyan and Yuliang Dam. Mausoleum buildings are designed as a special place for burial and sacrifice, reflecting religious characteristics, filial piety, and Feng Shui concepts. Civic architecture serves cultural and recreational purposes, combining practicality and artistry. Examples include academies and theaters, such as the Dongpo Academy and the Yuelu Academy. Residential architecture is a type of building designed to meet the basic needs of people. It is one of the earliest types of architecture in history. Social architecture, on the other hand, has a specific social function and is typically built by chambers of commerce and merchant groups. These buildings provide spaces for discussion, entertainment, and social interaction, such as meeting houses and post stations. Productive buildings such as salt wells, tea farms, and porcelain kilns are constructed during the production process. Garden architecture is a significant aspect of Chinese architectural art that incorporates the aesthetic qualities of classical Chinese philosophy, literature, and calligraphy. Defensive buildings, sacrificial architecture, and religious buildings are important types of buildings for different purposes. Defensive buildings serve national and urban security purposes, with military defenses such as city walls, towers, and post roads. Sacrificial architecture is a place for various rituals to express reverence and gratitude to heaven and earth or ancestors and generally pursues simplicity, dignity, and solemnity with rich symbolism. Its pattern is generally more meaningful than functional. Religious buildings are important places for people to engage in religious activities, including Buddhist temples, pagodas, grottos, Taoist temples, and Islamic mosques. Temple buildings are mostly built as courtyards, except for cave temples. Monumental buildings are constructed to honor significant individuals and events, featuring ideological, artistic, and lasting elements such as pagodas, monuments, and towers, which hold ornamental and commemorative significance. Palace buildings are grand structures constructed by rulers to solidify their authority, showcase the splendor of their power, and cater to both their spiritual and material pleasures. These buildings typically comprise palaces, government offices, halls, and mansions. Taihe Palace is a prime example of this architectural style.

Table 4. Types of heritage buildings in southern China by dynasty.

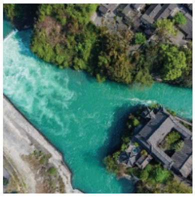
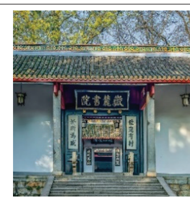
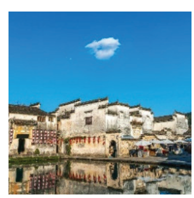
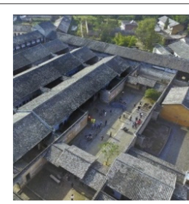
	Spring and Autumn Period–Northern and Southern Dynasties	**Tang–Song Dynasty**	**Yuan–Ming Dynasty**	**Qing Dynasty–Republic of China**
Water Building	 Dujiangyan	 Yuliang Dam	 She County Taiping Bridge	 Chengyang Yongji Bridge
Mausoleum Building	 Binh Duong Fu Junque		 Tomb of Taibo	 Tomb of Pang Tong
Civic architecture		 Huangshan Ancient Road	 Dongpo Academy	 Yuelu Academy
Residential Architecture	 Linga Ancient City	 Ancient Buildings of Quanzhou Port	 Hongcun Ancient Building	 Tung Sang Wai
Social Architecture			 Zheng'an County Affairs Main Hall	 Jeon Jin Guild Hall

Table 4. *Cont.*

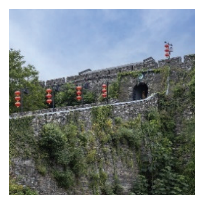
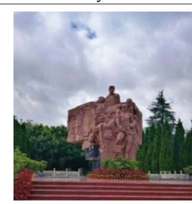
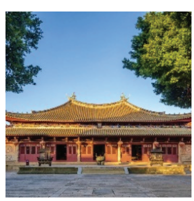
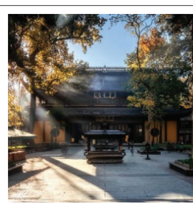
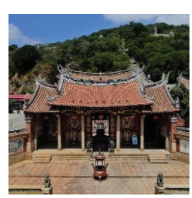
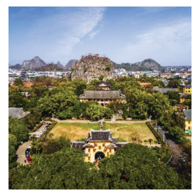
	Spring and Autumn Period–Northern and Southern Dynasties	Tang–Song Dynasty	Yuan–Ming Dynasty	Qing Dynasty–Republic of China
Productive Building		 Zhuo Tube Well	 Ancient Fiberway	 Suzhou Weaving Department
Garden Architecture			 Lion Forest Garden	 Qiyuan
Defensive Building	 Kedu Coach Road	 Danba Gu Diao Group	 Nanjing City Wall	 Xifeng Concentration Camp
Sacrificial Architecture	 Huishan Town Ancestral Hall	 Quanzhou Confucian Temple	 Taiping Mountain House	 Wuhou Temple
Religious Building		 Lingyin Temple	 Hoian Qingshan Palace	 Kokuseiji Temple

Table 4. *Cont.*

	Spring and Autumn Period–Northern and Southern Dynasties	Tang–Song Dynasty	Yuan–Ming Dynasty	Qing Dynasty–Republic of China
Monumental Building		 Yuan Zhou Tower	 Zhangzhou Stone Arch	 Taibai Building
Palace Building			 Jingjiang Royal Mansion	 Golden Hall of Taihe Palace

4. Discussion

This study shows that the distribution of heritage buildings in the southern region is uneven, with varying degrees of temporal and spatial agglomeration. The spatial distribution of heritage buildings in the south is notably uneven, with the eastern coast and Sichuan being the most prominent areas. The temporal distribution is also uneven, with the four temporal phases exhibiting distinct clustering characteristics. Furthermore, the distribution of heritage buildings in the south displays a clear generational gap, with no Pre-Qin period or Sui Dynasty heritage buildings found in the historical period. In terms of building types, religious, residential, and sacrificial architecture are the most prevalent, whereas other types are relatively scarce.

The number, construction time, and type of distribution of heritage building sites in the south vary across different provinces and are mainly influenced by natural, human, and socio-economic factors. Chen Junzi et al. and Han Ying et al. showed that natural resources, topography, and rivers play significant roles in determining the spatial distribution of these sites [43,44]. This finding is consistent with the results of Chen Jinhua et al. on the spatial distribution of cultural heritage in ASEAN countries [45]. The distribution and density of heritage buildings are influenced by both natural resources and topography. Availability of building materials and ease of access are factors that are impacted by the surrounding terrain. Human adaptation and use of nature play a significant role in the development of heritage buildings. Flat terrain is more conducive to the gathering of building materials and populations, making it easier to form and develop a heritage building. The impact of rivers on the distribution of heritage buildings is evident in several ways. First, fertile soil in the alluvial zones of rivers provides ideal conditions for agriculture, which in turn supports settlements. Second, the abundance of water along the rivers facilitates irrigation, enabling people to grow crops even in arid regions. Third, river valleys serve as channels of interaction between settlements, promoting cultural exchange and facilitating production. Finally, Feng Shui thinking often considers rivers as the gathering place of early human life, leading to the concentration of heritage buildings remaining in these areas. These observations are consistent with the findings of Han Zou et al.'s study on the spatial and temporal evolution of the relationship between water systems and historical settlement sites in Hankou, Wuhan, from 1635 to 1949 [46]. The distribution of heritage buildings is highly concentrated in provinces such as Sichuan, Jiangsu, Zhejiang, and Fujian, owing to their abundant resources, flat topography, and numerous rivers, all of which are natural factors that contribute to this phenomenon.

The distribution of heritage buildings is influenced by a variety of factors, including natural environmental factors, historical and cultural factors, and socio-economic factors. In addition to the study by Wu Qing and He Qiuxian on the spatial and temporal distribution characteristics and influencing factors of ancient buildings across the country [47], this conclusion also takes into account population migration factors. The distribution of heritage buildings in China can be attributed to both historical and cultural factors. Sichuan, Zhejiang, and Jiangsu provinces have a higher concentration of heritage building remains due to their significance as former capitals of various dynasties. For example, Chengdu in Sichuan served as the capital of the Shu Han period, Hangzhou in Zhejiang was the capital of the Southern Song Dynasty, and Nanjing in Jiangsu was the capital of the Ming, Jin, and Southern Dynasties. Nanjing is also famously known as "The ancient capital of the Six Dynasties". The second factor contributing to the development of heritage architecture in southern China was the migration of the Chinese population. Throughout Chinese history, there have been three major southward migrations, primarily toward the middle and lower regions of the Yangtze River. As a result of these migrations, the southern region saw an influx of people, leading to advancements in agricultural and handicraft technologies, increased grain production, and growth in commercial trade. The number of towns and cities in the southern region surpassed those in the north as well. This migration played a fundamental role in shaping the spatial and temporal distribution pattern of southern China's development. In addition to historical and cultural factors, socio-economic factors also play a crucial role in the conservation and development of heritage buildings. The level of economic development serves as the foundation for the preservation of these structures and financial support is essential for their continued protection and development. However, the uneven distribution of socio-economic development across different regions can lead to significant disparities in the abundance of heritage building remains and the intensity of their preservation and development efforts between provinces.

While this study provides valuable insights, it is important to note its limitations. First, the research methodology employed was homogeneous because the spatial and temporal distribution of heritage buildings was only analyzed using the nuclear density analysis method. To increase the diversity of research methods, future studies could incorporate additional analytical techniques. Second, the temporal classification of some heritage buildings in the National Key Cultural Relics Protection Units was unclear due to the lack of a clear date of completion. Therefore, this study used the date of the beginning of the heritage buildings as a basis for classifying their time period. In future studies, the date of construction of heritage buildings should be used as a basis for classification and authoritative documents should be consulted to improve the precision of classification. Finally, the study solely focused on analyzing heritage buildings that have been listed as cultural relics. However, there exist numerous heritage buildings that are not listed as cultural relics but still hold significant research value. In the future, more information on unlisted heritage buildings will be collected to conduct in-depth studies on these buildings. These efforts will further enhance our understanding of heritage buildings.

5. Conclusions

This study aimed to analyze the differences in the spatial distribution characteristics of cultural relics buildings across different periods and types in southern China and to examine their spatial clustering and distribution characteristics. Additionally, it sought to explore the factors contributing to the differences in spatial distribution characteristics and the variety of types.

This study examined 981 national-level cultural relic buildings in southern China that have been recognized by the State Council since the founding of New China. The research categorized these cultural relic buildings into four stages based on their construction period: Spring and Autumn Period–Southern and Northern Dynasties, Tang–Song Dynasty, Yuan–Ming Dynasty, and Qing Dynasty–Republic of China. Additionally, this study classified heritage buildings into 12 different types based on their functions and characteristics. The spatial distribution and distribution characteristics of buildings from different dynasties and types were analyzed using methods such as average nearest neighbor analysis, unbalance index, and kernel density estimation. It investigated the relationship between the distribution of cultural relics and buildings and the various natural, humanistic, and socio-economic factors. This study revealed several key findings. First, the spatial distribution of cultural relics buildings in southern China exhibited a general pattern of unevenness and agglomeration. Specifically, cultural relics buildings were predominantly concentrated on the eastern coast and in Sichuan Province. The spatial distribution of cultural relics and buildings also varied across different dynastic zones. Cultural relics and buildings in Sichuan Province were found to be primarily from the Spring and Autumn Period–Southern and Northern Dynasties period. In contrast, the Tang–Song Dynasty witnessed two aggregation zones, mainly located in the middle and lower reaches of the Yangtze River and Fujian Province. The Yuan–Ming Dynasty heritage buildings were mainly distributed in the middle and lower plains of the Yangtze River and Sichuan. Lastly, the heritage buildings from the Qing Dynasty to the Republic of China era were distributed across multiple cores, primarily in the Yangtze River's middle and lower plains. The number of heritage buildings varied greatly, with religious buildings being the most common type. When analyzing the distribution and number of cultural relic buildings, we found that natural, human, and socio-economic factors influenced their differences.

Previous research has predominantly focused on individual building research at a micro scale, often neglecting the broader spatial distribution of heritage buildings. This study aimed to address this gap by analyzing the spatial relationship between heritage buildings and the various types of differences at a macro scale. This study also considered the influence of population migration on the distribution of heritage buildings, a factor that has often been overlooked in previous studies. This study has practical significance. Analysis of the spatial distribution and types of heritage buildings allowed this study to conclude that an imbalance exists in the spatial distribution and types of heritage buildings. This conclusion provides guidance for the management department in declaring, protecting, and developing heritage buildings. It prompts the relevant departments to allocate human and financial resources more reasonably.

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Spatio-Temporal Evolution and Influencing Factors of Integrated Urban–Rural Development in Northeast China under the Background of Population Shrinkage

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Abstract: Population shrinkage has had a certain negative impact on urban and rural development in many aspects. The impact of population shrinkage on urban–rural integration has become one of the core scientific issues that needs to be addressed in the current research on promoting the goal of common prosperity in China. Northeast China is a typical region in China that is experiencing a decrease in population and economic activity. Investigating the integrated development of urban and rural areas in this region is highly important for revitalizing Northeast China. This research paper focuses on 32 prefecture-level cities in Northeast China and utilizes spatial correlation analysis and the Geographical Weighted Regression model to uncover the evolving spatial patterns and influential factors affecting integrated urban–rural development in the context of population decline. The findings revealed the following: (1) The level of integrated urban–rural development in Northeast China continues to rise despite the shrinking population. During the comprehensive population decline stage, the growth rate of the urban–rural coupling coordination degree surpasses that of the initial stage. The areas with high values of urban–rural coupling coordination degree shift from northeastern Heilongjiang to four sub-provincial cities. The spatial correlation between urban–rural coupling and coordinated development weakens, with the main type being low–low agglomeration. (2) Factors such as economic development level, labor force size, urbanization level, level of openness, urban–rural accessibility, and proportion of built-up areas significantly correlate with urban–rural coupling and coordination. The influence of each factor varies in magnitude and direction across different locations. Labor force size and urban–rural accessibility have the most-significant impact on integrated urban–rural development, with labor force size having a positive effect and urban–rural accessibility having a negative effect. The impact of the economic development level follows a pattern of initial increase and subsequent decrease as the population shrinks. (3) Although population decline does not hinder integrated urban–rural development in Northeast China, it is closely connected to changes in the factors influencing such development. To capitalize on the development opportunities presented by national policies, Northeast China should adopt a model of urban–rural development that promotes rural growth through cities. This entails attracting talented individuals to return, enhancing the flow of urban–rural development elements in both directions, and creating a spatial development pattern characterized by "big city, big agriculture, and big ecosystem". By doing so, the revitalization of Northeast China can be achieved.

Keywords: integrated urban–rural development; influencing factors; northeast China; population shrinkage; spatial heterogeneity

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1. Introduction

The interdependence of cities and rural areas involves constant changes and interactions. Rural regions give rise to cities, while cities foster the development of rural areas. These two entities differ significantly in terms of production, lifestyle, ecology, and other aspects. Achieving integrated urban–rural development in China requires finding ways to complement and allocate resources between urban and rural functions effectively. Due to China's reform and opening-up policy, along with rapid growth in industrialization, urbanization, and informatization, productive factors such as population, land, capital, and technology have shifted from rural regions to cities. This has led to cities advancing much further in comprehensive development compared to rural areas [1]. The disparities in income, consumption, public services, and infrastructure between urban and rural populations have widened due to insufficient rural development and a lack of coordination between urban and rural communities [2]. China's unique household registration and land tenure systems have perpetuated the urban–rural divide, exacerbating the contradiction between the two. Addressing the urban–rural divide is crucial for developing countries, as it is a visible sign of regional disparities during the intermediate stage of development. China recognizes that the principal contradiction in its current society lies between people's increasing demand for a better life and the imbalanced and inadequate development, including the imbalanced and inadequate urban–rural development. Therefore, China has put forth strategies such as new urbanization [3], rural revitalization [4], common prosperity, and its distinctive modernization approach to narrow the urban–rural gap and promote integration between urban and rural areas [5].

Globalization, deindustrialization, resource depletion, and other factors have contributed to the emergence and increase of shrinking regions in China and globally. A number of shrinking cities have emerged around the world, with nearly 180 shrinking cities in China [6]. Urbanization is closely tied to changes in the urban and rural populations. China's rapid urbanization has attracted a large number of people to cities, benefiting urban development. However, it has also resulted in various negative effects in rural areas, such as population decline, vacant houses, and abandoned land. Scholars around the world refer to this as rural shrinkage or rural decline [7]. China is currently experiencing a deepening stage of industrialization. The urban population will continue to grow, leading to a more-pronounced reduction in the rural population, which in turn will cause economic and social decline and other shrinking phenomena in rural areas [8,9]. Some scholars view shrinkage as a natural phase in the development process and consider it a neutral term. However, it has been demonstrated that population and economic shrinkage in regions can have adverse effects on various aspects of regional development. Given the context of both regional and rural shrinkage, it is crucial to study the evolving characteristics of urban–rural development, how to promote a healthy urban–rural relationship, and whether coordinated development in shrinking regions can be achieved. China has reached a stable phase of urbanization in its development. Given the current state of the economy and society, China sees integrated urban–rural development as a way to address the contradiction between urban and rural areas and overcome the middle-income trap.

Northeast China is a typical region in China that is experiencing a decline [10], and its progress in urban–rural development has undergone four distinct stages: the coexistence of urban and rural areas, a division between urban and rural areas, the integration of urban and rural areas, and finally, the achievement of integrated urban–rural development. In the early years of the People's Republic of China, the development model known as the urban–rural dichotomy was implemented, where agriculture supported industry and rural areas supported cities, in order to gather the necessary elements and funds for constructing the industrial system [11]. Through a national strategic plan, Northeast China was able to bypass the establishment of a light industrial system and directly transition to a heavy industrial system, benefiting from approximately 30% of the heavy industrial construction projects that were originally supported by the former Soviet Union and located in the region. This accelerated the process of urbanization in Northeast China, resulting in a higher level of urbanization compared to the rest of the country. Northeast China possesses favorable natural surroundings and a solid agricultural foundation. Its rural areas have consistently aimed at increasing agricultural production and improving farmers' income, although the pace of development has been slow. Since the implementation of economic reforms and opening up, the economy of Northeastern China has declined, and after entering the new century, the population of Northeastern China has been shrinking seriously, with great resistance to urban–rural development and a widening gap between urban and rural areas [12]. Following the 18th National Congress of the Communist Party of China, the focus of urban–rural development shifted from integration to a more-comprehensive approach, aiming at achieving integrated urban–rural development. In this context, studying the integrated urban–rural development in the Northeast region during the period of population contraction is of great significance in narrowing the urban–rural gap, realizing common prosperity, and promoting the transformation of the Northeast region and high-quality urban–rural development [13].

2. Research Review and Framework

2.1. Research Review

Thomas More's "Utopia" introduced the idea of integrated urban–rural development [14], which entails planning both urban and rural areas as a cohesive whole. This concept was put into practice by More's followers through the establishment of communities such as New Harmony and the Fourierist communities. Another influential figure, Howard, presented the Garden City theory [15], which examined the relationship between urban and rural settings to address planning challenges in the modern industrial era. This theory explored crucial aspects such as population density, urban economy, and urban landscaping. Later, theories such as satellite cities and organic decentralization further emphasized the integration of urban and rural areas. Adam Smith, known as the father of classical economics, developed the concept of natural order, recognizing that cities emerge from rural regions and that the urban–rural development gap varies depending on a country's history, culture, and political system. Von Thunen, a German economic geographer, proposed the concept of an isolated state in his book, analyzing the spatial distribution of different sectors in urban and rural locations. T.G. McGee, a Canadian scholar, introduced the Desakota model to address urban–rural development challenges in certain developing countries and Asian regions. This model examines the interconnectedness and interaction between urban and rural spatial structures, portraying the Desakota area as a hybrid with characteristics of both urban and rural environments. It is considered a transitional zone where urban and rural life strongly intersect. Takuro Kishine, a Japanese researcher, proposed the concept and paradigm of urban–rural integration design based on systems theory. His work analyzed the development and transformation of urban and rural regions in Japan aiming to create a human-operated space that transcends traditional urban–rural boundaries and harmonizes with nature.

Western researchers have primarily conducted micro-level studies on the integration of urban and rural areas. These studies focus on the social tensions that arise between cities and rural regions due to urbanization and examine issues of fairness and justice in regional spatial structure. These scholars advocate for high-quality regional development by bringing together urban and rural areas within a region. They propose concepts such as urban–rural spatial production and dynamic suburban development. Their research methodology combines qualitative and quantitative analysis and aims to explore various aspects of the urban–rural relationship [16], such as industrial development [17], spatial layout [18], interactions [19], integration [20], social cohesion [21], governance networks [22], and political coordination [23]. On the other hand, Chinese scholars approach the topic of urban–rural integration differently [24]. They mainly utilize a comprehensive evaluation index system and employ methods such as the comprehensive index approach and coupling coordination degree model to analyze the level of integration between urban and rural areas [25,26]. There are three main types of index systems used by Chinese scholars. The first type takes a holistic view of the urban–rural territorial system [27] and uses the urban–rural ratio index as a fundamental component [28]. The second type utilizes the coupling coordination model to assess comprehensive indicators from both urban and rural subsystems [29]. The third type combines elements from the first two types by integrating indicators of the urban–rural ratio with comprehensive indicators [30]. In the construction of the evaluation indicator system, the selection of indicators is similar and universal, but there is a lack of characteristic indicators that can reflect typical regions.

In studies examining the factors that impact integrated urban–rural development, both macro and micro analyses are commonly employed. The influencing factors encompass three main components. First, the systemic factors affecting urban–rural coordinated development, which consist of the natural environment system, economic system, social system, cultural system, and policy system, are examined using a combination of quantitative and qualitative analysis methods [31]. Second, the specific elements of urban–rural development, such as population, capital, transportation, infrastructure, and technology, display spatial heterogeneity and nonequilibrium, influencing urban–rural integration [32–34]. Third, various micro-level entities such as governments, businesses, and migratory labor engage in behavioral interactions during the process of urban–rural coupling and coordinated development [35,36]. Furthermore, scholars have primarily focused on the factors influencing urban–rural coordinated development due to the complex internal mechanisms involved in urban–rural development. However, research into the influencing mechanisms has been relatively limited. Nevertheless, there is a general consensus that urban–rural coordinated development is an ongoing process influenced by multiple factors, including endogenous factors, external assistance, market forces, and government actions [37]. In analyses of the impact mechanisms of urban–rural integration, qualitative and quantitative analyses are often independent parts, lacking a deep connection between quantitative and qualitative research methods.

Currently, scholars generally agree that achieving integrated urban–rural development requires close coordination and cooperation between urban and rural areas. The goal of integrated urban–rural development can be accomplished through positive interactions, such as complementing each other's roles, facilitating the movement of resources, and ensuring equal rights. However, the specific routes and strategies employed to achieve urban–rural coupling and coordinated development may vary across countries and regions due to differing circumstances. Several examples of urban–rural coordination and coupling can be observed, including the equalization model in Germany, the legislative-driven model in the United States, the transfer payment model in Canada, and the contemporary rural model in France [38]. Chinese scholars have devised a three-fold approach to integrated urban–rural development. Firstly, they rely on national policies such as new urbanization and rural revitalization strategies to establish a comprehensive framework for urban–rural integration, requiring collaborative efforts from both urban and rural regions [39,40]. Secondly, institutional reforms are emphasized to overcome the urban–rural divide and establish mechanisms that integrate urban and rural elements, thereby promoting positive interactions [41]. Lastly, a spatial planning system is constructed that takes into account land usage and promotes complementary urban–rural functions. This system recognizes the distinctive characteristics of urban–rural spatial development patterns, encompassing aspects such as production, lifestyle, and ecological spaces [42,43].

2.2. Research Framework

Based on the rules and policies regarding urban–rural development in China [44], the current state of urban–rural development in Northeast China is undergoing a transition from integrating urban and rural areas to achieving integrated urban–rural development [45]. The crucial foundation and requirement for this integrated development is the coordinated progress of urban and rural regions through their interaction and mutual influence. This principle aligns with the concept of the coupling coordination model [46]. Consequently, the degree of urban–rural coupling coordination is utilized to indicate the level of integration between urban and rural areas. The urban and rural regions together form a complex regional system that encompasses both human and environmental aspects. This urban–rural coupling and coordination system is an interconnected entity that relies on economic growth, signifies social progress, and depends on a healthy ecosystem in which humans play a central role (see Figure 1). Its objective is to achieve a dynamic equilibrium between urban and rural regions and promote equalization between them. The urban–rural coupling and coordination system consists of two main territorial systems—the urban system and the rural system—each characterized by distinct development strategies, foundations, and paths. While acknowledging the disparities in the meanings and manifestations of urban and rural regions, we can employ the orderly, rational, and efficient allocation of urban–rural elements to create a similar economic and social environment, as well as a comparable quality of life, in both urban and rural areas. When examining the development of the urban–rural relationship in Northeast China, it is important to consider the specific characteristics of this region, as well as the unique development and evolutionary traits of urban and rural areas. By doing so, we can effectively work towards the goal of achieving integrated urban–rural development.

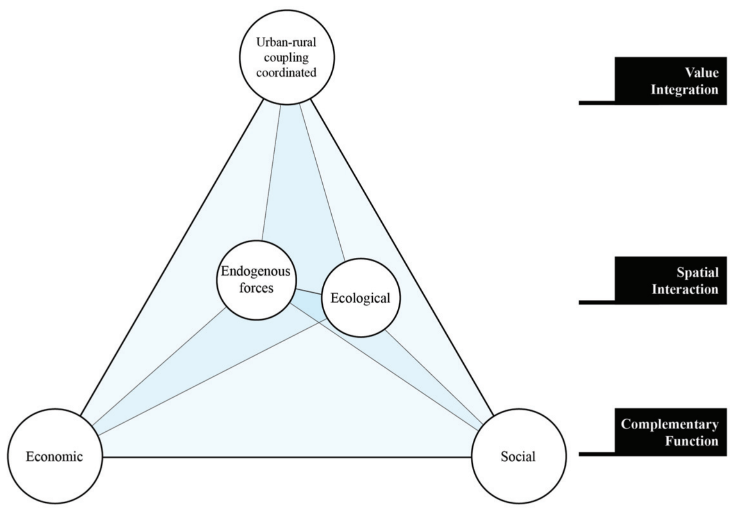

Figure 1. Urban–rural coupling and coordinated development goals.

The global economy is currently experiencing significant transformations and adjustments. The recovery of the world economy is slow, and the COVID-19 pandemic has worsened the global economic downturn. Northeast China's economy and society are confronted with numerous challenges, including the immense pressure of population decline and the widening gap between urban and rural areas. The reduction in population is a prominent feature of regions experiencing shrinkage. As a city goes through the process of shrinking, its development potential within the regional urban system declines either absolutely or relatively. This decline is evident in the outflow of development elements such as human capital, investment, factories, and businesses. Consequently, the city's central role in development weakens, making it difficult to drive rural development and diminishing the interaction between urban and rural areas [47]. This exacerbates the deprivation of rural regions by urban areas. In response, rural regions must utilize their agricultural and ecological advantages to achieve complementary urban–rural functions and gradually narrow the urban–rural gap. This approach may foster a higher level of integration between urban and rural areas. The research framework presented in Figure 2 of this paper aims to address the following questions: (1) How does population decline impact the coupling and coordinated development between urban and rural areas in Northeast China? (2) What changes occur in the spatial correlation characteristics of the coupling and coordinated development between urban and rural areas in Northeast China? (3) What factors influence the coupling and coordinated development between urban and rural areas in Northeast China, and to what extent do they contribute under the context of population shrinkage? To answer these questions, we analyzed the growth of urban and rural regions in Northeast

China, considering the impact of population decline, using a standard framework for geographical research that encompasses processes, patterns, and mechanisms.

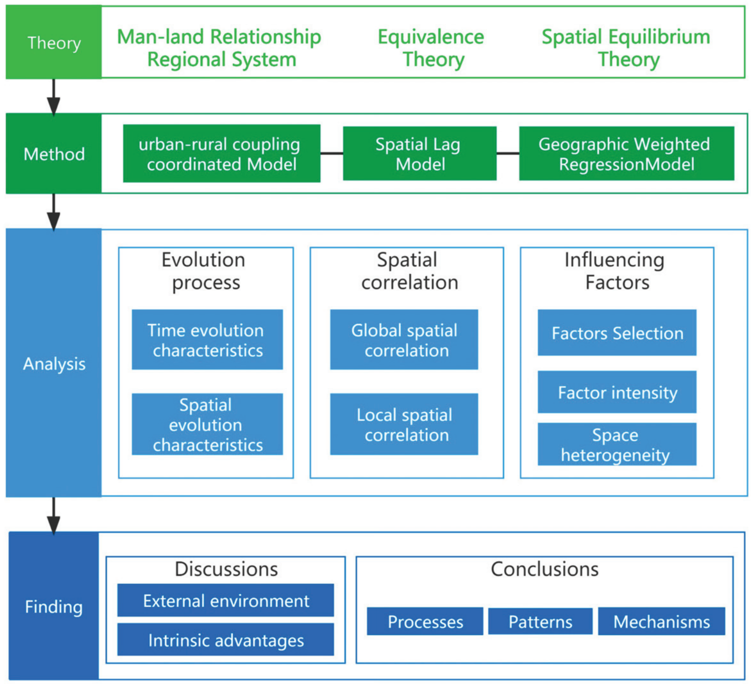

Figure 2. Theoretical framework diagram.

3. Study Area, Data Sources, and Research Methods

3.1. Study Area and Data Sources

3.1.1. Overview of the Study Area

Northeast China, situated in the northeastern part of China, possesses fertile land and abundant forest and mineral resources (Figure 3). It serves as a significant heavy industry and agricultural hub in China, playing a crucial role in ensuring national defense security, food security, ecological preservation, and industrial stability. As a distinct economic and geographical entity, Northeast China has undergone its own distinctive historical development. Following the establishment of the People's Republic of China, it emerged as a vital center for heavy industries, commodity grain production, energy production, and forestry, making substantial contributions to the country's economic progress. However, since the advent of economic reforms and opening up, the region has experienced a significant deceleration in economic growth, becoming one of the pressing challenges in China's regional economic development. The changes in population within Northeast China have closely paralleled its economic growth. Between 2000 and 2020, the total population of the region witnessed two distinct phases: A period of slow growth, followed by a period of rapid decline. From 2000 to 2010, the population increased from 106.55 million to 109.51 million, exhibiting a growth rate of approximately 2.7% and an average annual increase of 296,000 individuals. However, during this period, the population of 11 cities in the region experienced a decline. Subsequently, from 2010 to 2020, a period of swift population decrease occurred, resulting in the region's population dropping from 109.51 million to 98.51 million, reflecting a decrease rate of around 10% and an average annual decline of 1.1 million people. Only Shenyang, Dalian, and Changchun observed growth in their overall population. The population dynamics in Northeast China from 2000 to 2020 can be categorized as the initial stage of population shrinkage from 2000 to 2010, followed by a phase of comprehensive population decline from 2010 to 2020, based on the distinctive characteristics observed.

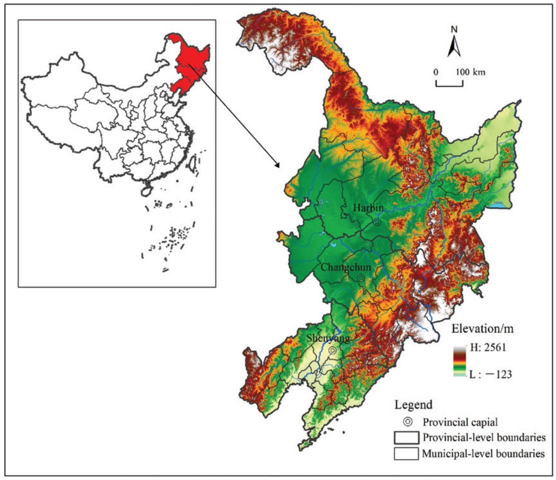

Figure 3. Overview of the research region.

3.1.2. Data Sources

The population data utilized in this research paper were obtained from the fifth, sixth, and seventh China Census Yearbooks. Economic and social data primarily originated from the China City Statistical Yearbook, Jilin Statistical Yearbook, Heilongjiang Statistical Yearbook, and Liaoning Statistical Yearbook. In instances where needed, we supplemented our analysis with data from the corresponding years' editions of the national economic and social development bulletins for the prefecture-level cities in Northeast China. The fundamental geographic data were derived from the 1:4 million database of the National Geomatics Center of China, while data on arable land, forests, grasslands, and water areas were gathered from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences (http://www.resdc.cn/ (accessed on 20 May 2023)). This analysis exclusively covers 34 prefecture-level cities in Heilongjiang, Jilin, and Liaoning provinces, as specific economic and social statistics for the Greater Khingan Mountains area and Yanbian Autonomous Prefecture are unavailable. Within this study, the term "urban" refers to the central urban regions of the prefecture-level cities, while "rural" pertains to the surrounding counties and county-level cities.

3.2. Study Methods

3.2.1. Evaluation of Integrated Urban–Rural Development Level

The meaning of integrated urban–rural development, which involves the positive relationship between urban and rural areas, can be understood through a logical analysis of the evolution process. To measure the level of integrated urban–rural development, a coupling coordination model was employed. Considering the strategic significance and distinct regional characteristics of Northeast China, a comprehensive indicator system was created to assess the coupling and coordination between urban and rural areas. This multi-dimensional system encompassed the dimensions of economy, society, and ecology [48] and was developed based on existing research findings [29,49–52], adhering to the principles of comprehensiveness, scientific rigor, comparability, and practicality (Table 1).

Table 1. Evaluation index system for the development level of urban–rural coupling and coordination.

System	Dimension	Indicators	Unit	+/−	System	Dimension	Indicators	Unit	+/−
Urban	Economy	Output value of secondary and tertiary industries	CNY	+	Rural	Economy	Output value of primary and secondary industries	CNY	+
		Proportion of the output value of secondary and tertiary industries	%	+			Proportion of the output value of primary and secondary industries	%	+
		Labor productivity of secondary and tertiary industries	CNY/person	+			Labor productivity of primary and secondary industries	CNY/person	+
		Total social fixed asset investment	CNY	+			Total social fixed asset investment	CNY	+
		Local fiscal revenue	CNY	+			Grain output	Ton	+
		Average wage	CNY	+			Average wage	CNY	+
	Society	Per capita disposable income	CNY	+		Society	Per capita disposable income	CNY	+
		Per capita consumption expenditure	CNY	+			Per capita consumption expenditure	CNY	+
		Public budget expenditure per capita	CNY	+			Public budget expenditure per capita	CNY	+
		Total number of teachers and students in primary and secondary schools per 1000 people	Person	+			Total number of teachers and students in primary and secondary schools per 1000 people	Person	+
		Number of beds in hospitals and health centers per 1000 people	Bed	+			Number of beds in hospitals and health centers per 1000 people	Bed	+
		Books collected in public libraries per 1000 people	Book	+			Books collected in public libraries per 1000 people	Book	+
	Ecology	Green area per capita	m^2	+		Ecology	Average fertilizer consumption per hectare	Ton/ha	−
		Green coverage rate of built-up area	%	+			Forest coverage rate	%	+
		PM2.5	um	−			Proportion of grassland area	%	+
		Proportion of built-up area	%	−			Proportion of water area	%	+

In this paper, we employed the entropy method to establish indicator weights, computed the urban development index and rural development index through a comprehensive index approach, and subsequently, employed the coupling coordination model to assess the level of coupling and coordination between urban and rural areas [53].

3.2.2. Analysis of the Spatial Pattern Characteristics of Integrated Urban–Rural Development

Spatial analysis techniques, encompassing global and local spatial correlation analysis, were utilized to investigate the spatial correlation and variance of the interconnectedness and coordination between urban and rural areas. To assess the overall spatial autocorrelation of the coordinated development between urban and rural areas in Northeast China, the global Moran's I index was employed. The calculation formula for this index is as follows:

$$I = n\sum_{i=1}^{n}\sum_{j\neq i}^{n} W_{ij}(x_i - \overline{x})(x_j - \overline{x}) / \sum_{i=1}^{n}\sum_{j\neq i}^{n} W_{ij}\sum_{i=1}^{n}(x_i - \overline{x})^2 \quad (1)$$

where n represents the number of observations, x_i and x_j represent the coordinates of x, $\overline{x}$ represents the mean value, and W_{ij} represents the spatial weight matrix adjusted according to adjacent standards.

The Z-test was used to determine the significance of the global Moran's I. The calculation formula is as follows:

$$Z(I) = [I - E(I)]/\sqrt{Var(I)} \tag{2}$$

where $E(I)$ is the mathematical expectation of Moran's I and $Var(I)$ is the variance of Moran's I.

The local Moran's I was used to explore specific clusters within spatial regions; even if the global Moran's I was 0, there may still be local spatial clustering phenomena. The calculation formula is as follows:

$$I_i = \frac{Z_i}{S^2}\sum_{j\neq i}^{n} w_{ij}Z_j, \tag{3}$$

where $Z_{i=}y_i - \overline{y}$, $Z_j = y_j - \overline{y}$, $S^2 = 1/n\sum(y_i - y_j)^2$, w_{ij} represents the spatial weight, n represents the total number of regions in the study area, and I_i represents the local Moran's index of the i-th region.

3.2.3. Analysis of Influencing Factors of Integrated Urban–Rural Development

The synchronized progress of urban and rural areas relies on both internal factors within these regions and external factors related to the overall urban–rural environment. These factors play a crucial role in promoting the harmonious development of urban and rural regions, as well as influencing their outward features. Urban–Rural factors such as population, economy, space, and natural environment [54] significantly influence the interconnection and coordinated growth of urban and rural areas [55] (Table 2).

Table 2. Selection and explanation of factors influencing urban–rural coupling and coordination.

Type	Variable	Variable Meaning
Population	Scale of urban and rural population	Total population of urban and rural regions (persons)
	Level of urbanization	Proportion of urban population to the total population of urban and rural regions (%)
	Labor force scale in urban and rural regions	Total employed population (persons)
	Urban and rural labor structure	Proportion of employed population in secondary and tertiary industries to the total population (%)
Economy	Regional economic development level	Per capital GDP (CNY)
	Level of opening up	Import and export trade volume (CNY)
Space	Proportion of built-up area	Proportion of built-up area to administrative area (%)
	Urban–rural connectivity	Proportion of road area to administrative area (%)
Natural conditions	Climatic conditions	Average temperature (°C)
	Topographic conditions	Mean elevation (m)

This paper introduces the Spatial Lag Model (SLM) and Spatial Error Model (SEM) in Geoda to analyze the global spatial correlation effects of the factors affecting urban–rural coupling and coordination, based on Ordinary Least Squares (OLS) in spss. In addition, the Geographic Weighted Regression (GWR) method is introduced to analyze spatial heterogeneity in arcgis.

In this paper, in the process of exploring the factors influencing the spatio-temporal evolution of urban–rural integration in the Northeast, ordinary least-squares regression (OLS) was first performed on the independent and dependent variables, and the independent variables with covariance can be accurately screened by excluding them through stepwise regression. The analysis of the spatial process of the evolution of urban–rural integration in Northeast China shows that there is a significant spatial correlation, so the Spatial Lag Model (SLM) and Spatial Error Model (SEM) are introduced to analyze the influencing factors of the changes in the level of urban–rural integration. Compared with Ordinary Least Squares (OLS), the Spatial Econometric Model fully considers the unit space and effectively avoids biased or invalid regression results, which weaken the explanatory ability of the model. The Geographic Weighted Regression (GWR) method is used to study spatial heterogeneity because changes in geographic location usually lead to changes in the relationship between the dependent variable and the independent variable, which in turn causes changes in the relationship or structure between the variables.

The expression of the spatial lag model is:

$$Y = \rho W_y + \beta X + \varepsilon \tag{4}$$

where Y is the dependent variable, X is the independent variable, W is the spatial weight matrix, W_y is the spatial lag term, and ρ is the spatial lag coefficient. β is the parameter vector of X. ε represents the random disturbance term, which follows a normal distribution, that is $\varepsilon \backsim \mathrm{N}\left(0, \delta^2\mathrm{I}\right)$, where I is the identity matrix.

The expression for the spatial error model is as follows:

$$Y = \rho W_y + \beta X + \varepsilon \tag{5}$$

$$\varepsilon = \lambda W \varepsilon + \mu$$

where Y is the dependent variable, X is the independent variable, W is the spatial weight matrix, β is the regression residual vector, and λ is the spatial error term coefficient. μ is a normally distributed random error vector, that is $\mu \backsim N\left(0, \delta^2 I\right)$.

We employed Geographical Weighted Regression (GWR) to identify the spatial diversity in the impacts of different independent factors on the interconnection and coordination between urban and rural areas in Northeast China. We also examined the magnitude and direction of these independent variables. The model expression is provided below.

$$y_j = \beta_0\left(\mu_j, v_j\right) + \sum_k \beta_k\left(\mu_j, v_j\right) x_{jk} + \varepsilon_j \quad j = 1, 2, \ldots, n \tag{6}$$

In the above equation, y_j and x_{jk} are the observed values of the dependent variable y and the independent variable x_{jk} at coordinates μ_j and v_j of the j-th sampling point, respectively. $\beta_k\left(\mu_j, v_j\right)$ is the k-th regression parameter at the j-th sampling point; point j is called the regression point, and $\varepsilon \backsim N\left(0, \delta^2 I\right)$.

4. Results and Analysis

4.1. Temporal Evolution Characteristics of Integrated Urban–Rural Development Level

The level of coordination between urban and rural areas in Northeast China experienced a significant upward trend (Table 3). The degree of urban–rural coupling and coordination increased from 0.429 in 2000 to 0.624 in 2019, resulting in a net increase of 0.195 and an annual growth rate of 2%. The city that exhibited the highest growth rate was Dalian, while Qitaihe showed the lowest growth rate. During the initial phase of population decline, the urban–rural coupling coordination degree rose from 0.429 to 0.527, with a growth rate of 22.84% and an average annual increase of 0.01. Dalian showed the highest growth rate, whereas Suihua had the lowest growth rate during this period. In the comprehensive population decline stage, the urban–rural coupling coordination degree increased from 0.527 to 0.624, with a growth rate of 18.41% and an average annual increase of 0.011. Changchun had the highest growth rate, whereas Tieling had the lowest growth rate in this stage. When comparing the urban–rural coupling coordination degree during the initial phase of population decline to that during the comprehensive population decline, it was observed that the average annual growth rate in the latter was higher than in the former. This indicates that population decline did not impede the process of integrated urban–rural development; instead, it accelerated it.

Table 3. Results of urban–rural coupling coordination degree of prefecture-level cities in Northeast China in 2000, 2005, 2010, 2015, and 2019.

Coupling Coordination Degree	2000	2005	2010	2015	2019
Shenyang	0.427	0.460	0.575	0.660	0.685
Dalian	0.441	0.501	0.630	0.701	0.755
Anshan	0.399	0.445	0.529	0.576	0.604
Fushun	0.425	0.457	0.528	0.586	0.626
Benxi	0.452	0.473	0.547	0.612	0.647
Dandong	0.434	0.458	0.521	0.555	0.595
Jinzhou	0.395	0.429	0.491	0.557	0.622
Yingkou	0.373	0.408	0.499	0.563	0.628
Fuxin	0.394	0.431	0.469	0.518	0.564
Liaoyang	0.380	0.403	0.483	0.548	0.601
Panjin	0.412	0.444	0.507	0.570	0.598
Tieling	0.399	0.426	0.504	0.527	0.565
Chaoyang	0.436	0.469	0.519	0.565	0.601
Huludao	0.426	0.449	0.512	0.538	0.592
Changchun	0.426	0.459	0.550	0.632	0.695
Jilin	0.444	0.480	0.565	0.631	0.647
Siping	0.397	0.429	0.495	0.560	0.585
Liaoyuan	0.390	0.424	0.496	0.546	0.569
Tonghua	0.433	0.457	0.523	0.579	0.600
Baishan	0.420	0.481	0.547	0.606	0.650
Songyuan	0.417	0.463	0.530	0.591	0.617
Baicheng	0.424	0.447	0.484	0.546	0.586
Harbin	0.470	0.516	0.606	0.709	0.733
Qiqihar	0.442	0.431	0.519	0.595	0.620
Jixi	0.459	0.480	0.527	0.586	0.629
Hegang	0.462	0.485	0.538	0.569	0.619
Shuangyashan	0.445	0.475	0.527	0.599	0.601
Daqing	0.510	0.549	0.621	0.667	0.688
Yichun	0.458	0.482	0.517	0.568	0.613
Jiamusi	0.446	0.476	0.536	0.622	0.633
Qitaihe	0.419	0.436	0.482	0.512	0.569
Mudanjiang	0.450	0.471	0.541	0.622	0.639
Heihe	0.462	0.478	0.537	0.602	0.643
Suihua	0.425	0.419	0.469	0.558	0.612
Mean	0.429	0.459	0.527	0.588	0.624

4.2. Analysis of the Spatial Correlation of Integrated Urban–Rural Development Level

4.2.1. Global Spatial Correlation

According to the analysis of the global Moran's I index for urban–rural coupling and coordination (Table 4), the level of urban–rural coupling and coordination in 2000 demonstrated that cities with high values of this degree were located close to each other, while cities with low values were also spatially adjacent. However, from 2005 to 2019, Moran's I index did not show any significant results ($p > 0.1$), suggesting the absence of a notable spatial correlation in urban–rural coupling and coordination in Northeast China. Moreover, Moran's I index displayed a fluctuating downward pattern, indicating a gradual weakening of the integration and development of urban–rural areas in Northeast China due to a decline in population.

Table 4. Global spatial correlation test of urban–rural coupling and coordination in Northeast China.

Measurement Result	2000	2005	2010	2015	2019
Moran's I	0.34	0.08	−0.12	−0.07	−0.06
p	0.00	0.22	0.29	0.62	0.72
Significance	***				

Note: significance levels: ***: $p < 0.01$.

4.2.2. Local Spatial Correlation

The urban–rural coupling and coordinated development of Northeast China between 2000 and 2019 can be categorized into four types based on local spatial correlation: high–high agglomeration, high–low agglomeration, low–high agglomeration, and low–low agglomeration (Figure 4). In 2000, the overall level of urban–rural coordinated development exhibited predominantly low–low agglomeration, with a total of nine agglomerations mainly located in the central and northern parts of Liaoning Province. Qiqihar belonged to the high–high agglomeration type. By 2005, the overall level of urban–rural coordinated development continued to exhibit low–low agglomeration, but with four fewer cities in this category compared to 2000. Shenyang transitioned from high–high agglomeration to high–low agglomeration. In 2010 and 2015, the overall level of urban–rural coordinated development showed three types of spatial correlation: high–low agglomeration, low–high agglomeration, and low–low agglomeration, with one agglomeration representing each type. In 2019, the overall level of urban–rural coordinated development was divided into high–low agglomeration and low–high agglomeration, with the same spatial distribution as in 2015. It is evident that the spatial agglomeration of integrated urban–rural development in Northeast China has significantly decreased during a period of comprehensive population shrinkage.

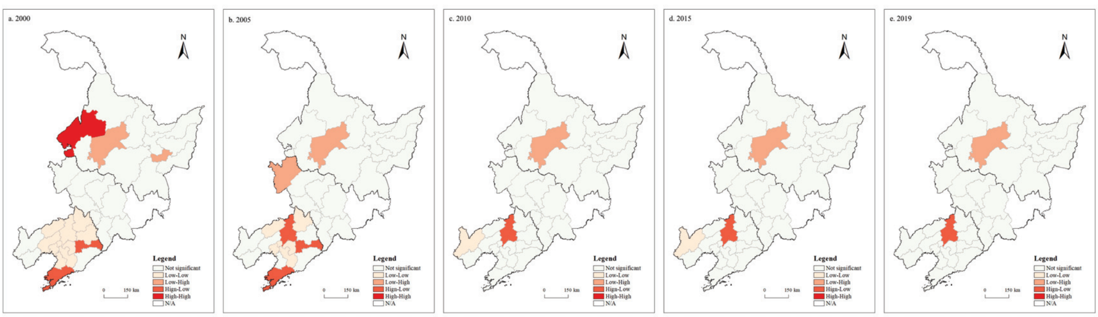

Figure 4. LISA clustering map of urban–rural coupling and coordination in Northeast China.

4.3. Analysis of Influencing Factors of Integrated Urban–Rural Development Level

4.3.1. Preliminary Study on Influencing Factors

Initially, we conducted an initial assessment of the independent variable related to the degree of urban–rural coupling and coordination. The assessment findings indicated a significant correlation between the degree of urban–rural coupling and coordination and six indicators: economic development level, labor force size, urbanization level, level of opening up, urban–rural accessibility, and proportion of built-up areas. It is worth noting that there was no multicollinearity observed among these variables.

To begin with, the GeoDa software was employed to conduct a regression analysis on the six factors mentioned earlier. After subjecting the model residuals to a spatial autocorrelation test, it was found that the Moran's I (error) values for the years 2000, 2005, 2015, and 2019 did not exhibit statistical significance. Additionally, both the Lagrange multiplier (lag) and Lagrange multiplier (error) were found to be insignificant. These results indicate that the ordinary least squares (OLS) model's regression outcomes are reliable, and there is no necessity to establish a spatial econometric model. However, in the case of the year 2010, the Moran's I (error) value amounted to 0.13 and demonstrated significance at a confidence level of 10.00%. This indicates the presence of significant spatial dependence in the regression error of the OLS model. Consequently, we decided to utilize the Spatial Lag Model (SLM) to estimate the influencing factors affecting the degree of coordination between urban and rural regions in 2010.

4.3.2. Factor Impact Analysis

Table 5 reveals the order of impact of various factors on urban–rural coupling and coordination in the year 2000. These factors, listed in descending order of influence, were urban–rural accessibility, economic development level, proportion of built-up areas, labor force size, and urbanization level. A negative correlation was found between urban–rural accessibility and the level of coordination between urban and rural regions. This means that improved accessibility of urban–rural roads resulted in a stronger "pull" effect from cities, leading to urban development at the expense of rural areas. A higher proportion of built-up areas within cities was found to have a detrimental effect on agricultural and rural development, as well as causing harm to the ecological environment. In 2005, the influencing factors ranked in descending order of impact were economic development level, urban–rural accessibility, proportion of built-up areas, urbanization level, and labor force size. The direction of impact remained consistent with that of the factors in 2000. The overall economic development level of prefecture-level cities emerged as the most-significant driver of urban–rural coordinated development. This suggests that higher economic development levels in prefecture-level cities corresponded to more-synchronized development between urban and rural regions.

Table 5. Analysis of factors affecting the degree of urban–rural coupling and coordination in Northeast China in 2000, 2005, 2010, 2015, and 2019.

Variable	2000	2005	2015	2019
Economic development level	0.63 ***	0.80 ***	0.73 ***	0.26
Labor force size	0.37 ***	0.27 **	0.77 ***	0.79 ***
Urbanization level	0.36 ***	0.28 **	0.03	0.16
Level of opening up	0.01	0.10	0.05	0.24 *
Urban–rural accessibility	−0.72 ***	−0.64 ***	−0.53 ***	−0.51 **
Proportion of built-up areas	−0.54 ***	−0.49 ***	−0.39 ***	−0.05
R^2	0.77	0.75	0.84	0.81
Adjusted R^2	0.72	0.69	0.81	0.76
LogL	−22.44	−24.20	−16.44	−19.90
AIC	58.88	62.40	46.88	53.81
SC	69.57	73.08	57.56	64.50

Note: significance levels: *: $p < 0.1$, **: $p < 0.05$, ***: $p < 0.01$.

The estimation was conducted to determine the factors influencing the degree of coordination between urban and rural areas in 2010. By employing the Spatial Lag Model (SLM) and examining Table 6, the fitting results of the model were enhanced and refined. The coefficient of determination (R2) improved to 0.89, while the spatial regression coefficient reached 0.23, indicating a close relationship between the coordination degree and the surrounding prefecture-level cities. When considering the spatial relationships of the units, it was found that the economic development level, labor force size, urbanization level, and the level of openness were positively associated with the coordination degree. Conversely, urban–rural accessibility and the proportion of built-up areas showed negative correlations with the coordination degree. In terms of impact, the influencing factors ranked as follows: the economic development level had the highest impact, followed by labor force size, urban–rural accessibility, proportion of built-up areas, level of openness, and urbanization level.

The order of influential factors on urban–rural coupling and coordination in 2015 was as follows: the size of the labor force had the greatest impact, followed by the level of economic development, urban–rural accessibility, and the proportion of built-up areas. The size of the labor force in cities at the prefecture level was the most-crucial factor in fostering coordinated development between urban and rural areas. In Northeast China, where labor-intensive industries were prominent, a larger labor force resulted in higher output value, thereby playing a significant role in the coordinated development of urban and rural regions. In 2019, the order of influential factors shifted, with the size of the labor force remaining the most-influential, followed by the level of opening up and urban–rural accessibility. The level of opening up had a positive correlation with coordinated development between urban and rural areas. The increase in total imports and exports contributed to economic and social development, providing support for urban–rural development.

Table 6. Analysis results of factors affecting the coordination degree of urban–rural coupling and coordination in Northeast China in 2010.

Variable	OLS		SLM	
	Weight	Standard Error	Weight	Standard Error
Economic development level	0.74 ***	0.1	0.74 ***	0.08
Labor force size	0.60 ***	0.09	0.58 ***	0.08
Urbanization level	0.14 *	0.08	0.15 **	0.07
Level of opening up	0.25 ***	0.07	0.23 ***	0.06
Urban–rural accessibility	−0.50 ***	0.12	−0.49 ***	0.11
Proportion of built-up areas	−0.26 ***	0.09	−0.28 ***	0.08
W-Y	-		−0.23	0.12
R^2	0.88		0.89	
Adjusted R^2	0.85		-	
LogL	−11.94		−10.29	
AIC	37.88		36.59	
SC	48.57		48.8	

Note: significance levels: *: $p < 0.1$, **: $p < 0.05$, ***: $p < 0.01$.

In conclusion, when the population decreases, several factors that influence the situation undergo intricate transformations in their effects. The influence of economic development level, urbanization level, urban–rural accessibility, and the proportion of built-up areas diminishes, while the influence of labor force size and the level of openness increases. When comparing the early stage of population decline with the later stage encompassing multiple aspects, the impact of the economic development level on the overall development of both urban and rural areas in Northeast China initially rises and subsequently declines.

4.3.3. Factor Spatial Heterogeneity Analysis

Spatial Heterogeneity Modeling Results

In ArcGIS 10.7, we compared and analyzed the factors that significantly impact the relationship between urban and rural areas in Northeast China, as identified in the previous section. We employed two regression methods, namely Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR). Table 7 presents the results, showing that the GWR model had a higher fitting coefficient and a lower AICc value compared to the OLS model. This suggests that the GWR model provides a better fit. After applying the GWR model, we examined the standardized residuals of the prefecture-level city units for the years 2000, 2005, 2010, 2015, and 2019. The analysis revealed that all of these years had standardized residuals falling within the range of [−2.5Std.Dev., 2.5Std.Dev.], with percentages of 100%, 100%, 100%, 97%, and 100%, respectively. This indicates that the GWR model produced residuals that are well-behaved and within the expected range. Furthermore, we conducted a spatial autocorrelation test on the standardized residuals based on the GWR model. The test resulted in Moran's I values of −0.01, −0.09, 0.07, −0.07, and −0.11 for the respective years, accompanied by corresponding Z-values of 0.12, −0.70, 1.08, −0.47, and −0.94. These values indicate that the regression residuals of the GWR model are randomly distributed across space and the model parameters have successfully passed the test.

Table 7. Comparison of parameter estimation between OLS and GWR models for factors influencing urban–rural coupling and coordination development.

Year	Model	R^2	Adjusted R^2	AICc
2000	OLS	0.774	0.733	63.290
	GWR	0.775	0.734	63.269
2005	OLS	0.740	0.694	67.931
	GWR	0.741	0.695	67.929
2010	OLS	0.878	0.851	45.643
	GWR	0.879	0.852	45.642
2015	OLS	0.839	0.817	48.367
	GWR	0.931	0.893	39.912
2019	OLS	0.758	0.734	59.320
	GWR	0.770	0.739	59.105

Spatial Heterogeneity Analysis

Figure 5 displays the GWR model fitting outcomes regarding the diverse factors influencing the coordination between urban and rural areas in Northeast China during the year 2000. The regression coefficients related to the level of economic development exhibit an increasing trend from the southern to the northern regions. This suggests that the integrated urban–rural development in Heilongjiang Province was significantly influenced by the economic development level. Conversely, the regression coefficients for the size of the labor force show a decreasing pattern from the southwest to the northeast. The large population and abundant labor resources in Liaoning Province, located in Northeast China, exert a substantial impact on the integrated urban–rural development. Regarding the urbanization level, the regression coefficients demonstrate a gradual weakening trend from the south to the north, with the most-notable influence observed in Dalian and its surrounding cities. In terms of urban–rural accessibility, the regression coefficients exhibit a gradual decline from the west to the east, indicating significant polarization. This suggests that inland cities are heavily affected by urban–rural accessibility. Lastly, the regression coefficients associated with the proportion of built-up areas reveal a gradual weakening pattern from the southeast to the northwest, highlighting the strong influence of this factor on the eastern border cities.

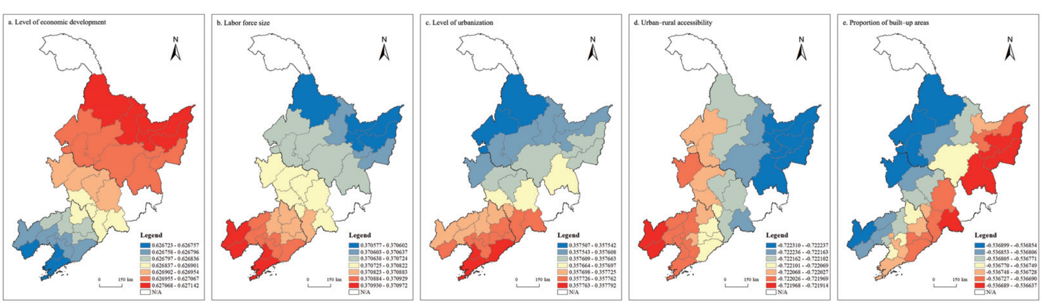

Figure 5. Spatial distribution maps of the changing impact of the influencing factors on the urban–rural coupling and coordination in 2000.

Figure 6 illustrates the outcomes of the GWR model fitting, which examines the factors influencing urban–rural coordination in different prefecture-level cities in Northeast China during 2005. The results indicate certain trends based on the regression coefficients of various variables. Specifically, the coefficients for economic development level, urbanization level, and the proportion of built-up areas exhibit an increasing pattern from the southwest to the northeast. The areas with higher coefficient values are predominantly located in Heilongjiang Province. Conversely, the coefficients for labor force size progressively decrease from the south to the north, suggesting a diminishing impact. However, eastern border cities exhibit a strong influence in this regard. Moreover, the coefficients for urban–rural accessibility gradually decline from the southwest to the northeast, with regions of higher coefficient values concentrated in Liaoning Province.

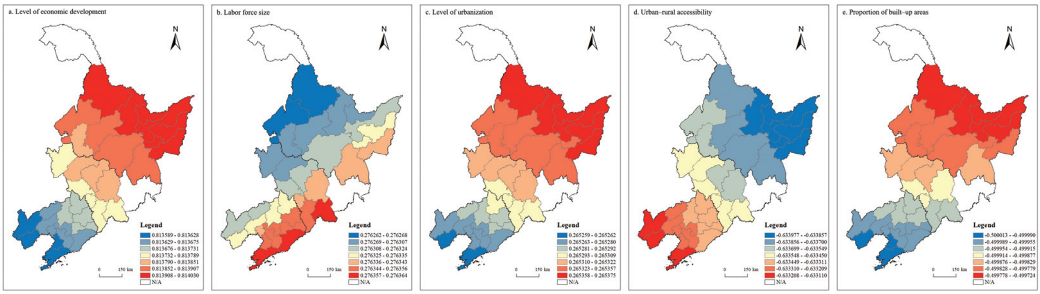

Figure 6. Spatial distribution maps of the changing impact of the influencing factors on the urban–rural coupling and coordination in 2005.

Figure 7 illustrates the outcomes of fitting the GWR model to examine the different factors affecting urban–rural coordination in Northeast China in 2010. The regression coefficients for the economic development level exhibit an upward trend from the northern to the southern regions, with areas of high value concentrated around Dalian and its neighboring cities. The coefficients for labor force size and the proportion of built-up areas display a progressive increase from the southwest to the northeast. As for the urbanization level, the regression coefficients gradually rise from the southern to the northern areas, particularly impacting Heilongjiang Province. In terms of the level of opening up, the coefficients follows a pattern of higher values in the western regions and lower values in the eastern regions, exerting a significant influence on cities in the west. Lastly, the regression coefficients for urban–rural accessibility show a gradual decrease from the southwest to the northeast, with southwestern cities in Liaoning Province having a strong influence.

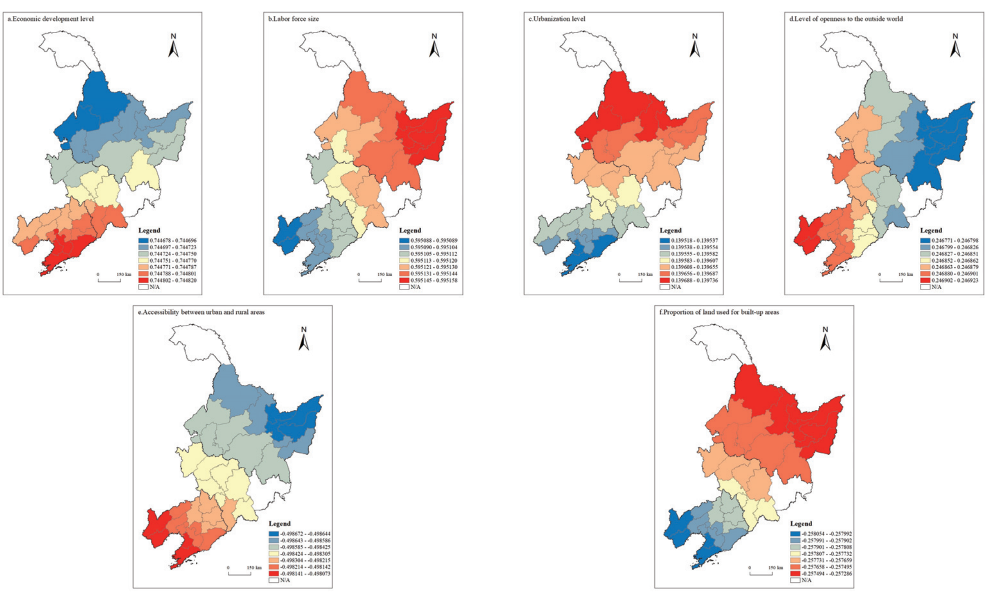

Figure 7. Spatial distribution maps of the changing impact of the influencing factors on the urban–rural coupling and coordination in 2010.

Figure 8 displays the GWR model fitting outcomes regarding the influencing factors of urban–rural coordination in different prefecture-level cities in Northeast China during the year 2015. The results reveal several trends. Firstly, the regression coefficients for the economic development level exhibit a progressive decline as one moved from the southeast to the northwest. These coefficients have a significant impact, particularly in the cities located on the border between Jilin Province and Liaoning Province. Secondly, the regression coefficients for the labor force size and proportion of built-up areas demonstrate higher values in the northern regions and lower values in the southern regions. In particular, the areas with high coefficients are concentrated in Heilongjiang Province. Lastly, the regression coefficients for urban–rural accessibility show a decreasing gradient from the southwest to the northeast. The cities in Liaoning Province experienced a substantial impact in terms of these coefficients.

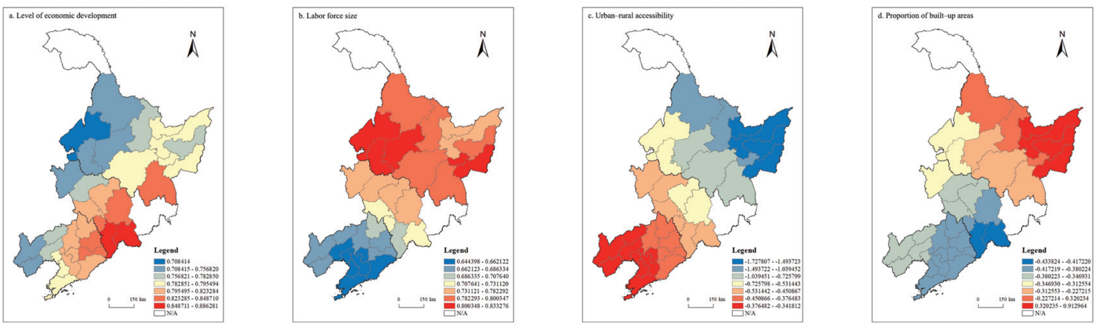

Figure 8. Spatial distribution maps of the changing impact of the influencing factors on the urban–rural coupling and coordination in 2015.

Figure 9 presents the outcomes of GWR model fitting, which examines the impact of different factors on urban–rural coordination in Northeast China during 2019. The findings indicate that the regression coefficients for labor force size demonstrate a declining trend from the northeast to the southwest. Similarly, the regression coefficients for the level of opening up exhibit a gradual weakening pattern from west to east. Furthermore, the regression coefficients for urban–rural accessibility indicate a progressive increase in gradients from the northeast to the southwest.

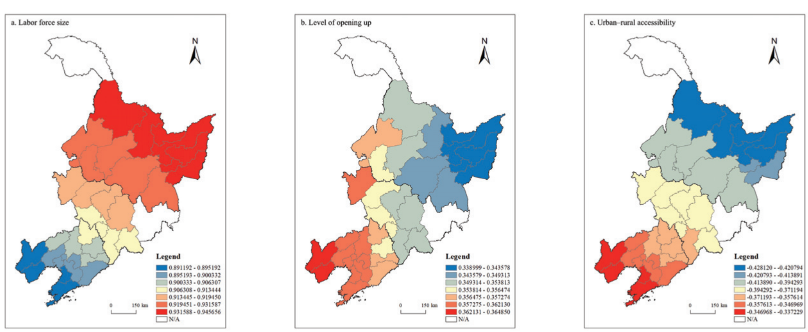

Figure 9. Spatial distribution maps of the changing impact of the influencing factors on the urbanrural coupling and coordination in 2019.

Empirical analysis demonstrates that the size of the workforce and the accessibility between urban and rural areas have the most-notable influence on the connection and coordination between these regions. Initially, when population shrinkage began, the impact of workforce size was low in the northeast and high in the southwest, but later shifted to high in the north and low in the south during comprehensive population shrinkage. Between 2010 and 2019, the total population of all cities in Heilongjiang Province decreased by 6.25 million, indicating a severe decline. Consequently, the influence of workforce size gradually increased, playing a more-significant role in the development of integrated urban–rural areas. The impact of urban–rural accessibility changed from being high in the west and low in the east to low in the northeast and high in the southwest. This suggests a stronger demand for urban–rural accessibility in the southwestern part of the region and a lack of access in rural areas caused by cities in the western part of Northeast China. Regarding the impact of the economic development level, it initially showed high values in the northeast and low values in the southwest during the population shrinkage phase. However, during comprehensive population shrinkage, the situation reversed, with low values in the north and high values in the south. The areas with high economic development shifted from Heilongjiang Province to Liaoning Province. Similarly, during comprehensive population shrinkage, the impact of the economic development level was low in the northwest and high in the southeast, with high-value areas shifting from Dalian and its surroundings to the border cities between Jilin Province and Liaoning Province. The influence of the proportion of built-up areas also changed throughout the population shrinkage process. Initially, it was low in the west and high in the east, but during comprehensive population shrinkage, it became high in the northeast and low in the southwest, with a greater impact in the northeast. A higher proportion of built-up areas corresponded to a higher level of rural development driven by cities and enhanced integrated urban–rural development. The impact of the urbanization level varied as well, initially being low in the north and high in the south during population shrinkage. The increasing urbanization level of cities in Heilongjiang Province played a role in improving integrated urban–rural development. On the other hand, the impact of the level of opening-up remained unchanged during the population shrinkage process, with the west showing high levels of openness and the east showing low levels of openness.

5. Discussion

5.1. Choosing to Follow the Suitable Path of Integrated Urban–Rural Development in Northeast China

There are two types of coordinated development models for urban and rural regions. The first type is when urban regions drive the development of rural regions. In this case, the progress of urban development has a positive effect on rural areas, leading to coordinated development. The second type is when rural regions promote the development of urban regions. In this scenario, rural areas contribute to urban development based on their own unique characteristics and advantages. In the case of Northeast China, the urban–rural relationship has traditionally followed the model where urban regions drive rural development. However, currently, Northeast China is facing a severe economic downturn, and there is increasing pressure on rural development driven by urban areas. Based on an analysis of the spatial development pattern, during the initial stage of population shrinkage, the areas with high-value integrated urban–rural development were primarily located in the northeastern part of Northeast China [56]. However, as the population shrinkage progressed, these high-value areas shifted towards sub-provincial cities and their surrounding regions [13]. This indicates that Northeast China still prioritizes the development of large cities, as they possess significant resources for high-quality development [57]. Particularly in the context of population shrinkage, the migration of people to large cities has provided them with a significant advantage in terms of labor force. These cities drive the development of the surrounding rural areas through positive ripple effects, facilitating urban–rural integration. Therefore, it is essential to optimize the spatial structure of large, medium, and small cities and towns in Northeast China. Upgrading the functional levels of cities such as Harbin, Changchun, Shenyang, and Dalian is necessary, along with promoting the construction and development of the Harbin–Changchun Megalopolis and the Central–Southern Liaoning Megalopolis [29]. Small- and medium-sized cities and towns are experiencing more-severe population shrinkage, so it is crucial to strengthen agricultural and ecological industries to guide transformation and facilitate rural revitalization.

5.2. History and Culture Work Together in Northeast China; Policies and the Economy Should Be Increased to Promote Urban–Rural Integration

The research findings suggest that the labor force size and accessibility between urban and rural areas are significant factors influencing integrated urban–rural development. These factors are closely linked to the actual circumstances of population decline and the historical urban–rural relationship in Northeast China [58]. The labor force serves as a regulating and dominant factor in the development of urban and rural areas, reflecting the level of knowledge, technology, and management. Population decline is an undeniable reality in Northeast China, particularly in small- and medium-sized cities and rural regions [59]. This is especially evident in the decreasing number of young and middle-aged workers, the growing aging population, and the significant outflow of highly skilled individuals. Consequently, there is a severe shortage of producers, implementers, and organizers of development in Northeast China, exacerbating the urban–rural gap [60]. The historical urban–rural divide in Northeast China, combined with ingrained thinking patterns and the lack of appeal in rural areas results in a one-way flow of population from rural to urban regions. This hinders the optimization of talent factors and impedes urban–rural integration. Urban–rural accessibility has a notably negative impact on the integrated development of urban and rural areas, highlighting the urban deprivation experienced by rural regions in Northeast China. This is due to a longstanding history of urban areas drawing resources from rural areas through attraction and, subsequently, driving rural development through radiating effects. As a result, urban development progresses at a faster pace than rural development. Following the reform and opening up, Northeast China struggled to adapt to a market-oriented development model, leading to slow development in major cities and a decline in rural areas. In the context of population decline, the influence of urban–rural accessibility on integrated urban–rural development has diminished. Therefore, it is crucial to address the one-way flow of urban and rural development elements in Northeast China [61]. Allowing the free movement of these elements is an essential requirement and a significant manifestation of urban–rural linkage and coordinated development. The government should implement policies that promote the unrestricted two-way flow of urban and rural development elements, ensuring that urban development elements also contribute to rural regions. This will foster a development model that supports rural progress through urban collaboration [62]. Since the founding of China, the Chinese Government has convened four Central Urban Work Conferences and 28 Central Rural Work Conferences, and since the 16th National Congress of the Party, it has issued 11 documents on Northeast China's revitalization and a number of policies on urban–rural integration and development, which have pointed out the direction of urban–rural development in the Northeast region. In the future, policies for the integrated development of urban and rural areas in Northeast China should be proposed in light of the characteristics of Northeast China and in accordance with local conditions.

5.3. The Shrinking Population Is an Opportunity to Create a New Model of Urban–Rural Development, Taking into Account the Characteristics of Northeast China

In the broader context of both domestic and international conditions, factors such as the global economic slowdown, slow economic recovery, decline in globalization, and power struggles among major nations have resulted in a reduced contribution of the export-oriented economy to China's economic growth. This situation presents significant challenges to China's economic development. In response, China has introduced the dual-circulation strategy, emphasizing domestic economic circulation as the primary focus [63]. The domestic economic circulation is closely linked to both urban and rural areas [64], with the rural regions holding considerable potential. As China undergoes rapid urbanization, the disparities between urban and rural areas have become increasingly evident. The relationship between urban and rural areas has shifted from rural areas supporting cities to cities driving rural development. Consequently, agricultural and rural development have gained significant attention [65]. Looking ahead, Northeast China is expected to continue experiencing a decline in population for a certain period. The urban population will mainly concentrate in large cities, while the rural population will further decrease. To address this situation, it is crucial to pursue integrated urban–rural development through a coordinated approach, fostering a mutually beneficial relationship between urban and rural areas. This approach is essential for promoting the transformation of Northeast China. Considering the current regional conditions and key development areas in China, Northeast China possesses a strong agricultural and ecological foundation [66], providing a favorable late-mover advantage. This advantage aligns with national policies and strategies. It is feasible to address the gaps in rural development in Northeast China, achieve industrial optimization, and undergo spatial reconstruction through transformative measures [67]. By attracting the return of the population, fostering positive interactions between urban and rural areas [68], and creating a development pattern characterized by significant urban centers, thriving agriculture, and a well-preserved ecosystem, a high-quality development of both urban and rural regions can ultimately be achieved [69].

Based on the study of spatial and temporal evolution characteristics and influencing factors of urban–rural integration development in Northeast China under the background of population shrinking, this paper empirically analyzed the stage, spatial correlation, and heterogeneity characteristics of urban–rural integration development in Northeast China and obtained some basic conclusions of practical significance, which can provide references for the revitalization of Northeast China and the high-quality urban–rural development. The planning response to urban–rural integration in Northeast China in response to population shrinkage and the paths and measures of response are also worthy of in-depth study in the future. Meanwhile, there are still some shortcomings in this paper, such as the indicators need to be further updated and some data are unavailable due to the impact of the New Crown Pneumonia epidemic, and the research will be carried out in the future by using a multisource data approach.

6. Conclusions

In relation to the decline in population, we focused on investigating the spatial and temporal changes and factors influencing the integrated development of urban and rural areas in Northeast China. We examined how urban and rural areas evolved and developed in coordination with each other in Northeast China. We identified the factors that impact the coordination and development between urban and rural areas in Northeast China and employed spatial econometric models to assess the extent and direction of influence of each factor. The key findings are summarized as follows:

The level of urban–rural coupling and coordination in Northeast China has shown a gradual increase from 2000 to 2019. During the comprehensive population shrinkage phase, the growth rate of the urban–rural coupling coordination degree was higher compared to the initial stage of population shrinkage. As the population decreases in Northeast China, the distribution of areas with a high urban–rural coupling coordination degree has become more concentrated in four sub-provincial cities, moving away from northeastern Heilongjiang. In 2000, there was a significant spatial correlation in the urban–rural coupling and coordination level of Northeast China on a global scale. When considering local spatial correlation, the urban–rural coupling and coordinated development in Northeast China can be classified into four types: high agglomeration, high–low agglomeration, low–high agglomeration, and low–low agglomeration, with the low–low agglomeration being the dominant type. As the population decreases, the spatial correlation of urban–rural coupling and coordinated development in Northeast China gradually diminishes.

The examination of the factors that affect the connection and cooperation between urban and rural areas in Northeast China revealed that there were significant correlations between urban–rural coupling and coordination and several variables, namely the level of economic development, size of the labor force, degree of urbanization, level of openness, urban–rural accessibility, and proportion of built-up areas. The impact of these various factors on urban–rural coupling and coordination displayed noticeable spatial variations, with differences in both the magnitude and direction of influence. Among these factors, the size of the labor force and urban–rural accessibility had the most-substantial effects on urban–rural coupling and coordination. The labor force size had a positive role, whereas urban–rural accessibility had a negative role. Furthermore, the impact of the economic development level demonstrated specific characteristics as the population decreased. Initially, it increased, but it later decreased during the stage of comprehensive population shrinkage.

Despite the population decline in Northeast China, it has not impeded the progress of integrated urban–rural development. However, this decline is closely linked to the influencing factors of integrated urban–rural development. In the future, Northeast China should capitalize on the development opportunities presented by national policies. By leveraging its strengths in industrial and agricultural foundations, as well as the ecological environment, Northeast China should elevate the development level of central cities and densely populated areas, strengthen the basis for rural development, and achieve industrial optimization and spatial reconstruction through a model of urban–rural development that promotes rural advancement through cities. Furthermore, it should encourage the return of talented individuals, facilitate the two-way flow of urban–rural development elements, establish a spatial development pattern characterized by significant cities, substantial agriculture, and a thriving ecosystem, foster high-quality urban and rural development, and ultimately, achieve the revitalization of Northeast China.

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buildings

Article

Reconstructing Social Segregation in Danwei: An Examination of High-Quality Education Resources' Impact on Housing Prices in Nanjing, China

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Abstract: This study investigates the impact of capitalizing educational resources on housing prices. As housing has gradually transitioned from a basic social right to a means of accumulating individual and familial wealth, it has emerged as a significant indicator of social stratification and has increasingly become a crucial tool for the intergenerational reproduction of social class. This paper takes Nanjing, China, as a case study and uses the geographically weighted regression model (GWR) and the hedonic pricing model (HPM) to investigate the impact of high-quality primary schools on housing prices. The results show that high-quality educational resources have become the most significant influencing factor on residential prices in Nanjing. The analysis in the mechanism section further indicates that the uneven distribution of educational resources in China is a continuation of the "danwei" system. Moreover, during the urbanization process, these high-quality educational resources are often leveraged by the government and developers, who see them as essential tools to attract investment and inflate housing prices. Therefore, the current overlap of the school district system and the marketization of housing in China not only intensifies residential segregation within the city, leading to severe residential inequality but also rebuilds social segregation within "danwei" and facilitates its reproduction.

Keywords: housing prices; school district system; social segregation; danwei; Nanjing; China

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1. Introduction

Housing equality, as a fundamental social right, has become a universal consensus among governments worldwide and policies relating to social fairness and equity should be advanced [1]. However, starting from the late 1970s, with the global penetration of neoliberal policies, housing has gradually shifted from a basic social right to an essential means of individual and familial wealth accumulation [2–4]. Relevant studies indicate that housing has not only become a significant indicator of social stratification but has also increasingly emerged as an important tool for the intergenerational reproduction of social class. For example, in China's basic education stage, due to the strict implementation of the "school district system", which requires students to attend nearby schools, urban advantaged families can ensure their children's eligibility to attend high-quality primary and secondary schools by purchasing housing in desirable school districts, thereby obtaining local household registration in that district [5]. Furthermore, research indicates that students from high-quality primary and secondary schools have a significantly higher proportion of admissions into top-tier high schools and prestigious universities compared to their counterparts from regular primary and secondary schools. This distinction subsequently influences their professional trajectories [6,7].

In fact, the school district system that allocates students to nearby public schools during the basic education phase is not unique to China. Most countries have adopted a similar method to address the issue of admission eligibility for public schools. However, due to the uneven distribution of high-quality educational resources, various methods, and studies targeting both developed and developing economies have consistently indicated a significant statistical correlation between housing prices and school quality [5,8–10]. Numerous studies have elucidated the process of the capitalization of educational resources from perspectives such as the accessibility of educational resources and imbalances between supply and demand, thereby revealing their spillover benefits on housing prices. For instance, research by Wen et al. [11] indicated that educational facilities have a positive impact on housing prices in Hangzhou. For every one-level improvement made in primary and junior high school quality, housing prices rise by 2.020% or 5.443%, respectively. Feng et al. [12], employing a natural experiment approach, confirmed that the differences between quantity and quality in high school educational facilities have been capitalized by Shanghai's housing prices. Residential inequality caused by the price filtering mechanism or housing affordability and the resulting residential segregation is very common [13]. However, as mentioned above, when residential segregation overlaps with high-quality educational resources, it not only intensifies social stratification but also facilitates the intergenerational transmission of this stratification.

Existing research has already provided many insights into the positive correlation between housing prices and high-quality educational resources. However, these studies often adopt singular perspectives rooted in economics or geography, largely focusing on the demand side of urban residents and positing that city dwellers are willing to pay higher housing prices to access superior educational resources. While the demand-side explanation is undeniably vital, it is equally crucial to delve into the supply side of the housing market. Such an exploration further elucidates the underlying reasons for the unequal distribution of educational resources and its capitalization, along with its subsequent impact on urban housing prices and housing inequality. Furthermore, most existing research is predicated on the context of the marketization and privatization of housing and educational resources. However, public schools are the primary providers of basic education in China, and the "Double Reduction" policy further requires de-privatization reforms in the field of basic education. Most research in the literature has overlooked this significant difference. Therefore, this paper further integrates the spatial patterns and differences in housing prices to probe the deeper societal reasons behind the coupling of the uneven distribution of educational resources and housing price disparities.

This study unfolds through a case study in Nanjing, China. It is worth noting that while this paper focuses on a Chinese context, and there might be distinct differences due to China's predominant public education system in comparison to other countries, the research remains highly relevant. In recent years, especially against the backdrop of the global spread of housing financialization, analyzing the impact mechanism of China's educational resources on housing prices could aid in understanding how governments or developers in other countries capitalize on scarce public resources. This, in turn, sheds light on their strategies to further stimulate the real estate market and the more pronounced housing inequalities that result from such strategies [14,15].

The subsequent organization of this paper is as follows: first, the theoretical analysis of this paper is introduced through a review of the literature. Then, the third section presents the case study area, data sources, and research methods. Quantitative analysis results are presented in the fifth section. In the subsequent discussion section, the paper introduces the concept of "danwei" (the work-unit system) to explore the historical reasons for an uneven distribution of educational resources. It argues for their coupling with the marketization of housing, which enables the reconstruction of social segregation associated with "danwei" within school districts. Finally, the paper concludes with policy recommendations.

2. Literature Review

Understanding the intricate relationship between the supply of public goods and real estate markets is crucial when informing urban planning and policy making [11,16]. Tiebot was among the earliest to link the supply of public goods, including urban education, healthcare, and transportation, with the real estate market [17]. In his research, urban residents select housing based on their income and preferences, and the quantity and quality of public goods around housing often serve as important criteria in this selection process. Therefore, the quantity and quality of public goods in the vicinity of housing are often reflected in housing prices [18].

For example, studies such as those by Black [19], Gibbons and Machin [20], and Figlio and Lucas [21] empirically demonstrate a significant positive correlation between school quality, determined by test scores, and housing prices within respective school districts. Research by Rosen [22] and Brasington [23] points toward a positive relationship between proximity to healthcare facilities and housing prices, indicating the value that homeowners place on this public amenity. Moreover, a vast array of research in the literature, including studies by McMillen and McDonald [24], Seo et al. [25], and Ahlfeldt [26], illustrate that the presence and quality of transport infrastructure plays a pivotal role in shaping real estate values. Reductions in commute times and enhanced accessibility to amenities significantly increase property values. Broadly speaking, these studies, from the perspective of the demand side, elucidate how urban residents, when selecting housing, prioritize the accessibility of public resources such as education and healthcare, as well as transportation convenience. They are willing to pay a premium for these amenities, thereby elevating housing prices.

The fact that the uneven supply of public goods can significantly impact housing prices has spurred wide discussions about housing affordability and the resulting social inequality. Research conducted by Chetty et al. [27] and Raco et al. [28] demonstrates that the unequal distribution of public facilities leads to socioeconomic disparity. Communities with superior amenities are unaffordable for low-income families, thereby exacerbating social stratification. The work of Quigley and Raphael [29] elucidates this relationship, particularly noting that, in densely populated cities, differences in the provision of amenities considerably impact affordability. Overall, existing research has comprehensively demonstrated the impact of the uneven distribution of public goods on housing prices and social inequality. However, this paper aims to discover some novel insights within these extensive discussions.

First, most studies are based on the underlying context of the privatization and marketization processes of public goods and housing supply after the 1980s, filled with evaluative analyses of this transition [30]. Indeed, China also initiated its reform toward privatization and marketization during this period. However, in the realm of public goods provision, although China has been continually attempting to introduce market mechanisms and allow private capital to enter these areas, this progress remains limited [31,32]. Essential public goods such as education and healthcare are still predominantly under public ownership. Taking the education sector as an example, the "Double Reduction" policy launched in 2021 not only requires existing subject training institutions to be uniformly registered as non-profit organizations, prohibiting them from going public for financing, but also calling for the "rectification and cleanup" of those previously in violation [33]. Moreover, a large number of private basic education schools are also required to undergo de-privatization [34].

Second, in contrast to the insufficient marketization of public product supply, housing supply in China is often criticized for being overly marketized [35]. The housing reform that began in 1998 marked the start of marketization in China's housing sector. Over the past two decades, the real estate industry has not only become one of China's pillar industries, but urban land transactions relating to it have also become a significant source of fiscal revenue for local governments [36]. Under this context, vigorously promoting the marketization of the housing supply and driving up housing prices through various forms of gentrification has become the main means for local governments to implement urban renewal and expansion [37,38]. For example, Wu et al. [39] conducted an in-depth examination of the rapid expansion of China's real estate market since the early 2000s, emphasizing the significant surge in housing prices, particularly after 2003. They underscored the impacts of policies, financial mechanisms, and speculative activities. Moreover, urban regeneration, especially the renovation and development of old districts, has played an indispensable role in propelling the commodification of the housing market. Concurrently, gentrification has fueled the commodification of the real estate market. Zhao et al. [40] discussed how the promotion of clustering facilities in education, science, culture, health, and other sectors in new urban centers has attracted high-income residents and upscale commercial activities, laying the groundwork for rising house prices.

As previously discussed, the unequal supply of public goods has a significant impact on both the real estate market and social inequality. However, in China, on the one hand, there is insufficient marketization alongside an even de-privatization of public product supplies in the education sector; on the other hand, there is excessive marketization of housing supply. What kind of socio-spatial effects could the combination of these two factors produce? Exploration in this regard is still insufficient. To answer this question, this paper proposes to introduce the concept of the "danwei" or work unit. Despite the market reforms that began in the 1980s, "danwei" gradually distanced itself from the daily lives of urban residents in China [41]. However, the uneven spatial pattern of many public goods and supplies, including education, still follows the "danwei" system [42]. During the planned economy era, China rigidly categorized urban residents into two main groups: cadres and workers. The public services enjoyed by these two groups were exclusively provided by their respective "danwei" [43]. Tracing back, a significant proportion of high-quality primary and secondary schools in China's major cities originated as institutions serving the children of cadres, primarily established for government officials, research institutions, and similar entities. Although post-market reforms have seen these "danwei" gradually relinquishing their responsibilities to deliver public goods to their employees and their children, the spatial distribution of public goods, resulting from the divisions created by these "danwei", remains uneven [41,42]. Moreover, in recent years, these elite educational institutions have displayed a trend toward "group schooling", expanding their scale through the merger of other schools. Furthermore, a study indicated that Chinese real estate developers, in an effort to promote their housing properties and elevate housing prices, have intentionally incorporated high-quality educational resources. This phenomenon is also referred to as "education-led gentrification" [44]. Thus, this paper argues that the marketization of housing and the uneven distribution of educational resources likely results in a resurgence of the social-spatial segregation of the "danwei" era, albeit in a more latent manner.

3. Study Area and Data Sources

Nanjing, the capital of Jiangsu, China, is known as the capital of the Six Dynasties of ancient China. The city has 11 districts with an area of 6600 km^2 and a total population of 9,423,400 (Figure 1). This study focuses on the main urban area of Nanjing City, examining the relationship between the school districts of public primary schools in Nanjing and housing prices, primarily for the following reasons. Firstly, as a regional metropolis, Nanjing is not like Beijing or Shanghai—the former being China's political hub and the latter its economic core. Instead, Nanjing better represents the general characteristics of major Chinese cities. Secondly, given its status as a regional metropolis, Nanjing boasts a wealth of educational resources, which provides a solid foundation for the conduct of this research.

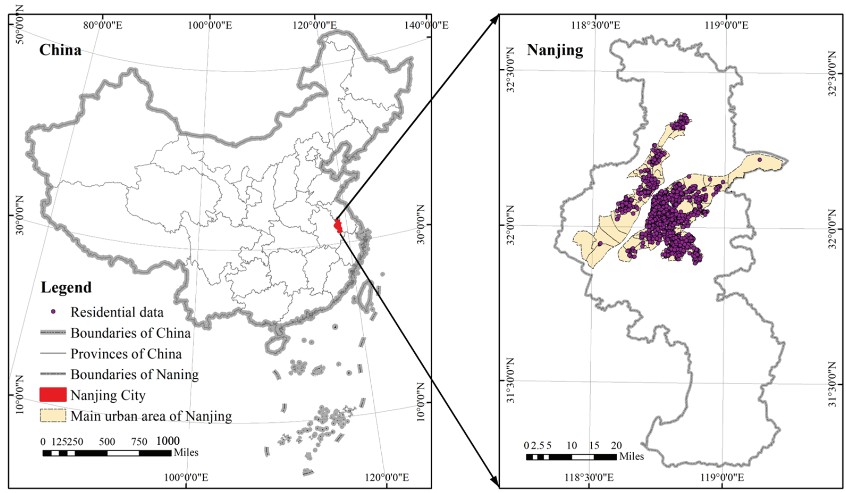

Figure 1. Location of study area.

According to the data provided by the Nanjing Education Bureau in 2018, 143 public primary schools were selected in downtown Nanjing. The distribution of the primary schools and their school districts can be obtained from the website of the Education Bureau of Nanjing City (http://edu.nanjing.gov.cn/ (accessed on 2 February 2023)). Education quality varied by school. Although there is no official ranking for compulsory schools in Nanjing, people usually consider the admission rate of Nanjing Foreign Language School (the best middle school in Nanjing) as the criteria to evaluate the quality of schools. Accordingly, public primary schools in Nanjing are classified into four grades based on their acceptance rates: general (admission rate < 0.5%), moderate (0.5–2%), high (2–10%), and top (>10%). The relevant dataset was obtained from publicly available data sources [45]. The dataset encompasses data from 2018, detailing the enrollment rate (which, in the context of this paper, refers to the proportion of students who secured admission into Nanjing Foreign Language School) and school district locations of public primary schools in Nanjing's main urban district. While the data are from 2018, the school district boundaries within Nanjing's primary urban district have remained unchanged in subsequent years. Furthermore, based on our research findings, post-2018, in compliance with the directives of the Nanjing Education Bureau, individual primary schools stopped publishing their enrollment rates. As a result, parents typically continue to reference 2018 enrollment data as a primary criterion for school selection.

The research scope of this dataset covers the main urban area of Nanjing with a total area of 868.3 km^2, consisting of Xuanwu district, Gulou district, Qinhuai district, Jianye district, Yuhuatai district (northeastern part), Jiangning district (northern part) and Qixia district (western part). It should be clarified that this dataset encompasses the main urban district of Nanjing and excludes the broader surrounding counties. On one hand, this is because elite schools in Nanjing predominantly reside within the central urban district. On the other hand, in recent years, administrative boundary adjustments and school district realignments in the counties around Nanjing's main urban district have been recurrent, which poses challenges for consistent research. Furthermore, housing prices in the counties surrounding Nanjing are typically below the average housing prices within Nanjing itself.

Residential data are provided by the Chinese Housing Market Platform (https://www.creprice.cn (accessed on 2 February 2023)), including information relating to the address, build year, housing types, average selling price, average rent, floor area ratio, and school districts. All data are updated to 2020. By geocoding the address, the point data for each residential community can be created with the help of ArcGIS Pro 3.0. To reduce the time for data processing, I selected circular regions centered at Xinjiekou (the central business district of Nanjing) with a radius of 30 km as the study area. The reason for this is that the shortest linear distance from the urban core (Xinjiekou) to the municipal boundary is about 30 km. Additionally, the transportation system is mainly concentrated in this area. Finally, 4997 residential communities are covered in this study area. By removing the record with missing data, finally, there were 1638 records for residential communities with completed information. It is worth noting that, given how a single school's district encompasses multiple residential communities, these 1638 housing community data entries cover all primary schools within the study area. Moreover, the dataset of Points of Interest (POIs), extracted from amap.com (accessed on 31 August 2023), includes various factors that have the potential to drive differences in housing prices. These factors include but are not limited to, transportation, infrastructure, and amenities within the 1 km buffer zone around each community. This paper also collected information on the distances from each residential area to Nanjing's central business district (Xinjiekou) measured in kilometers. These data were applied to investigate the impact of distance on housing prices.

4. Variable Description and Methods

4.1. Variable Description

This paper selected the admission rate as an indicator to measure the educational quality of school districts in different residential communities (Table 1). The quality of the residential community itself is assessed through the floor area ratio, green space area, and the building area of the residential community [46]. For developers, the residential floor area ratio determines the proportion of land cost in total house pricing. A higher floor area ratio indicates the greater area available for developers to sell, subsequently leading to increased profits. On the part of homebuyers, a lower floor area ratio suggests a lower building density and fewer floors, coupled with higher greenery rates and greater distances between buildings, which contributes to a better living environment. Conversely, a higher floor area ratio comes with an increase in the population density within a unit land area, leading to issues such as traffic congestion and inadequate infrastructure, resulting in a decreased level of residential comfort.

Table 1. Variable description, quantization, and expected sign.

Classification	Variable	Variable Definition	Expected Sign
Dependent variable	Housing prices	Housing price is measured as the mean selling price per square meter of housing units within the same residential community (CNY).	
Independent variable	Admission rate	To gauge the quality of educational resources in school districts based on the admission rate of Nanjing Foreign Language School, as mentioned above, we categorized them into four tiers. The top-tier school districts, where schools have an admission rate exceeding 10%, were assigned a value of 4, while ordinary school districts, with an admission rate of less than 0.5%, were assigned a value of 1.	+
	Floor area ratio	The floor area ratio denotes the ratio of the total floor area of buildings in a certain location to the size of the land of that location, serving as a measure of residential density. A higher floor area ratio indicates increased residential density, often implying a lower quality of living.	−

Table 1. *Cont.*

Classification	Variable	Variable Definition	Expected Sign
Independent variable	Building area of residential community	The building area of residential communities can be utilized to gauge the scale of the community. A larger building area generally denotes a larger community or a high-rise structure. Given the gradual shift toward larger and taller residential complexes in major cities in China, a more expansive building area usually indicates a newer development within the community (m^2).	+
	Green space	Green space is measured using the greenery rate of a residential community; a higher greenery rate indicates a larger amount of public space in the residential area, which often translates to a higher quality of living and is generally inversely related to the floor area ratio.	+
	Distance to Xinjiekou	The straight-line distance to Xinjiekou can also be used; a longer distance indicates further proximity from the city center (km).	−
	POI density	The POI density serves to quantify the concentration of facilities, such as scientific, educational, cultural, health, and transportation amenities, within the 1 km buffer zone surrounding a residential community. A higher density generally indicates a higher level of convenience in daily living.	+

Generally speaking, in communities with a good living environment, the floor area ratio should not exceed 4.5 for high-rise residences (12–18 floors) and should not surpass 2 for multi-story residences (7–11 floors), with the greenery rate not falling below 30% [47]. Moreover, the building area of a residential community serves as an indicator to gauge the scale of the community. Concurrently, owing to the recent trend where residential communities in China's major cities are increasingly evolving toward a larger scale and higher structures, a more extensive building area typically signifies a more recent development in the community.

The density of POIs surrounding residential communities typically reflects the concentration of various commercial and industrial service facilities in this area [11]. This commonly indicates the level of convenience for the work and daily life of residents in a community, thereby serving as a basis for understanding the impact of POIs on property prices. It should be noted that the housing prices referred to in this article denote the price per square meter of living space, not the total price of the house. Utilizing the price per square meter to gauge housing quality is a prevalent method amongst urban residents in China, and most studies employ this metric as a critical indicator to distinguish residential differentiation [48]. This approach helps to circumvent the influence of the housing area on pricing.

4.2. Spatial Autocorrelation Analysis Model

The spatial autocorrelation analysis aims to quantify the degree of similarity or dissimilarity in data and identify spatial patterns. Before constructing the regression model, it is important to measure the spatial autocorrelation of housing prices in the study area, which can reduce the overestimation of public service values due to spatial effects. If the variable has a significant spatial correlation, the geographically weighted regression model (GWR) can capture the spatial heterogeneity caused by spatial autocorrelation more effectively. Moran's Index is the most commonly used method for examining global spatial autocorrelation. On the one hand, Moran's Index can reflect not only positive correlations but also negative ones: a capability that many other indices lack. On the other hand, Moran's Index offers numerous advantages when testing for spatial autocorrelation in the error terms of regression models. Furthermore, there is a wealth of research associated with it, facilitating comparative analyses. Moran's Index can be calculated using the following equation:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})\left(x_j - \overline{x}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})^2} \tag{1}$$

where n is the total number of features, $\overline{x}$ is the mean housing price, x_i and x_j represent the housing price in the ith and jth space unit, and w_{ij} is the spatial weight matrix. Moran's Index can be measured using the Spatial Autocorrelation (Global Moran's I) tool in ArcGIS Pro 3.0.

4.3. Hedonic Prices Model

The hedonic housing prices model typically uses regression analysis to estimate the relationship between housing prices and their attributes. The traditional hedonic prices model sets attributes as explanatory variables and housing prices as the dependent variable. This method is commonly used to evaluate the implicit prices of variables in relation to the building characteristics, community characteristics, and location characteristics of the house. The hedonic prices model is a typical linear regression with housing prices, serving as the fixed dependent variable. This model can be constructed using the OLS tool in ArcGIS Pro.

4.4. Geographically Weighted Regression

Differing from OLS, geographically weighted regression (GWR) is a local regression method that captures the spatial non-stationarity of the housing price distribution. Thus, GWR was employed here to discern and quantify the spatial heterogeneity of educational capitalization and to further uncover the distributional features and the effect educational facilities have on housing prices. This model is shown as follows:

$$y_i = \beta_0(u_i, v_i) + \sum_{i=1}^{k} \beta_k(u_i, v_i)x_{ik} + \varepsilon_i \tag{2}$$

where y_i is the housing price for the ith sample point, (u_i,v_i) is the geographic location coordinate of the ith sample point, β_0 is a constant term, $\beta_k(u_i,v_i)$ is the kth regression parameter of the ith sample point, and ε_i is the random error term. This model can be constructed using the GWR tool in ArcGIS Pro (Figure 2).

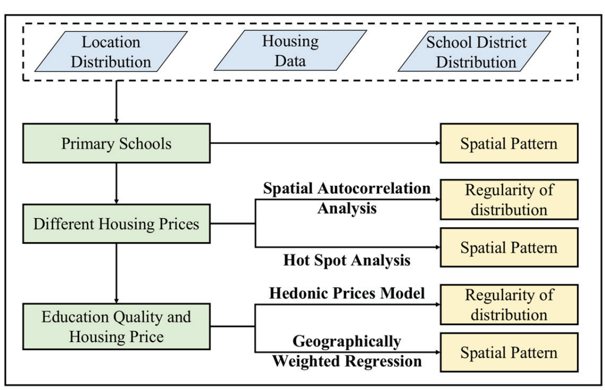

Figure 2. Schematic research framework.

4.5. Error and Uncertainty

By checking the admission rate of Nanjing Foreign Language School in the dataset, I found that only 260 (18%) public primary schools had an acceptance rate larger than zero. This could lead to the error of multicollinearity due to data redundancy since the software might consider the value of zero as a binary variable.

5. Result

5.1. Spatial Pattern of Primary Schools and Housing Prices

The choropleth map shows the clustering of top-level schools in the main urban area. Figure 3 shows that high-quality primary schools were mainly concentrated in the Gulou district and Xuanwu district.

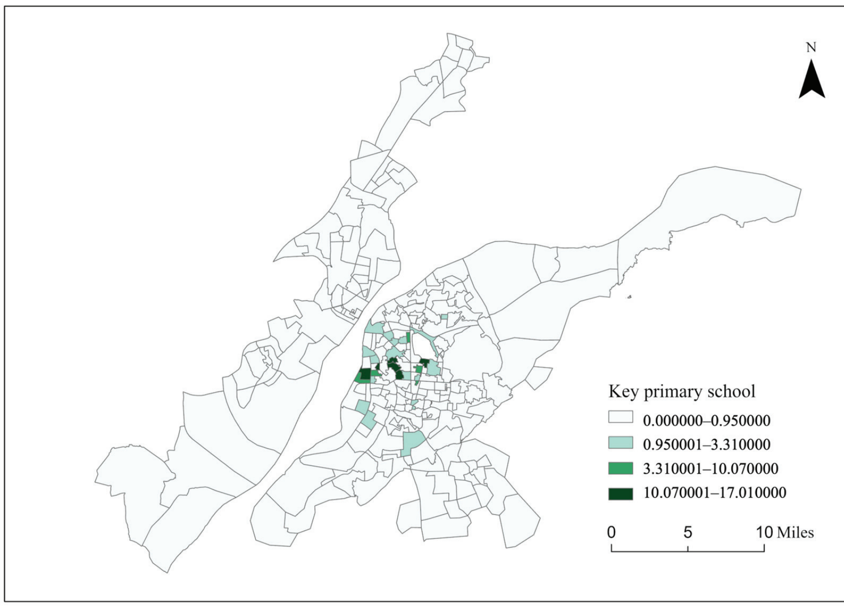

Figure 3. Spatial pattern of key primary schools.

Figure 4 highlights the clustering of housing prices in the main urban area, showing that high housing price areas are mainly concentrated in the Gulou, Jianye, Qinhuan, and Xuanwu districts.

From Figures 3 and 4, it is evident that areas with high-quality primary schools significantly overlap with regions with high property prices. This overlapping is primarily concentrated in the Gulou and Xuanwu districts of Nanjing, both of which are hubs for premium educational resources. However, regions with elevated property values also encompass the Jianye and Qinhuai districts. This can be attributed to Jianye housing, the key developmental zone of Hexi New City, while Qinhuai has stood at the forefront of urban renewal in Nanjing in recent years. The development of new urban areas and the revitalization of older cities have, to some extent, contributed to the surge in property prices. Concurrently, Nanjing's prestigious primary schools have begun extending their reach into these two districts through collaborative schooling and the establishment of branch campuses, which have also indirectly inflated housing prices.

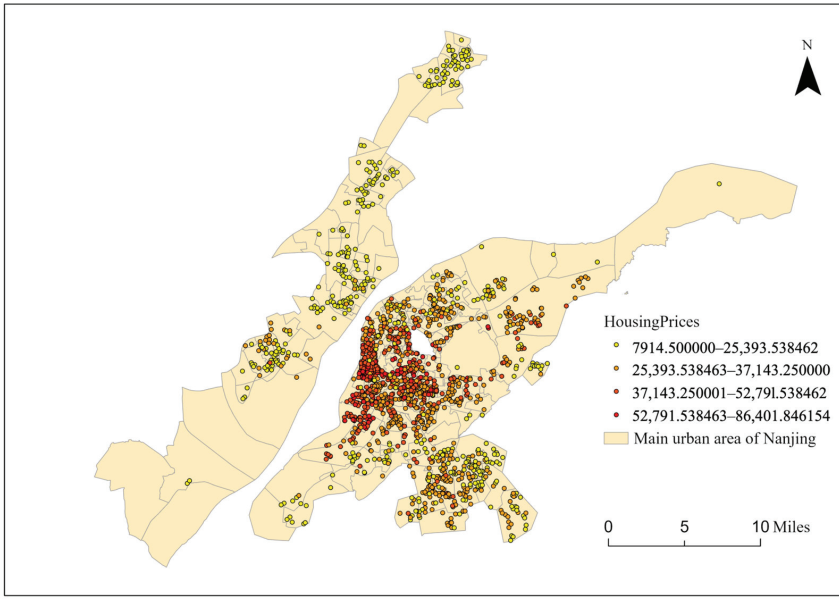

Figure 4. Spatial pattern of housing prices.

5.2. Spatial Autocorrelation Analysis

Moran's Index for housing prices is 0.297460 (Table 2). The positive Global Moran's Index indicates positive spatial autocorrelation, which means that residential communities with high housing prices are likely to cluster together, the same as cheap ones. The Z-score is 25.338294, and the p-value is 0.000000. This indicates that the data are statistically significant, and a random pattern is unlikely. Moran's Index further substantiates the aforementioned analysis. Although the Jianye and Qinhuai districts experienced a surge in property prices due to new urban development and old city renewal to some extent, there has also been a pronounced spatial correlation between high-quality schools and elevated housing prices.

Table 2. Results of Global Moran's I index analysis.

Statistical Indicators	Value
Moran's I	0.297460
Expected Index	−0.000611
Variance	0.000138
Z-score	25.338294
p-value	0.000000

5.3. Hedonic Prices Model

The result of the hedonic prices model shows that admission rates have had the greatest positive effect on housing prices. The adjusted R^2 is 0.535648, which indicates that almost 54% of the variance in housing prices can be explained using this model. The value of VIF for each variable is approximately equal to one, which means there is no multicollinearity among the independent variables. Among all the characteristic variables, the admission rate of Nanjing Foreign Language School has had the most significant effect on housing prices. A one percent increase in the admission rate leads to a rise in housing prices of CNY 2258.447 (Table 3).

Table 3. Results of hedonic prices model.

Variable	Coefficient	Std Error	*t*-Statistic	VIF
Intercept	32,531.7624	1128.27703	28.833134	
Admission rate	2258.44708	94.913682	23.794747	1.048997
Floor area ratio	−371.92243	147.909565	−2.514526	1.205783
Building area of residential community	0.001477	0.001203	1.227772	1.080423
Green space	182.464582	23.921567	7.627618	1.131632
Distance to Xinjiekou	−0.895349	0.034651	−25.83921	1.363253
POI density	1.050335	0.367236	2.860108	1.399053

In comparison, the impact of community green space and the floor area ratio on housing prices is considerably less. Specifically, for each additional unit, housing prices exhibit a marginal increase of CNY 182.465 and a decrease of CNY 371.922, respectively. The influence of residential community building areas on the unit price of houses is less significant. This could be attributed to the fact that in the past decade in Nanjing, the average building area of residential communities has surpassed 60,000 square meters, predominantly featuring high-rise buildings and large-scale communities. When purchasing homes, residents tend to give more consideration to the greenery level and floor area ratio within residential complexes rather than the size of the community itself.

Moreover, in fact, housing within premier school districts in Nanjing's inner city, even when constructed in the 1970s, has architecture and environments that have aged significantly and might even be unsuitable for habitation. However, their property values remain substantially higher than newer and better-quality housing in neighboring school districts. As a result, it can be inferred that when urban residents select housing for their families, the quality of the school district associated with a residence takes precedence. Families, within their means, prioritize the reputation of the school district over living quality.

The influence of the distance to the central business district and POI density on housing prices is even smaller. Due to rapid urbanization, the surrounding amenities of the residential area and the coverage of the transportation system do not exhibit significant variations. Convenient public transportation has also reduced buyers' demand to live in the city center.

5.4. Geographically Weighted Regression (GWR)

The GWR model, with its strength in capturing spatial heterogeneity and local variations, exhibits a significantly enhanced model fit compared to the hedonic prices model. It explains 58.0292% of the total variance in housing prices, which is a 4.46% improvement from the hedonic prices model. Therefore, GWR provides a more nuanced understanding of the influence of educational factors on housing prices across different geographical locations. Moreover, the GWR model outcomes further validate the significant impact of the admission rate of Nanjing Foreign Language School on housing prices: a trend similar to the hedonic prices model. However, a key distinction lies in GWR's ability to provide localized insights. It reveals how a one percent increase in the admission rate influences housing prices differently across various spatial locations, reflecting an average rise of CNY 2179 (Table 4). This information could be invaluable in identifying specific areas where the influence of education on housing prices is more pronounced.

Table 4. Results of geographically weighted regression.

Variable	Minimum	Maximum	Mean	Standard Deviation
Admission rate	2030.522695	2750.093888	2179.499594	134.763785
Floor area ratio	−1960.273441	−36.47181	−388.322439	166.271963
Building area of residential community	−0.00123	0.0013342	0.005477	0.003591
Green space	73.980219	229.239176	195.015252	25.692198
Distance to Xinjiekou	−2.012419	−0.535973	−1.33553	0.332387
POI density	−1.424806	3.72791	−0.0401	1.041125

The map of locally adjusted R-squared shows that the highest local R-squared values are present in downtown areas, such as Pukou and Luhe districts, which means buyers' preferences are adequately explained using the GWR model in these regions (as shown in Figure 5). Since this region merely has no top-level public primary school, disparities in school quality are not significant. However, if high-quality educational resources were introduced into this region, the capitalization of education might become extremely high, given the limited access to high-level educational resources. By contrast, in the city center, in areas such as Gulou, Jianye, and Qinhuai, the concentration of high-quality educational resources not only alleviates the supply-demand contradiction of premium educational resources but also, due to their proximity to the city center, the impact of distance to Xinjiekou and the density of POIs becomes less prominent. Furthermore, within the GWR model, the influence of POI density on housing prices has even transitioned from positive to negative. This could be due to the fact that a higher density might imply traffic congestion or that an overly high density of commercial facilities could disrupt the residential environment, thereby affecting the choices of potential buyers adversely. Concurrently, this also showcases the disparity between the GWR model and the hedonic model, with the former being more adept at capturing the specific impacts of geographical locations on housing prices.

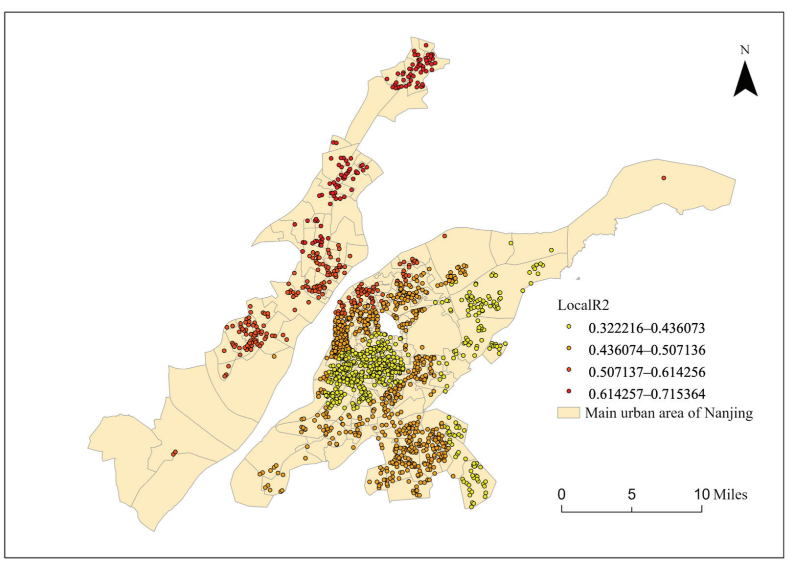

Figure 5. Spatial distribution of GWR performance.

In conclusion, the GWR model, through its inherent adaptability to local variations and its flexibility in identifying spatial patterns, offers a more realistic and nuanced understanding of the impact of educational resources on housing prices. This localized approach allows us to explore the profound capitalization effect of educational resources more accurately, thus providing researchers and policymakers with critical insights that the hedonic prices model might overlook.

6. Discussion: Rebirthing Social Segregation in Danwei through School District Division

6.1. Continuity and Historical Legacy of the Danwei in the Fied of Education

Quantitative analysis shows that high-quality educational resources in Nanjing are primarily distributed in the Gulou and Xuanwu districts: a pattern that is essentially a continuation of the city's historical social spatial differentiation. Before 1949, Nanjing's Gulou and Xuanwu districts were the concentrated areas of the central government, Jiangsu provincial government and Nanjing municipal government, as well as a significant number of higher education institutions. After 1949, even though Nanjing was no longer China's capital, the provincial government, city government, and universities remained clustered in this area. During the planned economy era, China's social organization revolved around "danwei", or work units, wherein the unit was responsible for housing, medical care, and even the education and employment of their employees' children [43,49]. Consequently, some of the best primary schools in Nanjing, including Langya Road Primary School, Lasa Road Primary School, and Lixue Primary School, were formerly "cadre children's schools" which provided educational services to the children of government officials and intellectuals working in nearby universities [50]. In fact, not only are primary schools concentrated in these two regions, but they also house the finest educational resources at all stages, from kindergarten to university. As a result, the residents of Nanjing generally believe that living in these areas can provide immense convenience, facilitating a journey from birth to employment. This is also a spatial consequence of the social stratification among three major social classes—officials, workers, and farmers—during the era of China's planned economy [51].

Even though these former "cadre children's schools" have opened their doors to all citizens of Nanjing after market-oriented reforms, access to these top-tier schools is still primarily dictated by the strict implementation of a school district system. This system essentially allows admission into these schools through the purchase of housing within these designated districts. Consequently, despite educational resources being public goods, they can be capitalized by the housing market, leading to a significant appreciation effect on surrounding properties. The market screening mechanism thus excludes the majority of ordinary urban residents from these public goods, resulting in severe social inequality. In fact, this inequality tends to accumulate as educational years increase. For example, students from Langya Road Primary School, Lasa Road Primary School, and Lixue Primary School consistently rank among the top three in terms of admissions into Nanjing Foreign Language School. Furthermore, in 2018, 96% of students from Nanjing Foreign Language School were admitted to the first tier of universities (admission to the first tier usually implies being admitted to the top 100 universities in China), while the same year's proportion of first tier university admissions across Jiangsu province was merely 25%.

6.2. Revival of the Danwei and Its Spatial Penetration

As mentioned above, after China's market-oriented reforms, public goods such as housing, medical care, and education, which were previously the responsibility of the "danwei", were predominantly supplied by the market, and it appeared that the "danwei" system was consequently disintegrated. However, former employees of the government and universities still enjoy certain competitive advantages. For example, housing within high-quality school districts, which was largely a welfare allocation by the government and universities during the planned economy era, has been privatized at extremely low costs due to market reform [52,53]. In other words, even aftermarket reforms, government and university employees can still ensure that their children have access to high-quality educational resources through the school district system. Furthermore, with the continuous increase in housing prices, not only are low-income families excluded from these high-quality school districts, but these former “danwei” households also benefit from a substantial appreciation in their property value. In fact, after the children of these former “danwei” employees enter high-quality primary schools, these families generally sell their properties at high prices, and those who move in are affluent urban families. Research indicates that these incoming families still consist of employees from government entities, universities, and state-owned enterprises, which are units in China that have relatively higher incomes, better benefits, and stability [54,55]. The advantage of an excellent education can be accumulated, giving children from elevated economic and social backgrounds a greater chance of achieving desirable careers and better social status [7,56].

In addition, these high-quality primary schools have continued to expand in the era of the market economy through collaborative education and the establishment of branch schools. In the process of Nanjing’s urbanization, many district governments have also provided financial or land support to attract these excellent educational resources for regional development. For example, since 2002, Jianye District in Nanjing has introduced a series of renowned school resources, establishing schools like the Xincheng Middle School, which is affiliated with Nanjing Normal University, the Hexi Branch of Jinling High School, Zhonghua Middle School, the Hexi Branch of Nanjing Foreign Language School, and Zhiyuan Foreign Language Primary School. Moreover, it continues to absorb new renowned school resources through “group schooling”, gradually achieving full coverage from primary to high school, which has greatly driven an increase in housing prices. This has made Jianye District, where Nanjing’s Hexi New Town is located, a new gathering place for affluent families in Nanjing. Therefore, in other words, although the “danwei” system was dismantled institutionally, it has also been reborn through the school district system.

7. Conclusions

This article has examined the effect of educational capitalization on housing prices in Nanjing based on 1441 pieces of housing data. The main conclusions are as follows:

(1) The results of the hedonic price and spatial econometric models verify the significant positive effect of school quality on housing prices. The enhanced adjusted R-squared value of the GWR model highlights the spatial heterogeneity of educational capitalization and further supports the idea that there are notable variations in the distribution and quality of elementary educational resources.

(2) The locked-in urban pattern determines the distribution characteristics of residents and the allocation of public resources. The high concentration of quality educational resources is both a continuation of the history of “danwei” and the result of the long-term accumulation of urban spatial differentiation patterns.

(3) The close link between the admission rate of top junior high and housing premiums is the most intuitive feature of capitalization’s effect on education. The remarkable housing premium induced by the rising quality of school districts increases the inaccessibility of high-quality education and further exacerbates social solidification. At the same time, the spatial differentiation of the “danwei” society is also reconstituted within the school district system.

The effects of capitalization resulting from the uneven distribution of high-quality educational resources in China have led to a premium on housing in desirable school districts, thereby creating significant inequalities within China’s urban landscape. This inequality not only exacerbates residential segregation within the city, re-establishing housing as a symbol of class differentiation, but also allows urban advantaged families to promote class reproduction through housing. Addressing disparities in school quality is a crucial approach to mitigating these societal challenges. As previously mentioned, allocating public education resources based on proximity to schools is a predominant model globally. While many international studies critique the social inequalities stemming from this model, these disparities do not seem as pronounced as in China. Perhaps

China can draw insights from experiences abroad. For instance, Japan's teacher rotation system has significantly balanced the distribution of educational resources. Encouragingly, pilot programs of this approach have already been initiated in several Chinese cities. Observing the case of Nanjing, housing prices in school districts have begun to decrease over recent years.

In conclusion, it is imperative to highlight that this study is primarily grounded in the case of Nanjing, China, emphasizing the implications of education—a public good—on urban housing prices and residential inequality. Our research resonates with the somewhat contentious perspective proposed by Saunders in 1984, which posits that the ownership of public goods like housing, transportation, education, and healthcare delineates a class divide between those who possess and those who do not [57]. Currently, against the backdrop of the financialization of housing, real estate is emerging once again as a pivotal determinant of class stratification [3]. However, housing is more than just a living space; the accessibility and potential ownership of various public goods inherent to it also influence its pricing. Focusing solely on education as a public good undoubtedly has its limitations, underscoring the necessity for more comprehensive research in subsequent studies.

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Do Consumers Have Colour Aesthetic Preferences for the Facade Materials of Condominium Buildings?

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Abstract: The distinct cultural environment of various regions leads to unique consumer preferences for building facades, including the colours and materials that are used for the exteriors of condominium buildings. Understanding these preferences holds significant industry reference value for urban planning authorities and residential development companies. However, the colour and material aesthetic preferences of consumers for building facades have not received much research attention. To fill this gap, this study empirically investigates these preferences within the cultural context of Fuzhou, China. Using house prices as a reference perspective and econometric methods as research tools, this study explores the specific aesthetic preferences of urban consumer groups and compares the preferences of groups with different levels of consumption. The results confirm the existence of specific consumer preferences for building facade colours and materials and a close connection among the variations in these preferences and various combinations of facade colours and materials. Different quantities and types of materials can lead to distinct preferences for the quantities and features of facade colours. Apart from providing precise professional insights for urban planning authorities and residential developers, this study also offers a feasible conceptual reference for future studies to be conducted in other regions.

Keywords: building facades; colour aesthetics; facade materials; colour culture; consumer preference; house prices

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1. Introduction

The colours and materials of condominium building facades (hereinafter, “building facades”) contribute to an overall visual impression that frequently influences people’s admiration of these structures. The Chinese proverb “clothes make the man” [1] emphasises the importance that the Chinese people place on their outward appearance. Similar to how clothes affect people’s perceptions of one another, facades can affect the overall image of a building. A pleasing building facade frequently leaves a positive impression that plays a crucial role in many social interactions, including condominium purchase. As a result, many building developers pay close attention to the facades of their buildings, especially in terms of their colour and material.

The colour of building facades is often an important consideration for consumers when purchasing condominiums. The consideration of colour factors also reveals similarities in the preferences of the entire urban population [2], a gender group [3] or an occupational group [4]. These groups consistently exhibit shared preferences. However, colour preferences may vary across regions. For example, people in Antalya, Türkiye, tend to favour cool hues, such as blue, purple and green, for building facades [5], whilst people in Shanghai, China, tend to prefer warm and light hues (e.g., red) and moderate-to-low chroma [6]. Exploring the similarities in the preferences of regional groups has significant and positive impacts on the urban development process [7].

People's sensory preferences for building facade materials are objectively presented. These preferences may stem from diverse factors, such as cultural influences that are derived from natural environments, as seen in Finland [8] and New Zealand [9]; economic considerations, as seen in the US [10] and Western Europe [11]; and sustainability demands arising from environmental pressures, as found by Hu et al. [12]. However, this preference scenario is pervasive across the globe, especially in Europe [13], the Americas [14] and Asia [15]. In the context of global urbanisation and construction, preferences for building facade materials become a crucial issue that cannot be overlooked. Similar to the colour of building facades, the choice of facade materials also plays a significant role in urban development, planning and management. Consequently, discussions surrounding housing prices and their correlation with building facade materials have become focal points of scholarly attention in the past decade.

Previous studies on the correlation between building facade materials and house prices have mostly focused on the correlation between material manufacturing costs and market supply chains and house prices in South Korea [16,17], Nigeria [18], Palestine [19], Malaysia [20–24], Canada [25], South Africa [26] and New Zealand [27,28], amongst others. These studies conclude that house prices are positively correlated with costs. However, these findings contradict those of other scholars who analyse the correlation between facade materials and house prices from the perspective of consumers' sensory preferences. Although based on consumer perspective theory [29], these studies have not been carried out empirically with important reference to the consumption process and price.

Using house prices as a reference to understand consumer preferences towards building facade colours offers some significant research value [30,31]. Given the real-life context, where residences represent substantial and essential commodities in people's lives, the deliberations of consumers during their purchasing process are inevitably meticulous [32]. Within these deliberations, inclinations towards facade elements are undoubtedly included [33]. Therefore, the consumer preference information embedded in the transaction prices of residential properties within the market trading model is inherently more reliable and accurate than the preference information gathered through questionnaire surveys [34]. A more accurate picture of consumer preferences for residential facades in a local market can be obtained with price information [35]. The management of markets and cities can be improved with the help of this knowledge. However, this perspective has been ignored in previous research. Conversely, it is generally known that the interior comfort of a residential living environment can be improved by carefully selecting building facade colours and materials to create a more pleasant sensory experience, ultimately improving the inner sense of comfort in residential living environments [36–39]. The preferences for building facade materials and colour combinations have also received scant research attention. Therefore, this particular area remains relatively unexplored.

To fill these gaps, this study evaluates the colour and material aesthetic preferences of consumers for building facades based on consumer theory and by utilising second-hand house prices as a benchmark. This study investigates the general colour aesthetic preferences of different consumer groups to provide relevant professional guidance for urban administrators, construction companies and individual consumers. Modern cities are often characterised by chaos and disorder that, to some extent, stem from an inadequate understanding of the numerous factors within the human collective. Similarly, the collective preferences of populations towards the compositional elements of building facades have received limited scholarly attention. In this case, this study aims to contribute to a more orderly urban life by objectively revealing the preferences of different population groups for urban facades, thus offering insights for professionals in relevant industries that would help them collectively construct a highly organised urban environment.

The remainder of this paper is organised as follows: Section 2 discusses the data and methodology. Section 3 presents the data analysis results. Section 4 concludes the paper and highlights its limitations.

2. Materials and Methods

2.1. Research Planning

According to a Chinese proverb, consumers in China place a high value on the aesthetics of the products that they purchase [40–42], and this is also true of residential items. This study selects Fuzhou, China, as the research site and builds a corresponding research framework. Fuzhou is the capital of Fujian Province (E: 119.28, N: 26.08) (Figure 1) located north of Taiwan and near Hong Kong and Macao. As the ancestral home of a large number of Chinese expatriates [43], Fuzhou has close cultural ties with many countries and regions in East and Southeast Asia. Fuzhou has a population of nearly nine million people and a large number of residential samples, thereby providing a sufficient amount of transaction data for this study to ensure the generalisability and scientific validity of its results.

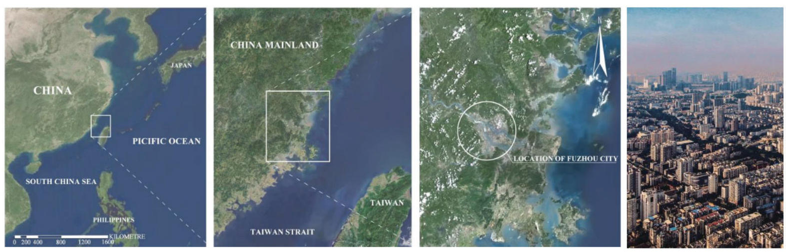

Figure 1. Geographic location and current state of the research area.

This study is divided into three steps, as depicted in Figure 2. In the first step, condominium samples in the selected research area are selected for data collection and variable design. The variable design encompasses both the colours and materials of building facades. In the second step, a linear regression analysis of the correlation between the research variables and house prices is conducted for the entire urban consumer group to demonstrate their correlation and to understand the price correlation between the moderating effects of facade colour and material. This correlation reflects the increase or decrease in house prices due to a consumer group's aesthetic preference for specific facade colours or materials. In the third step, a quantile regression analysis of condominium transaction prices is conducted to demonstrate the correlation amongst the differences in the preferences of various consumer groups. This correlation reflects the price fluctuations triggered by the differences in the preferences for combinations of facade colours and materials amongst condominium consumer groups with varying levels of consumption.

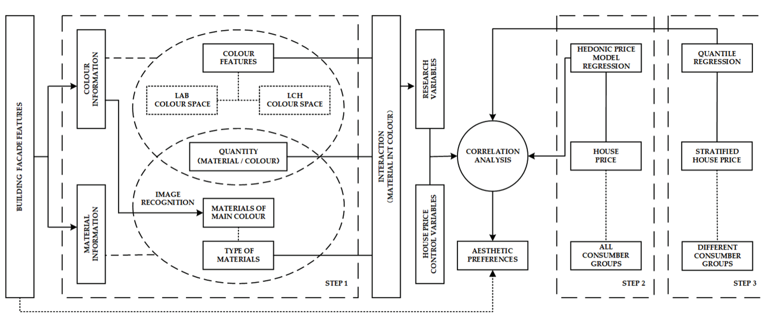

Figure 2. Research framework.

2.2. Variable Design

Data on a cross-sectional sample of second-hand condominium transactions in 906 residential neighbourhoods in Fuzhou, China, in 2020 were collected. The chosen samples have a uniform appearance, thus avoiding the interferences caused by variances in building appearance. The data were obtained mainly via online or field research. The variables are detailed in Table 1. These data include the outcome variable (i.e., the actual overall average transaction price of the residential sample), the control variables (i.e., house prices) and the research variables.

Table 1. Descriptive statistics of the variables (N = 906).

Variables		**Description**	**Mean**	**Expect**
Outcome Variable				
	Pri	House prices (ten-thousand yuan/m^2)	2.790	/
Control Variables				
	ADM	Dummy variable, 1 for the condominium being inside the higher-level administrative region, 0 otherwise	/	+
	LC1	Dummy variable, 1 for the condominium being inside the second ring road, 0 otherwise	/	+
	LC2	Dummy variable, 1 for the condominium being inside the third ring road, 0 otherwise	/	+
	POP	Quantity of population in March 2021 (ten thousand)	52.085	+
	GDP	Per capita GDP in March 2021 (hundred million yuan)	118,558.400	+
	COM	Dummy variable, 1 for the condominium being a pure commercial condominium, 0 otherwise	/	+
	T500	Dummy variable, 1 for the developer being in China's top 500, 0 otherwise	/	+
	MIN	Dummy variable, 1 for the developer originating from Fujian province, 0 otherwise	/	+
	PRI	Dummy variable, 1 for the condominium having a high-quality primary school, 0 otherwise	/	+
	MID	Dummy variable, 1 for the condominium having a high-quality middle school, 0 otherwise	/	+
	AGE	Dummy variable, 1 for the condominium being built after 2000, 0 otherwise	/	+
	DEN	Density of buildings (c)	2.356	-
	GRER	Greening rate of community (c)	0.345	+
	FEE	Monthly management fee (yuan/m^2)	1.184	+
	RAI	Distance to the closest rail station (m)	1375.514	+
	MAR	Distance to the closest market (m)	1098.150	+
	HOS	Distance to the closest grade-A tertiary hospital (m)	1899.717	-
	SCE	Distance to the closest scenic spot (m)	1080.911	+
	GRE	Distance to the closest green space (m)	726.217	+
	WAT	Distance to the closest main water source (m)	1135.450	+
	FUN	Distance to the closest funeral facility (m)	3176.560	-
	FAC	Distance to the closest factory (m)	1596.437	-
	GAS	Distance to the closest gas station (m)	1180.834	-
	DUM	Distance to the closest dump (m)	9617.311	-
Research Variables				
	2C	Dummy variable, 1 for building facades with 2 colours, 0 otherwise	/	+
	3C	Dummy variable, 1 for building facades with 3 colours, 0 otherwise	/	+
	4C	Dummy variable, 1 for building facades with 4 and more colours, 0 otherwise	/	+
	M①	The first standard of main colour (lightness in LAB/LCH) (c)	/	+
	M②	The second standard of main colour (red–green in LAB/saturation in LCH) (c)	/	+ (red–green) + (saturation)
	M③	The third standard of main colour (yellow–blue in LAB/hue in LCH) (c)	/	– (yellow–blue) no sig. (Hue)
	2M	Dummy variable, 1 for building facade colours with two materials, 0 otherwise	/	/
	3M	Dummy variable, 1 for building facade colours with three materials, 0 otherwise	/	/

Table 1. *Cont.*

Variables		Description	Mean	Expect
	4M	Dummy variable, 1 for building facade colours with four materials and more, 0 otherwise	/	/
	STO	Dummy variable, 1 for building facade colours with stone bricks, 0 otherwise	/	+
	GLA	Dummy variable, 1 for building facade colours with glass curtains, 0 otherwise	/	/
	MET	Dummy variable, 1 for building facade colours with metal sheets, 0 otherwise	/	/
	COA	Dummy variable, 1 for building facade colours with coating, 0 otherwise	/	/
	CER	Dummy variable, 1 for building facade colours with ceramic tiles, 0 otherwise	/	+
	ALU	Dummy variable, 1 for building facade colours with aluminium–plastic boards, 0 otherwise	/	/
	CON	Dummy variable, 1 for building facade colours with as-cast-finish concrete, 0 otherwise	/	/

2.2.1. Control Variables

A set of control variables showing relatively stable correlations with house prices is obtained from previous research (Table 2). These variables are utilised to ensure that the analytical outcomes of this study provide an accurate reference value. The control variables primarily fall into three categories [44,45], namely location environment variables (e.g., the administrative category of the region, whether the location is within the second ring road, whether the location is inside the third ring road, population and GDP per capita) [46–49], self-characteristic variables (e.g., the type of pure commercial condominiums, whether the developers are within China's top 500, whether the developers originate from Fujian Province, whether the condominium is near a high-quality primary or middle school, whether the condominium was built after 2000, the density of buildings, the greening rate of the community and monthly management fees) [50–56] and facility accessibility variables (e.g., the distances to the closest rail station, market, grade-A tertiary hospital, green space, main water source, scenic spot, factory, gas station, dump and funeral facilities) [57–66].

Table 2. Studies on the control variables.

Variables	Title	References	Research Area	Samples	Methods	Key Findings
ADM	Identifying the determinants of housing prices in China using spatial regression and the geographical detector technique	[46]	China	2760 counties	Spatial Regression Models Geographical Detector Technique	The house prices in China are heavily influenced by the administrative level of the region.
LC1/LC2	Quantile house price indices in Beijing	[47]	Beijing, China	260,366 housing units	Hedonic Price Model Quantile Regression	Houses located within the second ring road are valued more than equivalent houses located beyond the second ring road.
POP	Does the planning system affect housing prices? Theory and evidence from Hong Kong	[48]	Hong Kong, China	52 observations	Time Series Regression	The increase in population will bring more demand for housing. It will boost house prices.
GDP	The Impact of Economic Growth on the Market and Communication Value of Real Estate: Case Slovenia	[49]	Slovenia	150 respondents	Questionnaire	GDP affects the house price trend directly and earlier.

Table 2. *Cont.*

Variables	Title	References	Research Area	Samples	Methods	Key Findings
COM	Types of Resident and Price Distribution in Urban Areas: An Empirical Investigation in China Mainland	[50]	Fuzhou, China	1079 residences	Hedonic Price Model Stepwise Regression Model Econometric Interaction Model	The COM variable has a substantial positive influence on house prices.
T500	Types of Resident and Price Distribution in Urban Areas: An Empirical Investigation in China Mainland	[50]	Fuzhou, China	1079 residences	Hedonic Price Model Stepwise Regression Model Econometric Interaction Model	T500 has a positive influence on house prices.
MIN	Types of Resident and Price Distribution in Urban Areas: An Empirical Investigation in China Mainland	[50]	Fuzhou, China	1079 residences	Hedonic Price Model Stepwise Regression Model Econometric Interaction Model	MIN has a positive influence on house prices.
PRI	Education quality, accessibility, and housing price: Does spatial heterogeneity exist in education capitalization?	[51]	Hangzhou, China	516 communities	Hedonic Price Model GWR Model Geographical Information Systems (GIS)	The quality of primary schools has significant effects on house prices.
MID	House Prices And School Zones: Does Geography matter?	[52]	New Zealand	1781 house sales	Spatial Lag Model Spatial Error Model Ordinary Least Squares (OLS)	House buyers are willing to pay a premium of over $130,000 in order to reside in the enrolment zone of popular secondary schools.
AGE	Age-Related Heteroskedasticity in Hedonic House Price Equations	[53]	Dallas, USA	8500 transactions of single-family homes	Hedonic Price Model	Depreciation rates vary considerably with dwelling age.
DEN	Measuring the value of apartment density? The effect of residential density on housing prices in Seoul	[54]	Seoul, Republic of Korea	200 housing units	Hedonic Price Model Ordinary Least Squares (OLS) Quantile Regression Model	The density of buildings has negative effects on house prices.
GRER	Housing market hedonic price study based on boosting regression tree	[55]	China	253 samples	Hedonic Price Model Gradient Boosting Machine Learning Regression Tree Algorithm Based on Gradient Boosting	The higher the greening rate, the higher the price.
FEE	Impact of Homeowners Association Fees on Condominium Prices	[56]	San Diego, USA	1087 residences	Hedonic Price Model	Homeowners Association Fees do appear to have a marginally positive effect on house prices.
RAI	The impact of metro services on housing prices: a case study from Beijing	[57]	Beijing, China	2835 samples of online property sales data	Spatial Error Model (SEM)	All the metro service variables have positive effects on property values.
MAR	Which types of shopping malls affect housing prices? From the perspective of spatial accessibility	[58]	Hangzhou, China	22 shopping malls 523 housing communities	Hedonic Price Model GWR Model	The spatial accessibility to shopping malls has a significant positive impact on house prices.
HOS	The determinants of house prices in the Klang valley, Malaysia	[59]	Kuala Lumpur, Malaysia	2338 housing units	Geographical Information Systems (GIS)	The house prices would increase by approximately MYR 5.52 per metre of distance from the hospital.

Table 2. *Cont.*

Variables	Title	References	Research Area	Samples	Methods	Key Findings
SCE	Incorporating neighbourhoods with explainable artificial intelligence for modelling fine-scale housing prices	[60]	Shanghai, China	57,842 housing units	Hedonic Price Model Explainable Artificial Intelligence Model	Scenic spots are positively related to housing prices.
GRE	What Makes a Locality Attractive? Estimates of the Amenity Value of Parks for Victoria	[61]	Victoria, Australia	290,000 residences	Hedonic Price Model	Parks can have a significant positive impact on house prices.
WAT	What's in a view?	[62]	Auckland, New Zealand	5000 sales	Hedonic Price Model	Wide views of water add an average of 59% to the value of a waterfront property, but this effect diminishes quite rapidly as the distance from the coast increases.
FUN	Nonlinear rail accessibility and road spatial pattern effects on house prices	[63]	Fuzhou, China	1245 residential community samples	Space Syntax Analysis Linear Regression Model Spatial Regression Model	The farther the funeral facilities are from the house, the better people's inner experience and environmental feelings, which will raise the house prices.
FAC	House values, incomes, and industrial pollution	[64]	New England States, USA	2257 census tracts	Three Stage Least Squares (3SLS)	The house would be valued 1.9% more if it were located 1 mile further from the factory.
GAS	Effects of expanding electric vehicle charging stations in California on the housing market	[65]	California, USA	14 million housing transaction records	Difference-in-differences	Gas stations are found to decrease nearby housing values by 10%.
DUM	Price effects of landfills on house values	[66]	Ramsey, USA	708 nearby homes	Ordinary Least Squares (OLS)	Landfills located within two miles of the housing community negatively affect house prices. House prices increase by 6.2% as the distance to the landfills increases by one mile.

2.2.2. Research Variables

In order to accurately discuss the characteristics of colour and material variables, the study established quantitative parameters for the materials and colours of residential building facades, encompassing a total of four variable categories. The first aspect of the study focused on quantifying and characterizing the exterior colours of residential samples. Using computer image recognition technology, the quantity and composition of the colours of the building facades of the sampled residences are determined within a colour tolerance of a standard deviation of less than 20 for colour matching. The process is illustrated in Figure 3. The first type of research variable, which represents the quantity of colours on building facades, is measured using dummy variables (one, two, three and four colours or more). The main colour is analysed using the second type of research variable, namely the colour feature index. Specifically, the colour feature indices are extracted using field measurements of a colourimeter. To reduce data errors in the field measurement, the main colour features are measured thrice, and the average is taken as the precise measurement. These colour feature indices address the four aspects of colour lightness, saturation, colour balance and hue. Numerous standard description systems are available for these indices, amongst which LAB and LCH are intuitive colour description systems. The relationship between LAB and LCH is depicted in Figure 4, where "A" and "B" produce a colour composite equivalent to that produced by "C" and "H". In the LAB colour space, "L" represents colour lightness ranging from 0 (black) to 100 (white); "A" represents the red–green colour tendency, with positive and negative values indicating red and green colour tendencies, respectively; and "B" represents the yellow–blue colour tendency with values ranging from −100 to 100 and with positive and negative values denoting yellow and blue colour tendencies, respectively [67]. In the LCH colour space, "L" indicates colour lightness and takes a value between 0 and 100, "C" indicates colour saturation and ranges between 0 and 100, and "H" indicates the hue or overall tendency of the colour with a value range of 0 to 360. The value of H represents the quantity of degrees of the angle on the colour wheel [68]. This study's colour characteristic metrics involved the direct measurement of "L", "A", "B", "C" and "H" values using a colourimeter. To minimize the data errors associated with on-site measurements, this study used three random sampling points for each sample and averaged the results for data reference. Due to their intuitive properties, these two systems are distinct. This study therefore employs two sets of colour criteria to examine the relationship between colour features and house prices. The quantity and features of the facade materials used by the sampled condominiums are then determined by scanning field research records. These facade materials are divided into seven categories and are encoded as dummy variables. As shown in Figure 5, these categories are stone bricks, glass curtains, metal curtains, aluminium–plastic boards, ceramic tiles, coatings and as-cast-finish concrete. The third and fourth types of research variables are the total quantity of material categories present on the building facades and their main colour areas, respectively. Although the information covered by these research variables has been discussed in approximate terms in previous studies (Table 3), there has been no dedicated research on the topics targeted by these research variables. Therefore, this study made innovative attempts in the setup of these variables.

Figure 3. Computer vision image of building facades.

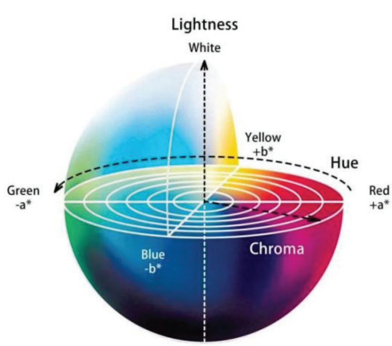

Figure 4. Schematic diagram of the colour variables. Source: made by the authors.

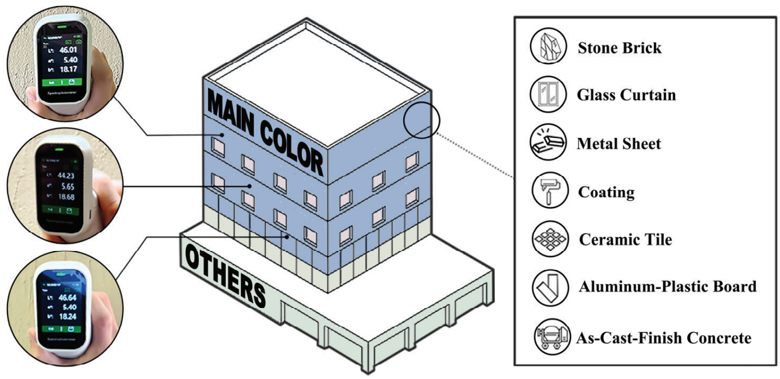

Figure 5. Schematic diagram of the material variables. Source: made by the authors.

Table 3. Related studies on the research variables.

Variables	Title	References	Research Area	Samples	Methods	Key Finding
3M	Dreams of light for the city	[69]	Thessaloniki, Greece	900 participants	Questionnaire	Most people prefer individual houses with three colours.
4M	Dreams of light for the city	[69]	Thessaloniki, Greece	900 participants	Questionnaire	Most people prefer apartments and public houses with four colours.
M①	Research on colour harmony of building facades	[70]	Taipei, Taiwan	43 participants	Experimental Questionnaire	People prefer facades with a primary colour of a high lightness level.
M②	Colour associations with different building types: an experimental study on American college students	[71]	Athens, USA	98 participants	Experimental	Residences were mostly associated with the colour red.
	Study of the colour characteristics of residential buildings in Shanghai	[72]	Shanghai, China	4179 residential building neighbourhoods	Data Collection Statistical Analysis	Studies showed significant effects of saturation on colour preference; more saturated colours are preferred more. The colours of residential buildings are mostly warm colours with low saturation.
M③	A comparison between wishes and status: Gray is not the preference for residents while the city shows neutral colours	[3]	Changzhou, China	1065 participants	Questionnaire Site survey	Colours in blue are welcome.
	Hue, saturation, lightness, and building exterior preference: An empirical study in Turkey comparing architects' and nonarchitects' evaluative and cognitive judgments	[4]	Izmir, Turkey	60 participants	Experimental Questionnaire	A certain amount of agreement in judged pleasantness of hues.

Table 3. *Cont.*

Variables	Title	References	Research Area	Samples	Methods	Key Finding
STO GLA MET COA CER ALU CON	An examination of people's preferences for buildings and streetscapes in New Zealand	[9]	Auckland and Wellington, New Zealand	156 streets	Questionnaire Focus Group	At the scale of the individual building facade, people were found to prefer traditional cladding materials such as brick and those that could be painted or refinished.

2.3. Methods

2.3.1. Hedonic Price Model Regression

Hedonic price models are often used to express the relationship between price explanatory variables and prices. Considering the marginal effects of price behaviour, log-linear models are often used in correlation analyses [73]. Given that the colour decomposition variables in this study contain zero values, the following linear relationship model is established to explore the correlation between colour and price. The expression Equation (1) can be written as follows:

$$\ln P = \beta_0 + \sum_{i=1}^{n} \beta_i \ln x_i + \sum_{j=1}^{m} \beta_j c_j + \varepsilon \tag{1}$$

where P is the house price $\left(\mathrm{CNY/m^2}\right)$, β_0 is a constant term, x_i denotes the characteristic variables (i.e., control variables) and is not taken as a logarithm when the indicator is a dummy variable, β_i indicates the characteristic price coefficient of the characteristic variable, c_j represents the colour correlation variable for the object, β_j is the correlation coefficient of the colour variable, ε denotes the error term and n and m are the corresponding quantity variables.

2.3.2. Quantile Regression

Quantile regression is a cutting-edge technique in econometrics research that employs several quantiles of an explanatory variable (including quartiles, deciles and percentiles) to obtain the appropriate quantile equation for the conditional distribution of the explanatory variable [74]. Equation (2) represents the quantile regression model [75]:

$$\ln P_i = \beta_{0q} + \sum_{n=1}^{N} \beta_{nq} \ln X_{in} + \beta_c c_j + \varepsilon_i \tag{2}$$

where β_{0q} is a constant, β_{nq} is the coefficient of the n-th characteristic variable corresponding to the q-th quantile, β_c is the unknown colour correlation parameter and c_j is the continuous variable of the colour feature [76]. β_q (the vector and its elements β_{nq}, $n = 0, 1, \ldots, N$) is estimated by minimising the given objective function Equation (3):

$$\hat{\beta}_q = \operatorname{argmin}\left[\sum_{\varepsilon_i \geq 0} 2q\varepsilon_i - \sum_{\varepsilon_i < 0} (2-2q)\varepsilon_i\right] \tag{3}$$

Asymmetric weights are often used, and only the median regression ($q = 0.5$) uses symmetric weights.

2.3.3. Interaction Regression

The partial linear model with interaction terms is a generalisation of the partial linear model that is combined with the interactions between the partial covariates of the parameters [77]. The general form of this model is expressed as Equation (4):

$$P_i = \sum_{d=1}^{p_n} \beta_d X_{id} + \sum_{l=1}^{L} m_l(U_{il}) + \sum_{d,j=1}^{p_n} \gamma_{dj} X_{id} X_{ij} + \varepsilon_i \tag{4}$$

where $X_{ij}^2(i = 1, 2, \cdots, n, 1 \le d = j \le p_n)$ and $X_{id}X_{ij}(i = 1, 2, \cdots, n, d < j = 1, \cdots, p_n)$ are the quadratic and second-order interaction terms, respectively, and $\gamma_{dj}(d \le j = 1, 2, \cdots, p_n)$ is the regression parameter vector of the interaction term.

3. Results

The data analysis results are presented in two distinct sections, namely the Linear Regression Section and the Quantile Regression Section.

3.1. Linear Regression

When fitting the linear regression results, robustness tests are conducted to ensure the stability and consistency of the linear regression data [78]. The results are presented in Table 4. The adjusted fit evaluation values of all regression functions are greater than 0.7, whereas the residual autocorrelation values are greater than 1.87. These results indicate that all regression functions show a good fit, thus highlighting the favourable stability of the results.

Table 4. Coefficients of the linear regression analysis (N = 906).

Variables	OLS				Robustness Test	
	Control	VIF	LAB	LCH	LAB	LCH
(Constant)	−2.894 ***	-	−3.033 ***	−2.987 ***	−3.374 ***	−2.518 ***
ADM	0.414 ***	3.096	0.401 ***	0.396 ***	0.466 ***	0.335 ***
LC1	0.112 ***	2.119	0.117 ***	0.117 ***	0.131 ***	0.096 ***
LC2	0.113 ***	3.208	0.115 ***	0.115 ***	-	0.142 ***
POP	0.153 ***	1.858	0.136 ***	0.137 ***	0.177 ***	-
GDP	0.157 ***	2.332	0.175 ***	0.176 ***	0.187 ***	0.211 ***
COM	0.090 ***	1.458	0.080 ***	0.080 ***	0.079 ***	0.081 ***
T500	0.093 ***	1.381	0.095 ***	0.095 ***	0.102 ***	0.097 ***
MIN	0.049 ***	1.118	0.050 ***	0.050 ***	0.044 ***	0.053 ***
PRI	0.263 ***	1.165	0.253 ***	0.254 ***	0.261 ***	0.256 ***
MID	0.186 ***	1.564	0.177 ***	0.174 ***	-	0.194 ***
AGE	0.063 ***	1.356	0.044 ***	0.046 ***	0.050 ***	0.037 ***
DEN	0.020 ***	1.078	0.018 ***	0.018 ***	0.028 ***	-
GRER	0.014 ***	1.234	0.010 *	0.011 **	0.018 ***	0.010 **
FEE	0.127 ***	1.580	0.106 ***	0.106 ***	0.098 ***	0.108 ***
RAI	−0.036 ***	1.554	−0.036 ***	−0.037 ***	−0.026 ***	−0.037 ***
MAR	−0.022 ***	1.880	−0.020 ***	−0.020 ***	−0.024 ***	−0.011 ***
HOS	−0.036 ***	2.558	−0.036 ***	−0.036 ***	−0.059 ***	−0.033 ***
SCE	0.013 ***	1.755	0.014 ***	0.012 ***	0.002	-
GRE	−0.006**	2.142	−0.005 **	−0.005 **	−0.019 ***	0.001
WAT	−0.044 ***	1.308	−0.042 ***	−0.042 ***	-	−0.038 ***
FUN	0.035 ***	1.460	0.037 ***	0.036 ***	0.049 ***	0.015 ***
FAC	0.029 ***	1.598	0.023 ***	0.023 ***	0.032 ***	0.023 ***
GAS	0.018 ***	1.228	0.015 ***	0.015 ***	0.028 ***	0.015 ***
DUM	0.110 ***	1.752	0.114 ***	0.111 ***	0.094 ***	0.090 ***
2C	-	-	0.010	0.013	0.014 *	0.025 ***
3C	-	-	0.025 ***	0.029 ***	0.032 ***	0.055 ***
4C	-	-	0.001	0.010	0.000	0.047 ***
M①	-	-	0.000 **	0.000	0.000	0.000
M②	-	-	0.002 ***	−0.001 **	0.002 ***	−0.001 ***
M③	-	-	−0.001 **	−0.000	−0.001 **	−0.000
2M	-	-	0.046 ***	0.050 ***	0.056 ***	0.052 ***
3M	-	-	0.029 ***	0.032 ***	0.037 ***	0.036 ***
4M	-	-	0.035 ***	0.036 ***	0.036 ***	0.043 ***
STO	-	-	−0.031 ***	−0.032 ***	−0.025 **	−0.027**

Table 4. *Cont.*

Variables	Control	VIF	OLS LAB	OLS LCH	Robustness Test LAB	Robustness Test LCH
GLA	-	-	0.025 ***	0.025 ***	0.043 ***	0.027 ***
MET	-	-	−0.020 ***	−0.021 ***	−0.022 ***	−0.024 ***
COA	-	-	−0.018 *	−0.023**	−0.021 *	−0.025**
CER	-	-	−0.064 ***	−0.066 ***	−0.069 ***	−0.069 ***
ALU	-	-	0.047 ***	0.044 ***	0.052 ***	0.038 ***
CON	-	-	−0.092 ***	−0.099 ***	−0.083 ***	−0.098 ***
Adj-R^2	0.706		0.718	0.717	0.695	0.710
DW	1.871		1.850	1.849	1.724	1.795

Note: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

The above results reveal a significant correlation between the selected control variables and house prices. The variables that are positively correlated with house prices include the regional administrative category; the regional geographic centrality (whether it is inside the second or third ring road); the regional economic development level (GDP per capita); the regional population; the type of pure commercial condominiums; whether the developers are amongst the top 500 in China; whether the developers originate from Fujian Province; whether the condominium is near a high-quality primary or middle school; whether the condominium was built after 2000; the density of buildings; monthly management fees; and distances to the closest scenic spot, factory, gas station, dump and funeral facilities. Meanwhile, the greening rate of the community only shows a slightly positive correlation with house prices, whereas facility accessibility variables, including the distances to the closest rail station, market, grade-A tertiary hospital, green space and main water source show a negative correlation. Amongst the variables showing a positive correlation, the regional administrative category and school resources (near a high-quality primary or middle school) have the largest coefficients, thereby suggesting that these variables have the highest correlation with house prices. Meanwhile, the distance to the closest dump shows the highest positive correlation with house prices.

The results for the quantity of building facade colours reveal that condominiums with three facade colours can offer greater price increases than those with only a single facade colour. In the regression function based on the LAB criterion, the lightness of the main colour of the building facade shows a significant correlation with house prices, but its coefficient is 0, which can be interpreted as no correlation. Meanwhile, the red and yellow tendencies of the main colour of the building facade show positive and negative correlations with house prices, respectively. In the regression function based on the LCH criterion, only the saturation of the main facade colour shows a negative correlation with house prices. Two building facade materials provide the highest markup for house prices, followed by four or more facade materials and three facade materials. However, compared with one facade material, all of these three cases provide additional markup for house prices. The presence of glass curtains and aluminium–plastic boards is positively correlated with house prices, with aluminium–plastic boards commanding a higher premium. The other categories of facade materials, including marble stone bricks, metal sheets, coatings, ceramic tiles and plain concrete, all show negative correlations with house prices, with plain concrete providing the greatest reduction in prices.

The interaction regression focuses on the significance of the interaction terms and their corresponding coefficient signs. The results in Table 5 (the full table can be seen in Table A1) indicate that the interaction terms between certain facade material variables and colour variables are statistically significant, thereby suggesting that house prices are correlated with the combination of building facade material characteristics and colour features. For two or three building facade materials, the red and yellow tendencies of the main colour are negatively and positively correlated with house prices, respectively. The degree of such correlation is at its peak for two facade materials. In the case of two facade materials, a significantly positive correlation can be observed between the lightness and saturation of the main colour and house prices. As for the features of the main colour materials, the brighter the main colour and the more yellow the colour balance tendency, the higher the positive correlation with house prices. The other materials have a higher positive correlation with house prices when the colour balance tendency is bluer. However, when the main colour materials include coatings, ceramic tiles and as-cast-finish concrete, a lower lightness of the main colour corresponds to a higher positive correlation. When the main colour material consists of stone bricks and metal sheets, a significant positive correlation can be observed between the saturation of the main colour and house prices. When the material consists of aluminium–plastic boards and plain concrete, a significant negative correlation is observed. In the case of two facade materials, having two or three colours is positively correlated with house prices. For only one facade colour, glass curtains and metal sheets are positively and negatively correlated with house prices, respectively. For two facade colours, the main colour materials consisting of coatings and ceramic tiles are positively correlated with house prices. For three facade colours, the main colour materials consisting of coatings and ceramic tiles or metal sheets are negatively correlated with house prices, whereas the main colour materials consisting of aluminium–plastic boards shows a positive correlation. For four facade colours, the main colour materials consisting of glass curtains and metal sheets are positively and negatively correlated with house prices, respectively.

3.2. Quantile Regression

The results of the quantile regressions are presented in Tables 6 and 7. Table 6 shows that the correlation between the number of facade colours and house prices is primarily concentrated in the lower quartile regressions, which reveal that distinct quantities of facade colours have significant positive correlations with house prices. Meanwhile, the low and middle quartile regressions indicate a positive correlation for the tendency of red in the red–green colour balance and a negative correlation for the tendency of yellow in the yellow–blue colour balance. The lower quartile regression results also reveal a negative correlation between colour saturation and house prices. For the quantity of facade materials, the middle quartile regression results indicate the strongest positive correlation for two materials, whilst the high quartile regression results indicate the strongest positive correlation for four or more materials. In the lower quartile regression results for the features of the facade main colour and materials, glass curtains and aluminium–plastic boards exhibit a (marginally significant) positive correlation with house prices, whereas stone bricks, ceramic tiles and as-cast-finish concrete exhibit a negative correlation. Glass curtains, coatings and aluminium–plastic boards are positively correlated with house prices, whereas stone bricks, metal sheets and as-cast-finish concrete show a negative correlation. Glass curtains and aluminium–plastic boards exhibit significant positive correlations in the high quartile regression results, whereas metal sheets, ceramic tiles and as-cast-finish concrete exhibit significant negative correlations.

Table 5. Interactive coefficients of the linear regression analysis (N = 906).

Research Variables			OLS						Robustness Test					
			LAB		LCH		Quantity of Colours		LAB		LCH		Quantity of Colours	
Quantity	Features [1]	Features [2]	Quantity	Features [1]	Quantity	Features [1]	Quantity	Features [2]	Quantity	Features [1]	Quantity	Features [1]	Quantity	Features [2]
Table A1														
M①	M①	2C	0.000	0.005 ***	−0.001	0.007 ***	-	0.160 ***	0.000	0.004 ***	−0.001	0.007 ***	-	0.199 ***
M②	M②	3C	0.007 ***	−0.009 ***	−0.003 **	0.002	-	0.123 **	0.003 *	−0.011 ***	−0.001	0.000	-	0.195 ***
M③	M③	4C	−0.002 ***	0.011 ***	0.000 ***	0.000	-	−0.133	−0.001*	0.010 ***	0.000 **	0.000 *	-	0.021
2M	STO	STO	−0.063	−0.294 ***	−0.173 ***	−0.264 ***	-	0.014	−0.084	−0.319 ***	−0.216 ***	−0.314 ***	-	0.002
3M	GLA	GLA	0.017	0.015	−0.010	0.047 *	-	0.064 ***	−0.030	−0.017	−0.053	0.033	-	0.113 ***
4M	MET	MET	0.036	0.026	−0.052	−0.057	-	0.004	0.037	0.023	−0.001	−0.084 *	-	0.019
M① × 2 M	COA	COA	0.001	0.308 ***	0.002 ***	0.470 ***	-	0.105 *	0.001	0.285 ***	0.003 ***	0.449 ***	-	0.087
M② × 2 M	CER	CER	−0.008 ***	0.265 ***	0.004 ***	0.424 ***	-	0.032	−0.006 ***	0.215 ***	0.002	0.429 ***	-	0.049
M③ × 2 M	ALU	ALU	0.005 ***	−0.017	0.000*	0.138 **	-	−0.138 ***	0.004 ***	−0.045	0.000 **	0.151 **	-	−0.137 ***
M① × 3 M	CON	CON	0.000	0.236 ***	−0.000	0.349 ***	-	−0.003	0.000	0.175**	0.001	0.283 ***	-	0.014
M② × 3 M	M① × STO	2C × STO	−0.006 ***	0.003 ***	0.002	0.003 ***	-	−0.044	−0.003	0.003 ***	0.000	0.004 ***	-	−0.027
M③ × 3 M	M② × STO	2C × GLA	0.002 **	−0.004	0.000	0.004 ***	-	−0.037	0.003 ***	−0.004	0.000	0.006 ***	-	−0.088 ***
M① × 4 M	M③ × STO	2C × MET	0.000	0.009 ***	0.000	0.000 ***	-	−0.006	−0.000	0.010 ***	0.000	0.000*	-	−0.032*
M② × 4 M	M① × GLA	2C × COA	−0.003	0.000	0.002	−0.001	-	−0.164 ***	−0.001	0.000	−0.001	0.000	-	−0.144 **
M③ × 4 M	M② × GLA	2C × CER	0.001	0.003 **	0.000 ***	−0.000	-	−0.155 **	0.001	0.004 ***	0.000 ***	0.000	-	−0.161 **
2C	M③ × GLA	2C × ALU	-	−0.002 ***	-	0.000	0.004	0.202 ***	-	−0.001	-	0.000 *	-0.009	0.212 ***
3C	M① × MET	2C × FAI	-	0.000	-	0.000	0.031	−0.107 *	-	0.000	-	−0.000	0.035	−0.138 **
4C	M② × MET	3C × STO	-	0.000	-	0.003 **	−0.012	−0.086	-	0.001	-	0.003 *	-0.047	−0.094
2M	M③ × MET	3C × GLA	-	−0.004 ***	-	0.000 ***	−0.028	−0.043 *	-	−0.005 ***	-	0.000 ***	-0.029	−0.088 ***
3M	M① × COA	3C × MET	-	−0.005 ***	-	−0.007 ***	0.014	−0.071 ***	-	−0.005 ***	-	−0.007 ***	0.017	−0.090 ***
4M	M② × COA	3C × COA	-	0.010 ***	-	−0.002	0.016	−0.114 *	-	0.013 ***	-	−0.002	0.005	−0.097
2C × 2M	M③ × COA	3C × CER	-	−0.011 ***	-	0.000	0.083 ***	−0.070	-	−0.011 ***	-	0.000	0.092 ***	−0.090
2C × 3M	M① × CER	3C × ALU	-	−0.005 ***	-	−0.007 ***	0.005	0.191 ***	-	−0.004 ***	-	−0.007 ***	0.014	0.190 ***

Table 5. *Cont.*

Research Variables			OLS						Robustness Test					
			LAB		LCH		Quantity of Colours		LAB		LCH		Quantity of Colours	
Quantity	Features [1]	Features [2]	Quantity	Features [1]	Quantity	Features [1]	Quantity	Features [2]	Quantity	Features [1]	Quantity	Features [1]	Quantity	Features [2]
2C × 4M	M② × CER	3C × FAI	-	0.009 ***	-	−0.003	0.033	−0.155 **	-	0.011 ***	-	−0.002	0.044	−0.216 ***
3C × 2M	M③ × CER	4C × STO	-	−0.012 ***	-	0.000	0.069 ***	−0.044	-	−0.012 ***	-	0.000	0.059**	−0.010
3C × 3M	M① × ALU	4C × GLA	-	0.001	-	−0.001	−0.000	0.152 ***	-	0.001	-	−0.001	-0.016	−0.181 ***
3C × 4M	M② × ALU	4C × MET	-	0.020 ***	-	−0.004 **	0.014	−0.173 ***	-	0.021 ***	-	−0.004 **	0.019	−0.168 ***
4C × 2M	M③ × ALU	4C × COA	-	−0.003 **	-	0.000	0.071*	0.149 *	-	−0.003 **	-	−0.000	0.099**	0.105
4C × 3M	M① × CON	4C × CER	-	−0.005 ***	-	−0.007 ***	0.040	0.214 **	-	−0.004 ***	-	−0.006 ***	0.048	0.105
4C × 4M	M② × CON	4C × ALU	-	0.008	-	−0.006 **	0.017	0.099 *	-	0.008	-	−0.005 *	0.047	0.002
-	M③ × CON	4C × FAI	-	−0.015 ***	-	0.000	-	-	-	−0.012 ***	-	0.000 **	-	-
	$Adj\text{-}R^2$		0.709	0.728	0.710	0.723	0.710	0.723	0.662	0.717	0.662	0.711	0.687	0.686
	DW		1.870	1.863	1.872	1.849	1.853	1.852	1.793	1.863	1.821	1.821	1.802	1.715

Note: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Table 6. Coefficients of the quantile regression analysis (N = 906).

Variables	LAB			LCH		
	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75
Table A2						
(intercept)	−1.862 ***	−1.258 ***	−1.259 ***	−1.769 ***	−1.258 ***	−1.231 ***
[ADM = 0]	−0.442 ***	−0.367 ***	−0.305 ***	−0.425 ***	−0.356 ***	−0.310 ***
[LC1 = 0]	−0.107 ***	−0.103 ***	−0.106 ***	−0.104 ***	−0.104 ***	−0.108 ***
[LC2 = 0]	−0.109 ***	−0.085 ***	−0.110 ***	−0.119 ***	−0.087 ***	−0.099 **
POP	0.099 ***	0.107 ***	0.090 ***	0.111 ***	0.113 ***	0.091 ***
GDP	0.156 ***	0.172 ***	0.193 ***	0.157 ***	0.172 ***	0.198 ***
[COM = 0]	−0.067 ***	−0.077 ***	−0.073 ***	−0.070 ***	−0.079 ***	−0.076 ***
[T500 = 0]	−0.063 ***	−0.083 ***	−0.084 ***	−0.063 ***	−0.086 ***	−0.082 ***
[MIN = 0]	−0.045 ***	−0.053 ***	−0.048 ***	−0.054 ***	−0.051 ***	−0.044 ***
[PRI = 0]	−0.108 ***	−0.317 ***	−0.377 ***	−0.134 ***	−0.320 ***	−0.377 ***
[MID = 0]	−0.176 ***	−0.179 ***	−0.195 ***	−0.167 ***	−0.169 ***	−0.192 ***
[AGE = 0]	−0.055 ***	−0.054 ***	−0.039 ***	−0.054 ***	−0.059 ***	−0.040 ***
DEN	0.021 ***	0.028 ***	0.030 ***	0.020 ***	0.028 ***	0.030 ***
GRER	0.014 ***	0.000	0.012 **	0.015 ***	0.002	0.012 **
FEE	0.086 ***	0.118 ***	0.125 ***	0.090 ***	0.116 ***	0.124 ***
RAI	−0.044 ***	−0.044 ***	−0.038 ***	−0.049 ***	−0.045 ***	−0.039 ***
MAR	−0.024 ***	−0.021 ***	−0.021 ***	−0.025 ***	−0.021 ***	−0.019 ***
HOS	−0.024 ***	−0.041 ***	−0.042 ***	−0.024 ***	−0.042 ***	−0.045 ***
SCE	0.008 **	0.015 ***	0.017 ***	0.004	0.014 ***	0.018 ***
GRE	0.000	−0.011 ***	−0.013 ***	−0.001	−0.011 ***	−0.013 ***
WAT	−0.027 ***	−0.027 ***	−0.034 ***	−0.029 ***	−0.027 ***	−0.035 ***
FUN	0.024 ***	0.034 ***	0.035 ***	0.019 ***	0.034 ***	0.037 ***
FAC	0.025 ***	0.020 ***	0.014 ***	0.025 ***	0.019 ***	0.015 ***
GAS	0.017 ***	0.014 ***	0.015 ***	0.014 ***	0.014 ***	0.017 ***
DUM	0.135 ***	0.101 ***	0.097 ***	0.138 ***	0.099 ***	0.084 ***
[2C = 0]	−0.031 ***	0.009	0.007	−0.031 ***	0.004	0.005
[3C = 0]	−0.045 ***	−0.003	−0.015 *	−0.045 ***	−0.007	−0.016 *
[4C = 0]	−0.031 ***	−0.005	−0.008	−00.043 ***	−0.007	−0.015
M①	0.000 *	0.000	−0.000	0.000 *	0.000	−0.000
M②	0.004 ***	0.002 ***	0.001 **	−0.002 ***	0.000	0.001 **
M③	−0.002 ***	−0.001 ***	−0.000	−0.000	0.000	0.000
[2M = 0]	−0.015	−0.031 ***	−0.025 **	−0.018	−0.032 ***	−0.028 **
[3M = 0]	0.000	−0.030 ***	−0.028 ***	−0.000	−0.031 ***	−0.026 ***
[4M = 0]	0.004	−0.022 ***	−0.033 ***	0.001	−0.017 **	−0.029 ***
[STO = 0]	0.105 ***	0.028 ***	0.001	0.104 ***	0.033 ***	0.005
[GLA = 0]	−0.038 ***	−0.040 ***	−0.045 ***	−0.028 ***	−0.041 ***	−0.047 ***
[MET = 0]	0.001	0.020 ***	0.037 ***	0.011	0.020 ***	0.036 ***
[COA = 0]	0.002	−0.028 ***	0.015	0.009	−0.017	0.015
[CER = 0]	0.034 ***	0.002	0.055 ***	0.038 ***	0.009	0.054 ***
[ALU = 0]	−0.021 **	−0.044 ***	−0.049 ***	−0.013	−0.040 ***	−0.048 ***
[CON = 0]	0.067 ***	0.039 ***	0.083 ***	0.078 ***	0.050 ***	0.083 ***
Pse R^2	0.474	0.491	0.523	0.470	0.490	0.523
MAE	1.472	0.1192	0.1436	0.1472	0.1196	0.1438

Note: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Table 7. Interaction coefficients of the quantile regression analysis (N = 906).

Research Variables			LAB						LCH						Quantity of Colours					
			Quantity			Features 1			Quantity			Features 1			Quantity			Features 2		
Quantity	Features 1	Features 2	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75
M①	M①	[2C = 0]	0.000	0.001 **	0.001 *	0.003 ***	0.003 ***	0.000	0.000	0.001	0.000	0.001	0.004 ***	0.004 ***	-	-	-	−0.060	−0.071	−0.187 ***
M②	M②	[3C = 0]	0.005 ***	0.001	−0.002	−0.007 **	−0.004	−0.013 ***	−00.000	−0.004 ***	−0.006 ***	−0.005 **	0.000	0.005 **	-	-	-	−0.062	−0.117 **	−0.262 ***
M③	M③	[4C = 0]	−0.001	−0.003 ***	−0.003 ***	0.008 ***	0.007 ***	0.013 ***	0.000 ***	0.000 **	0.000 ***	0.000 **	0.000	0.000	-	-	-	0.246 ***	0.051	−0.110
[2M = 0]	[STO = 0]	[STO = 0]	0.141 ***	0.012	0.027	0.328 ***	−0.001	0.052	0.194 ***	0.075 *	0.142 ***	0.414 ***	0.228 ***	−0.158 ***	-	-	-	−0.102	−0.045	−0.004
[3M = 0]	[GLA = 0]	[GLA = 0]	0.014	−0.050	−0.021	0.001	−0.031	−0.093 ***	−0.042	−0.040	0.030	0.003	−0.038	−0.084 ***	-	-	-	−0.073 ***	−0.050 **	−0.006
[4M = 0]	[MET = 0]	[MET = 0]	0.112 ***	−0.048	−0.094 **	−0.036	0.077 *	−0.037	0.090 **	0.016	0.014	0.013	0.058	0.017	-	-	-	−0.030 **	−0.008	0.013
M① × 2 M	[COA = 0]	[COA = 0]	0.002 ***	0.000	0.000	−0.228 ***	−0.189 ***	0.031	0.002 ***	0.000	0.001	−0.137 *	−0.313 ***	−0.319 ***	-	-	-	−0.013	−0.171 ***	−0.206 ***
M② × 2 M	[CER = 0]	[CER = 0]	−0.003	−0.001	−0.001	−0.190 ***	−0.159 **	0.035	0.001	0.005 ***	0.005 ***	−0.048	−0.273 ***	−0.283 ***	-	-	-	0.055	−0.035	−0.118 **
M③ × 2 M	[ALU = 0]	[ALU = 0]	0.001	0.004 ***	0.006 ***	0.033	0.076	0.146 **	0.000 ***	0.000	0.000	−0.065	−0.136 **	0.094	-	-	-	0.053	0.095 **	0.142 ***
M① × 3 M	[CON = 0]	[CON = 0]	0.000	−0.001 **	−0.001 *	−0.112	−0.124	−0.045	−0.001	−0.001 **	−0.001	−0.034	−0.261 ***	−0.338	-	-	-	0.083	−0.006	−0.081
M② × 3 M	M① × STO	[2C × STO = 0]	−0.003	0.001	0.002	0.003 ***	−0.001	−0.001	−0.001	0.004 ***	0.006 ***	0.005 ***	0.003 ***	−0.002 **	-	-	-	0.233 ***	0.106 *	0.004
M③ × 3 M	M② × STO	[2C × GLA = 0]	−0.001	0.002 ***	0.004 ***	0.000	−0.013 ***	−0.012 ***	0.000 **	0.000	0.000 *	0.006 ***	0.001	0.000	-	-	-	0.041 *	0.011	−0.027
M① × 4 M	M③ × STO	[2C × MET = 0]	0.002 ***	−0.001	−0.001 **	0.009 ***	0.012 ***	0.011 ***	0.001	0.000	−0.001 *	0.000 ***	0.000 ***	0.000 **	-	-	-	0.026	−0.003	−0.017
M② × 4 M	M① × GLA	[2C × COA = 0]	0.003	0.001	0.004 *	0.001 *	0.000	−0.001 *	−0.002	0.002 **	0.005 ***	0.000	−0.000	−0.001 **	-	-	-	0.053	0.151 ***	0.221 ***
M③ × 4 M	M② × GLA	[2C × CER = 0]	−0.003 ***	0.001	0.001	0.002	−0.001	0.002	0.000 ***	0.000 ***	0.000 ***	−0.002 ***	−0.002 ***	0.001	-	-	-	0.022	0.055	0.192 ***
[2C = 0]	M③ × GLA	[2C × ALU = 0]	-	-	-	−0.002 ***	−0.003 ***	−0.003 ***	-	-	-	0.000 ***	0.000	0.000	−0.048 **	0.029	0.007	−0.085 *	−0.134 ***	−0.236 ***
[3C = 0]	M① × MET	[2C × FAI = 0]	-	-	-	0.000	0.001	−0.001	-	-	-	−0.000	−0.000	−0.001	−0.065 ***	−0.008	−0.022	0.001	0.040	0.169 ***
[4C = 0]	M② × MET	[3C × STO = 0]	-	-	-	0.002	0.003	−0.003	-	-	-	−0.000	0.001	0.000	0.036	0.047	−0.060 *	0.230 ***	0.080	0.019

Table 7. *Cont.*

Research Variables			LAB						LCH						Quantity of Colours					
			Quantity			Features [1]			Quantity			Features [1]			Quantity			Features [2]		
Quantity	Features [1]	Features [2]	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75
[2M = 0]	M③ × MET	[3C × GLA = 0]	-	-	-	−0.004 ***	−0.002 **	−0.002 *	-	-	-	−0.000	0.000 *	0.000 **	0.008	0.039 **	0.039 *	0.055 **	0.029	−0.042 *
[3M = 0]	M① × COA	[3C × MET = 0]	-	-	-	−0.004 ***	−0.003 ***	0.000	-	-	-	−0.002 **	−0.004 ***	−0.004 ***	−0.015	0.001	0.012	0.080 ***	0.083 ***	0.092 ***
[4M = 0]	M② × COA	[3C × COA = 0]	-	-	-	0.011 ***	0.006 **	0.014 ***	-	-	-	0.004 **	0.000	−0.004 *	0.006	0.016	0.031	0.029	0.180 ***	0.289 ***
[2C × 2M = 0]	M③ × COA	[3C × CER = 0]	-	-	-	−0.009 ***	−0.007 ***	−0.012 ***	-	-	-	0.000 ***	0.000 *	0.000	−0.009	−0.078 ***	−0.048 *	−0.007	0.061	0.213 ***
[2C × 3M = 0]	M① × CER	[3C × ALU = 0]	-	-	-	−0.003 ***	−0.003 ***	0.000	-	-	-	−0.001	−0.004 ***	−0.004 ***	0.020	−0.026	−0.010	−0.117 **	−0.149 ***	−0.163 ***
[2C × 4M = 0]	M② × CER	[3C × FAI = 0]	-	-	-	0.007 **	0.005 *	0.012 ***	-	-	-	0.005 **	0.000	−0.005 ***	−0.030	−0.065 ***	−0.067 **	0.090	0.154 ***	0.250 ***
[3C × 2M = 0]	M③ × CER	[4C × STO = 0]	-	-	-	−0.009 ***	−0.008 ***	−0.013 ***	-	-	-	0.000 **	0.000	0.000	−0.035	−0.062 ***	−0.044	0.237 ***	0.090	0.045
[3C × 3M = 0]	M① × ALU	[4C × GLA = 0]	-	-	-	0.001	0.002 **	0.003 ***	-	-	-	0.000	−0.001	0.002 **	0.024	−0.008	−0.003	0.150 ***	0.041	−0.013
[3C × 4M = 0]	M② × ALU	[4C × MET = 0]	-	-	-	0.018 ***	0.020 ***	0.016 ***	-	-	-	−0.006 ***	−0.001	−0.002	−0.005	−0.025	−0.056 **	0.069	0.125 ***	0.178 ***
[4C × 2M = 0]	M③ × ALU	[4C × COA = 0]	-	-	-	0.000	−0.002	−0.004 **	-	-	-	0.000 ***	−0.000	−0.000	−0.125 ***	−0.075 **	0.038	−0.285 ***	0.007	0.122
[4C × 3M = 0]	M① × CON	[4C × CER = 0]	-	-	-	−0.003 **	−0.002 **	−0.001	-	-	-	−0.001	−0.004 ***	−0.005 ***	−0.103 ***	−0.082 **	0.022	−0.354 ***	−0.111	0.057
[4C × 4M = 0]	M② × CON	[4C × ALU = 0]	-	-	-	0.015 ***	0.006	0.013 **	-	-	-	−0.001	−0.003	−0.008 ***	−0.062	−0.047	0.031	0.035	0.109 **	−0.158 ***
-	M③ × CON	[4C × FAI = 0]	-	-	-	−0.013 ***	−0.012 ***	−0.016 ***	-	-	-	0.000 **	0.000	0.000	-	-	-	-	-	-
	Pse R^2		0.464	0.484	0.514	0.483	0.499	0.530	0.462	0.485	0.516	0.476	0.493	0.526	0.463	0.484	0.513	0.477	0.497	0.529
	MAE		0.1491	0.1208	0.1459	0.1438	0.1173	0.1410	0.1489	0.1207	0.1451	0.1453	0.1187	0.1434	0.1485	0.1210	0.1459	0.1455	0.1178	0.1419

Note: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

The interaction quantile regression results are shown in Table 7 (the full table can be seen in Table A2). Given the substantial amount of information in the interaction quantile regression results, this section only provides an overview of these results, and the discussion is saved for the next section. Across various combinations of building facade quantities with colour characteristics, combinations of main colour features with main colour material characteristics, combinations of facade material quantities with colour quantities and combinations of main colour material characteristics with colour quantities, a discernible variation can be observed in the preferences of different consumer groups. For example, the low quantile regression results for the quantity of facade materials and colour features reveal that, when there is one facade material, the redder the main colour tendency of the facade, the higher the house prices. Meanwhile, in the median and high quantile regression results, when there is one facade material, the more yellow the main colour tendency or the higher the saturation, the lower the house prices.

To illustrate the price correlation features of these variables as they change across different consumer groups, the variables that emerge as significant in the different quantile regression results are selected as representatives. The coefficient regression changes are plotted in Figure 6. These constant variables focus primarily on the interaction between the external and material primary colour features. Coatings, ceramic tiles, aluminium–plastic board and as-cast-finish concrete emerge as the most dissimilar materials.

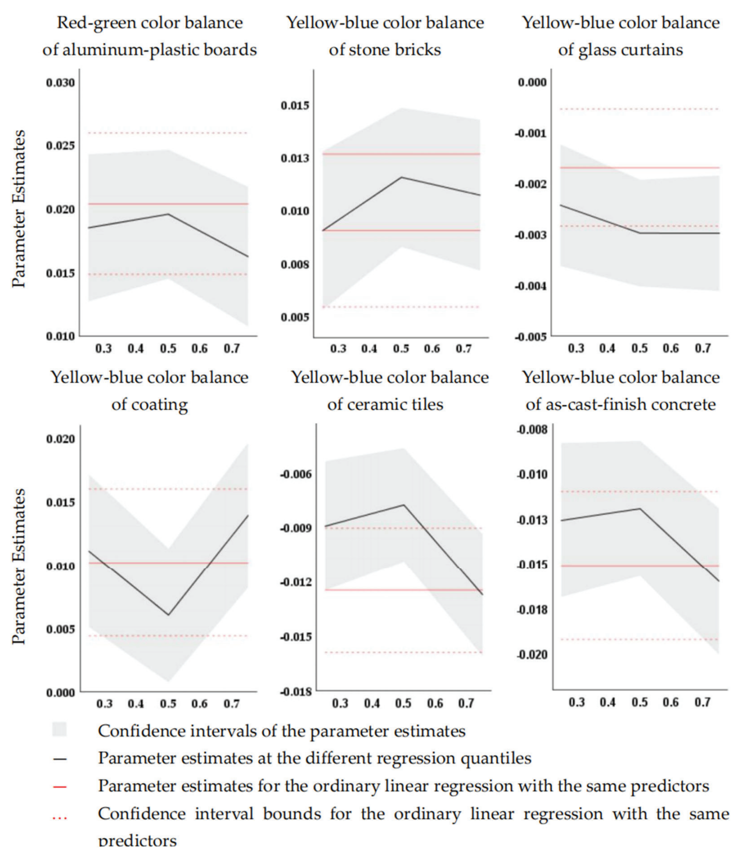

Figure 6. Change results of quantile coefficients.

4. Discussion

4.1. All Consumer Groups

The results of the linear regression analysis for the control variables are comparable with the findings of previous research. Therefore, the following discussion focuses only on the research variables. The consumers' predilection for three facade colours suggests the existence of a common aesthetic perception towards the quantity of colours in Fuzhou. This result echoes that of Tosca [69], who observed a similar preference for the quantity of colours on individual building facades in Greece. However, different conclusions emerge for condominium buildings. Specifically, Greek individuals show a stronger inclination towards condominium buildings with facades featuring four or more colours. This disparity may be due to regional cultural variations or the fact that condominium buildings are the predominant type of individual housing in China. From the perspective of the main colour features, the red and blue tendencies of the main colour are positively correlated with house prices for the overall consumer population, and the coefficient of the red tendency is approximately five times larger than that of the blue tendency, indicating that the public's overall colour aesthetic preference is within the range of burgundy. In conjunction with the positive correlation of low saturation, this finding indicates that the urban condominium consumption group as a whole prefers light burgundy as the main colour, whereas a main colour of red with a colder hue is more popular among consumers. This colour aesthetic preference may be related to the celebratory significance of red in China [79]. Furthermore, the preference for a red tendency in building facades is not solely confined to China; Kaya and Crosby [71] arrived at a similar conclusion in Athens, US. Therefore, the preference for red hues on facades may not solely stem from cultural influences but may also be rooted in the psychological commonalities among consumers. Meanwhile, the analytical results for facade lightness are not significant, thereby highlighting the diversity in the aesthetic preferences of consumer groups for the lightness of the main colours. Interestingly, in Taiwan, not far from mainland China, consumers prefer a higher facade lightness for condominium buildings [70]. The underlying reasons for this finding warrant further exploration in future research. In terms of the quantity of materials for the main colour of the facade, the combination of two facade materials can provide a higher house price than the combination of three and four or more materials, thus confirming the lack of an absolute correlation between material costs and the final selling price. The general consumer preference for two types of materials indicates that consumers place greater emphasis on the sensory combination of materials rather than on a simple accumulation of costs. This novel finding is not only highly valuable but also highlights a new perspective in the field. In terms of the material features of the main facade colour, aluminium–plastic boards and glass curtains are preferred by consumers, whereas other materials, particularly plain concrete, are detested by consumers. This result may be due to the high-quality impression created by aluminium–plastic boards and glass curtains and the low-quality impression created by plain concrete. However, this preference for materials may exhibit strong regional variations. Research conducted in Finland [80] and New Zealand [9] revealed that the residents in these areas mostly prefer traditional local building materials, such as wood.

When the building facade material factor is considered in conjunction with the colour factor, the general population shows a consistent aesthetic preference. In terms of the relationship between the main colour of the building and the quantity of materials, all consumer groups prefer yellow–green when there are two or three materials, and a greater preference for yellow–green corresponds to a higher transaction price. These groups also prefer high lightness and saturation, particularly in the case of two facade materials. Therefore, when the quantity of facade materials is relatively limited, the main body should use brightly coloured materials to be in line with the aesthetic preferences of consumers. In terms of the relationship between the main colour features of the facade and the material type of the main colour features, consumers generally prefer stone bricks with a high lightness, high saturation and yellowish colour balance; glass with a blueish colour balance;

metal sheets with a high saturation and blueish colour balance; burgundy coatings and burgundy ceramic tiles with a low lightness; burgundy aluminium–plastic boards with a low lightness; and concrete with a low lightness, low saturation and blueish colour balance. These findings indicate that the varying preferences of consumers for the colour features of different facade materials are driven by these materials' distinct textures. Different facade materials can evoke different colour resonances appreciated by consumers. Such an exploration of the premises of colour preferences goes beyond the conventional discussions centred solely on colour aspects in urban consumer facade preferences. This discussion also substantiates the claim that some fixed material–colour combinations can effectively captivate the preferences of consumers. In terms of the relationship between the quantity of building facade materials and colours, consumers prefer condominiums with two and three facade colours in the case of only two facade materials, thereby indicating that, when the quantity of facade materials is small, consumers prefer facade styles with a relatively coincident colour quantity. This trend suggests that all consumer groups prefer plain and distinct material colour combinations for the exterior aesthetics of condominium buildings. People share a common aesthetic preference for distinct main colour materials in terms of the quantity of colour combinations and the features of the main colour materials used for building facades. This preference may be related to the complexity of the texture of these materials. Some materials, such as coatings, ceramic tiles and glass, have a single texture. If the colour combination is simple, then people will feel that the building is cheap, thus showing no interest in the purchase. Therefore, a diverse colour combination is required to improve the overall quality of the structure. Certain materials, such as aluminium–plastic boards, have a delicate texture and, thus, require appropriate colour matching to bring out their attractiveness. In addition, some materials, such as metal panels, are preferred by consumers due to their inherent complexity and lustre. Therefore, the quantity of colours must be limited to emphasise the texture of these metals.

4.2. Different Consumer Groups

Based on the results of the quantile regression analysis, the aesthetic preferences of different consumer groups are summarised in Table 8. Consumers in the low-consumption group are more traditional and conservative than those in the middle- and high-consumption groups, and the traditional way of thinking is more prevalent amongst consumers with a lower consumption level. For instance, the preference for burgundy with low saturation is an expression of conservatism based on regional cultural inertia [81]. In terms of colour aesthetic preference, the middle-consumption group shares some similarities with the low-consumption group but is less conventional. In terms of material aesthetic preferences, the high-consumption group is similar to the low-consumption group but does not prefer aluminium–plastic boards and metal sheets. This finding indicates that, as their level of consumption raises, consumers become more attuned to the minute differences amongst similar materials, thus increasing the nuance of their aesthetic perceptions. This finding also indirectly demonstrates the close correlation between economic foundational levels and the state of existential well-being [82]. As for consumers in the high-consumption group, the absence of a group-wide colour preference highlights the diversity of their aesthetic preferences. Although some consumers may prefer red as the main colour, they hold an open and tolerant outlook in life. These consumers also prefer highly diverse material combinations, which further demonstrates the complexity and inclusivity of their preferences for materials. Based on these arguments, one may hypothesise that the degree of diversity in building facade materials within a city is positively correlated with the region's economic level [83]. However, in terms of material preference, the conceptual preferences between the high-consumption group and the two other groups remain consistent without any significant differences.

Table 8. Aesthetic preferences of different consumer groups.

		Low-Consumption Group	Middle-Consumption Group	High-Consumption Group
Colours and Materials				
Quantity of Colours		Preference order: three colours, two colours, four colours or more, one colour	-	-
Features of the Main Colour Materials	Lightness	-	-	-
	Red–Green	Prefer red, preference degree higher than middle-consumption group	Prefer red	Prefer red (marginal significant)
	Yellow–Blue	Prefer blue, preference degree higher than middle-consumption group	Prefer blue	-
	Saturation	Low	-	-
Quantity of Materials		-	Preference order: two and three materials, four materials or more	Preference order: four materials or more, three materials
Features of the Main Material		Prefer glass curtains, dislike stone bricks, ceramic tiles and as-cast-finish concrete	Prefer glass curtain and aluminium–plastic board, dislike stone brick, metal sheet and as-cast-finish concrete	Prefer glass curtain and aluminium–plastic board, dislike metal sheet, ceramic tile and as-cast-finish concrete
Features of the Primary Colour				
Quantity of Materials	1	Prefer red	Prefer blue and low saturation	Prefer blue and low saturation
	2	Prefer high lightness	Prefer yellow and high lightness	Prefer yellow and high saturation
	3	-	Prefer yellow, low lightness and high saturation	Prefer yellow and high saturation
	4 or More	Prefer blue and high lightness	May prefer high saturation (marginally significant)	Prefer high saturation
Features of the Main Colour Materials	Stone Brick	Prefer yellow, high lightness and high saturation	Prefer green and yellow	Prefer green and yellow
	Glass Curtain	Prefer blue and low saturation	Prefer blue and low saturation	Prefer blue and may prefer low lightness
	Metal Sheet	Prefer blue	May prefer blue (marginally significant)	-
	Coating	Prefer red, blue and low lightness	May prefer red (marginally significant), blue and low lightness	Prefer red and blue
	Ceramic Tile	Prefer blue	Prefer blue and low lightness	Prefer red and blue
	Aluminium–plastic Board	Prefer red	Prefer red, may prefer high lightness (marginally significant)	Prefer red, blue and high lightness
	As-cast-finish Concrete	Prefer red and blue	Prefer blue, may prefer low lightness (marginally significant)	Prefer blue and low saturation
Quantity of Colours				
Quantity of Materials	1	Prefer three colours, may prefer two colours	-	-
	2	Prefer four colours or more, preference degree higher than three materials	Preference order: two colours, three colours, may prefer four colours or more	-
	3	Prefer four colours or more	May prefer four colours or more	-
	4 or More	-	Prefer two colours	May prefer two colours and three colours
Features of the Main Colour Materials	Stone Brick	Prefer one colour. Dislike order: four colours or more, two colours, three colours	-	-
	Glass Curtain	Dislike four colours or more	-	-
	Metal Sheet	Dislike three colours	-	-
	Coating	Dislike four colours or more	Dislike two colours and three colours	Dislike order: three colours, two colours
	Ceramic tile	Dislike four colours or more	-	Dislike order: three colours, two colours
	Aluminium–plastic Board	-	Prefer two colours and four colours or more	Preference order: two colours, three colours, four colours or more
	As-cast-finish Concrete	-	Dislike three colours	Prefer one colour. Dislike order: three colours, two colours

Urban development and planning administrators should formulate corresponding regulations and policies based on the overarching preference patterns within the city to facilitate orderly control over urban development. For regions inhabited by consumption groups with varying economic capacities, targeted facade transformations can be implemented to enhance the quality of life of the predominant population. For instance, when renovating the facades of old condominium buildings in urban areas, upscale materials can be used for the facades of economically well-off apartments, whereas areas with lower economic development can opt for low-saturation burgundy-coloured facades. Meanwhile, by inferring the residents' economic capacities from the current facade characteristics, a compensatory construction of public services can be carried out for those areas lacking in facilities. For instance, in urban zones surrounded by conservative traditional condominium buildings, the addition of public transportation facilities can be considered to meet the travel needs of lower-income groups. Furthermore, normative guidance can be provided for anticipated plans in newly developed residential areas to direct the flow of people. For example, if urban planning and development departments aim to attract higher-income groups to a new area, they can introduce regulations and policies that set a minimum quantity of facade materials for condominium buildings in the planning and design of the relevant regions. Doing so would encourage the incorporation of a greater variety of materials in building facades.

When incorporating facade material factors into the analysis of colour aesthetic preferences, different consumption groups exhibit similar variations in their preferences. When the quantity of materials is the same, the low-consumption group pays attention to the quantity of colours and the lightness of the main colour of the façade; the middle-consumption group considers the lightness, saturation and quantity of colours collectively; and the high-consumption group focuses on the saturation of the main colour. This behaviour may reflect the divergent atmospheric preferences of different consumer groups for building surroundings. The low-consumption group prioritises colour diversity and the cheerful ambiance brought by light primary hues, whilst the high-consumption group prioritises higher colour saturation in their primary hues and aims for intense sensory experiences. The considerations of the middle-consumption group seem to balance certain aspects of both the low- and high-consumption groups, making their preferences less distinct. When the quantity of building facade materials is limited, the low-consumption group prefers red in the red–green colour balance. However, when the quantity of building facade materials is large, this group prefers blue in the yellow–blue colour balance. By contrast, the middle- and high-consumption groups favour blue and yellow when the quantity of facade materials is low and high, respectively. When the primary features of a colour material are identical, different consumption groups exhibit distinct preferences. Similarly, when the main facade material of condominium buildings remains constant, these consumption groups exhibit significant disparities in their preferences for the quantity of colours on the facade and the main colour features. In terms of the quantity of colours on the facade, the middle- and high-consumption groups pay attention to the colour quantity of aluminium–plastic boards and as-cast-finish concrete, whilst the low-consumption group pays attention to the overall colour quantity of stone bricks, glass curtains and metal sheets. The coating material is important for different consumption groups, but the low- and middle-consumption groups show different preference trends. The low-consumption group tends to favour facade designs with fewer colours, whilst the middle- and high-consumption groups prefer facades with a greater variety of colours. Therefore, the sensory experience evoked by coatings as a primary material is complex and warrants further research. As for the primary colour features of building facades, the differences in the preferences of consumer groups are manifested in highly intricate details. Figure 7 displays the colour aesthetic preferences of different consumer groups for various types of materials to intuitively convey the colour feature attributes of their preferred materials. In addition to the differences in the direction of preference for the colour balance, the lightness and the saturation of the fundamental colours, varying degrees of preference differences can also be observed for the same direction of preference. For instance, Figure 6 reveals that, for stone bricks, the preference for a yellow tendency in the colour balance is greater for the middle- and high-consumption groups than for the low-consumption group. For coatings, ceramic tiles and as-cast-finish concrete, the preference for a blue tendency in the colour balance is greater for the high-consumption group. For aluminium–plastic boards, the preference for a red tendency in the colour balance is greater for the middle-consumption group. However, for glass materials, the preferences of the different consumption groups are nearly identical, thereby suggesting that glass is the most popular choice for all groups. This finding may partly explain why the facades of modern urban condominium buildings are increasingly utilising glass as the primary building material [84]. This material also allows these buildings to command higher selling prices.

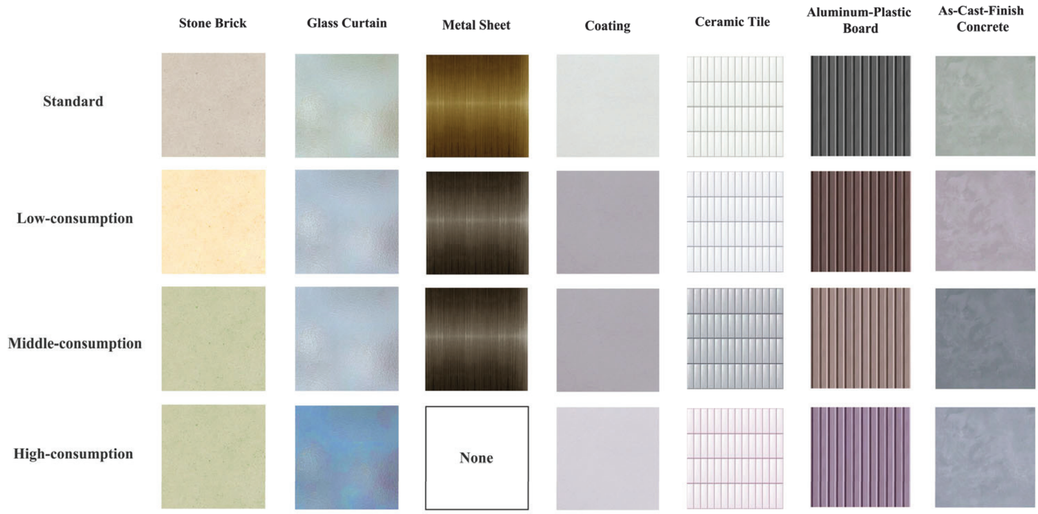

Figure 7. Colour aesthetic preference of different consumer groups for building facade materials.

Residential developers may derive several key findings from the aforementioned discussion. Firstly, when designing the facades of residential properties, these developers need a clear product positioning because different consumption groups have varying preferences for the combination of colours and materials in building facades. Tailoring facade designs to the consumption level characteristics of potential consumer groups in the region may lead to high market acceptance. For instance, to cater to the mid- to high-end consumer market, if only brick is available as the main facade material, then selecting bricks with a stronger yellow colour tendency may be a strategic choice. Secondly, residential developers need to adopt a dynamic perspective when interpreting the differences in the preferences of various consumer groups. To some extent, high-consumption groups represent those with a relatively strong economic foundation in the city. As the city develops, almost all population segments tend to experience an improvement in their economic status [85]. Therefore, the preferences of higher-income groups hold significant implications for all consumers' future aesthetic preferences for building facades. Residential developers should continuously align their offerings with evolving aesthetic preferences.

5. Conclusions

Using house prices as a point of reference and the Chinese city of Fuzhou as a case study, this study examines the differences in the aesthetic preferences of different consumer groups for building facade colours and materials. Previous studies have explored colour aesthetic preferences using imprecise reference measures, and material-based colour aesthetic preferences are even less commonly explored. This study contributes to the literature on the intersection of psychology, economics and urban planning in mainland China by experimenting with economics-related theories in this discipline.

Urban consumers, as represented by consumers in Fuzhou, share common aesthetic preferences for colour and materials, but some differences may be observed in the direction and intensity of such preferences across different consumer groups. In terms of facade colour, consumers generally prefer three colours and demonstrate a common obsession with the colour red. In terms of building facade material, consumers typically prefer building facade colours with two materials and are willing to pay for aluminium–plastic boards and glass curtains. These consumer groups also have a fixed preference for various facade materials in terms of the quantity of colour combinations and the combination of colour features. For example, when the quantity of facade materials is relatively small, these consumers prefer the main body to be made of brightly coloured materials or a facade style in which the quantity of colours matches the quantity of materials. When using certain materials with a single texture (e.g., coatings, ceramic tiles and glass), these consumers prefer a variety of colour combinations to enhance the sense of class of their residence. Meanwhile, the preference for matching and combining is inconsistent across these consumer groups. For example, with the same quantity of building facade materials, the low-consumption group pays attention to the lightness of the main colour and the quantity of colours; the middle-consumption group considers the lightness, saturation and quantity of colours; and the high-consumption group pays attention to the saturation of the main colour. In addition, the middle- and high-consumption groups pay attention to the colour matching of aluminium–plastic boards and as-cast-finish concrete, and the low-consumption group pays attention to the overall colour coordination of stone bricks, glass curtains and metal sheets. Diverse consumption groups express admiration for glass curtains as a facade material when it serves as the main colour material. These match and combination preferences may stem from regional cultural traditions [86] or distinctions in the life experiences [87] of these groups. This paper also analyses the possible causes of these differences.

The above conclusions offer relevant insights for urban development and planning administrators and residential developers. Specifically, urban development and planning administrators may improve their control over the overall urban development, which is based on collective preferences, and subsequently achieve a highly sustainable form of "smart growth" [88]. Meanwhile, residential developers may obtain a clear understanding of the demand characteristics of different market segments [89], which would ensure their continuous survival and increase their growth prospects.

However, some deficiencies can be found in the research design, which may be due to quantitative flaws in the establishment of control variables. The large number of significant control variables in this study can accurately reflect the correlation and degree of the influence of colour and material. However, many aspects of the house price correlation variables remain unobserved. This study also focuses on the differences in the consumption levels of different consumer groups in a categorical manner but does not delve into other differences, such as the differences in the spatial distribution of condominiums. The empirical findings are obtained from the cultural context of Fuzhou, China. Therefore, the findings of this study may only reflect the preferences of different consumer groups in Fuzhou and may not be applicable to consumer groups from other geographical and cultural contexts [90]. The preferences of these groups may also change with time. Therefore, the findings of this study need to be improved and supplemented in future research.

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Appendix A

Table A1. Interactive coefficients of the linear regression analysis (N = 906).

Control Variables	OLS						Robustness Test					
	LAB		LCH		Quantity of Colours		LAB		LCH		Quantity of Colours	
	Quantity	Features	Quantity	Features	Quantity	Features	Quantity	Features	Quantity	Features	Quantity	Features
(Constant)	−2.930 ***	−3.297 ***	−2.798 ***	−3.423 ***	−2.929 ***	−3.122 ***	−2.346 ***	−3.787 ***	−1.640 ***	−3.227 ***	−2.965 ***	−1.825 ***
ADM	0.412 ***	0.409 ***	0.410 ***	0.409 ***	0.401 ***	0.406 ***	0.461 ***	0.434 ***	0.326 ***	0.357 ***	0.403 ***	-
LC1	0.109 ***	0.106 ***	0.113 ***	0.112 ***	0.113 ***	0.121 ***	0.123 ***	0.133 ***	-	0.111 ***	0.106 ***	0.072 ***
LC2	0.107 ***	0.107 ***	0.109 ***	0.110 ***	0.111 ***	0.110 ***	0.071 ***	0.126 ***	0.126 ***	0.149 ***	0.112 ***	0.244 ***
POP	0.150 ***	0.145 ***	0.150 ***	0.150 ***	0.139 ***	0.143 ***	0.257 ***	0.136 ***	0.118 ***	0.127 ***	0.136 ***	0.020 *
GDP	0.161 ***	0.172 ***	0.161 ***	0.173 ***	0.165 ***	0.178 ***	-	0.165 ***	0.170 ***	0.194 ***	0.151 ***	0.217 ***
COM	0.088 ***	0.075 ***	0.089 ***	0.076 ***	0.089 ***	0.078 ***	0.116 ***	0.077 ***	0.093 ***	-	-	0.066 ***
T500	0.096 ***	0.094 ***	0.096 ***	0.095 ***	0.095 ***	0.099 ***	0.117 ***	0.090 ***	0.095 ***	0.108 ***	0.095 ***	0.109 ***
MIN	0.049 ***	0.048 ***	0.051 ***	0.047 ***	0.050 ***	0.049 ***	0.048 ***	0.044 ***	0.058 ***	0.041 ***	0.023 ***	0.058 ***
PRI	0.255 ***	0.238 ***	0.261 ***	0.252 ***	0.259 ***	0.257 ***	0.256 ***	0.265 ***	-	0.256 ***	0.263 ***	0.244 ***
MID	0.190 ***	0.184 ***	0.183 ***	0.176 ***	0.184 ***	0.163 ***	0.216 ***	0.217 ***	0.231 ***	0.182 ***	0.159 ***	0.195 ***
AGE	0.064 ***	0.047 ***	0.064 ***	0.045 ***	0.051 ***	0.041 ***	0.067 ***	0.048 ***	0.019 **	0.064 ***	0.052 ***	-
DEN	0.021 ***	0.023 ***	0.018 ***	0.020 ***	0.021 ***	0.012 **	0.041 ***	0.025 ***	0.017 ***	0.018 ***	0.025 ***	0.014 ***
GRER	0.012 **	0.015 ***	0.012 **	0.013 **	0.012 **	0.015 ***	0.020 ***	0.019 ***	0.004	0.023 ***	0.021 ***	0.018 ***
FEE	0.123 ***	0.108 ***	0.123 ***	0.107 ***	0.122 ***	0.105 ***	-	0.099 ***	0.125 ***	0.125 ***	0.143 ***	0.106 ***
RAI	−0.035 ***	−0.035 ***	−0.036 ***	−0.037 ***	−0.035 ***	−0.033 ***	−0.018 ***	-	−0.056 ***	−0.042 ***	−0.026 ***	−0.051 ***
MAR	−0.023 ***	−0.024 ***	−0.022 ***	−0.021 ***	−0.022 ***	−0.021 ***	−0.043 ***	−0.038 ***	−0.022 ***	−0.018 ***	−0.017 ***	−0.020 ***
HOS	−0.035 ***	−0.037 ***	−0.035 ***	−0.038 ***	−0.034 ***	−0.039 ***	−0.040 ***	-	−0.060 ***	−0.031 ***	−0.031 ***	−0.029 ***
SCE	0.016 ***	0.015 ***	0.015 ***	0.012 ***	0.013 ***	0.012 ***	0.010 ***	0.016 ***	−0.011 ***	0.009 ***	0.002	0.008 **
GRE	−0.007 ***	−0.008 ***	−0.006 **	−0.006 **	−0.006 ***	−0.005 **	−0.018 ***	−0.010 ***	−0.010 ***	−0.005 *	−0.017 ***	−0.026 ***
WAT	−0.043 ***	−0.040 ***	−0.044 ***	−0.041 ***	−0.044 ***	−0.041 ***	0.045 ***	−0.033 ***	−0.042 ***	−0.036 ***	-	−0.037 ***
FUN	0.036 ***	0.042 ***	0.032 ***	0.040 ***	0.036 ***	0.037 ***	0.083 ***	0.040 ***	0.029 ***	-	0.030 ***	0.000
FAC	0.026 ***	0.024 ***	0.026 ***	0.023 ***	0.026 ***	0.023 ***	0.034 ***	0.024 ***	0.016 ***	0.018 ***	0.031 ***	−0.006 *
GAS	0.018 ***	0.017 ***	0.016 ***	0.017 ***	0.015 ***	0.014 ***	0.013 ***	0.015 ***	0.007 *	0.024 ***	0.021 ***	0.002
DUM	0.109 ***	0.111 ***	0.109 ***	0.109 ***	0.111 ***	0.113 ***	0.176 ***	0.130 ***	0.070 ***	0.107 ***	0.105 ***	0.086 ***
Table 5												

Note: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Table A2. Interaction coefficients of the quantile regression analysis (N = 906).

Control Variables	LAB						LCH						Quantity of Colours					
	Quantity			Features			Quantity			Features			Quantity			Features		
	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75	q = 0.25	q = 0.5	q = 0.75
(intercept)	−1.757 ***	−1.169 ***	−0.818 ***	−1.751 ***	−1.139 ***	−1.283 ***	−1.692 ***	−1.217 ***	−0.949 ***	−1.860 ***	−0.838 ***	−0.421 *	−1.196 ***	−0.932 ***	−0.917 ***	−2.294 ***	−1.964 ***	−1.705 ***
[ADM = 0]	−0.448 ***	−0.366 ***	−0.326 ***	−0.429 ***	−0.362 ***	−0.318 ***	−0.446 ***	−0.355 ***	−0.317 ***	−0.440 ***	−0.361 ***	−0.326 ***	−0.418 ***	−0.353 ***	−0.295 ***	−0.408 ***	−0.365 ***	−0.319 ***
[LC1 = 0]	−0.089 ***	−0.095 ***	−0.103 ***	−0.084 ***	−0.093 ***	−0.100 ***	−0.102 ***	−0.094 ***	−0.102 ***	−0.101 ***	−0.103 ***	−0.103 ***	−0.104 ***	−0.099 ***	−0.103 ***	−0.108 ***	−0.108 ***	−0.102 ***
[LC2 = 0]	−0.094 ***	−0.090 ***	−0.099 ***	−0.100 ***	−0.085 ***	−0.102 ***	−0.098 ***	−0.102 ***	−0.104 ***	−0.105 ***	−0.082 ***	−0.104 ***	−0.116 ***	−0.096 ***	−0.111 ***	−0.119 ***	−0.076 ***	−0.100 ***
POP	0.129 ***	0.106 ***	0.108 ***	0.118 ***	0.107 ***	0.105 ***	0.137 ***	0.104 ***	0.091 ***	0.133 ***	0.116 ***	0.111 ***	0.126 ***	0.106 ***	0.083 ***	0.118 ***	0.107 ***	0.097 ***
GDP	0.137 ***	0.172 ***	0.167 ***	0.155 ***	0.171 ***	0.177 ***	0.142 ***	0.170 ***	0.178 ***	0.147 ***	0.175 ***	0.177 ***	0.136 ***	0.171 ***	0.188 ***	0.153 ***	0.175 ***	0.200 ***
[COM = 0]	−0.089 ***	−0.087 ***	−0.074 ***	−0.065 ***	−0.078 ***	−0.075 ***	−0.087 ***	−0.086 ***	−0.074 ***	−0.072 ***	−0.075 ***	−0.075 ***	−0.083 ***	−0.088 ***	−0.084 ***	−0.077 ***	−0.074 ***	−0.070 ***
[T500 = 0]	−0.065 ***	−0.077 ***	−0.087 ***	−0.075 ***	−0.084 ***	−0.086 ***	−0.070 ***	−0.076 ***	−0.079 ***	−0.071 ***	−0.084 ***	−0.079 ***	−0.066 ***	−0.077 ***	−0.085 ***	−0.066 ***	−0.091 ***	−0.084 ***
[MIN = 0]	−0.058 ***	−0.044 ***	−0.025 ***	−0.045 ***	−0.058 ***	−0.049 ***	−0.066 ***	−0.047 ***	−0.031 ***	−0.053 ***	−0.054 ***	−0.049 ***	−0.052 ***	−0.042 ***	−0.034 ***	−0.044 ***	−0.052 ***	−0.050 ***
[PRI = 0]	−0.085 ***	−0.339 ***	−0.400 ***	−0.111 ***	−0.307 ***	−0.391 ***	−0.112 ***	−0.335 ***	−0.416 ***	−0.096 ***	−0.329 ***	−0.401 ***	−0.101 ***	−0.332 ***	−0.395 ***	−0.115 ***	−0.330 ***	−0.374 ***
[MID = 0]	−0.170 ***	−0.171 ***	−0.242 ***	−0.176 ***	−0.181 ***	−0.210 ***	−0.164 ***	−0.179 ***	−0.228 ***	−0.177 ***	−0.171 ***	−0.195 ***	−0.153 ***	−0.171 ***	−0.237 ***	−0.167 ***	−0.164 ***	−0.195 ***
[AGE = 0]	−0.071 ***	−0.086 ***	−0.088 ***	−0.053 ***	−0.057 ***	−0.066 ***	−0.073 ***	−0.084 ***	−0.085 ***	−0.055 ***	−0.057 ***	−0.054 ***	−0.061 ***	−0.072 ***	−0.075 ***	−0.050 ***	−0.062 ***	−0.045 ***
DEN	0.019 ***	0.033 ***	0.033 ***	0.022 ***	0.026 ***	0.026 ***	0.023 ***	0.032 ***	0.027 ***	0.021 ***	0.027 ***	0.028 ***	0.018 ***	0.034 ***	0.035 ***	0.021 ***	0.020 ***	0.023 ***
GRER	0.009	0.011 **	0.004	0.017 ***	0.000	−0.002	0.019 ***	0.004	0.005	0.021 ***	0.003	0.009 *	0.010 *	0.013 ***	0.003	0.020 ***	0.004	0.012 **
FEE	0.106 ***	0.136 ***	0.143 ***	0.082 ***	0.114 ***	0.130 ***	0.103 ***	0.137 ***	0.147 ***	0.085 ***	0.116 ***	0.129 ***	0.099 ***	0.132 ***	0.141 ***	0.083 ***	0.112 ***	0.128 ***
RAI	−0.045 ***	−0.045 ***	−0.036 ***	−0.045 ***	−0.044 ***	−0.038 ***	−0.048 ***	−0.046 ***	−0.038 ***	−0.050 ***	−0.047 ***	−0.039 ***	−0.047 ***	−0.045 ***	−0.036 ***	−0.043 ***	−0.044 ***	−0.039 ***
MAR	−0.023 ***	−0.022 ***	−0.023 ***	−0.029 ***	−0.024 ***	−0.021 ***	−0.022 ***	−0.021 ***	−0.021 ***	−0.025 ***	−0.022 ***	−0.021 ***	−0.024 ***	−0.024 ***	−0.022 ***	−0.025 ***	−0.022 ***	−0.022 ***
HOS	−0.032 ***	−0.042 ***	−0.043 ***	−0.032 ***	−0.042 ***	−0.048 ***	−0.032 ***	−0.039 ***	−0.044 ***	−0.031 ***	−0.044 ***	−0.048 ***	−0.033 ***	−0.038 ***	−0.039 ***	−0.031 ***	−0.046 ***	−0.050 ***
SCE	0.006 *	0.014 ***	0.018 ***	0.007 **	0.014 ***	0.022 ***	0.011 ***	0.013 ***	0.022 ***	0.003	0.016 ***	0.022 ***	0.006	0.013 ***	0.019 ***	0.006	0.015 ***	0.018 ***
GRE	−0.002	−0.009 ***	−0.015 ***	−0.004 *	−0.011 ***	−0.017 ***	−0.003	−0.009 ***	−0.013 ***	−0.003	−0.011 ***	−0.014 ***	−0.002	−0.010 ***	−0.013 ***	−0.003	−0.010 ***	−0.010 ***
WAT	−0.033 ***	−0.027 ***	−0.036 ***	−0.027 ***	−0.028 ***	−0.033 ***	−0.038 ***	−0.028 ***	−0.041 ***	−0.030 ***	−0.030 ***	−0.035 ***	−0.033 ***	−0.028 ***	−0.038 ***	−0.030 ***	−0.028 ***	−0.038 ***
FUN	0.024 ***	0.026 ***	0.036 ***	0.033 ***	0.038 ***	0.042 ***	0.023 ***	0.021 ***	0.030 ***	0.026 ***	0.035 ***	0.041 ***	0.023 ***	0.030 ***	0.032 ***	0.024 ***	0.038 ***	0.034 ***
FAC	0.025 ***	0.025 ***	0.021 ***	0.025 ***	0.023 ***	0.018 ***	0.023 ***	0.024 ***	0.024 ***	0.028 ***	0.020 ***	0.017 ***	0.029 ***	0.023 ***	0.017 ***	0.022 ***	0.017 ***	0.013 ***
GAS	0.015 ***	0.017 ***	0.015 ***	0.015 ***	0.015 ***	0.016 ***	0.010 ***	0.014 ***	0.015 ***	0.012 ***	0.013 ***	0.018 ***	0.017 ***	0.013 ***	0.016 ***	0.010 ***	0.018 ***	0.015 ***
DUM	0.124 ***	0.093 ***	0.082 ***	0.129 ***	0.098 ***	0.097 ***	0.129 ***	0.098 ***	0.079 ***	0.134 ***	0.096 ***	0.093 ***	0.133 ***	0.103 ***	0.085 ***	0.138 ***	0.098 ***	0.085 ***
Table 7																		

Note: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

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Review

Research Progress and Trends in Urban Residential Segregation

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Abstract: With the acceleration of urbanization and profound socioeconomic changes, the influx of people from various social strata into cities has led to the phenomenon of residential segregation. Currently, the international community has accumulated profound theoretical foundations and rich practical experiences in the study of residential segregation. This research, primarily based on the WOS literature database, sorts and summarizes relevant studies on residential segregation in recent years (focusing on publications from 2020 to 2024), emphasizing the following four key aspects: (1) tracing the evolution of the theory of residential segregation and analytical methods; (2) analyzing the main characteristics of urban residential segregation; (3) exploring the driving mechanisms and effects of urban residential segregation; and (4) summarizing research trends and providing future perspectives. This study aids urban planners in more accurately identifying areas and characteristics of residential segregation, optimizing urban layouts, and providing richer and more in-depth theoretical support and practical guidance for the field of urban planning science.

Keywords: residential segregation; research progress; driving mechanisms; effects; review

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1. Introduction

Residential segregation is an important topic of multidisciplinary concern in urban geography, urban economics, and urban sociology. Additionally, it is a key entry point for studying and judging the structure of urban residential space and socio-spatial segregation. In urban space, owing to differences in race, class, income, education level, occupation, and other socio-economic factors, different groups of people show unevenness in geographic distribution, constituting residential segregation. Typically, residential segregation is a collective result of residential choice behavior, but it can also be due to history, policy, discrimination, or other macro-structural factors. Residential segregation involves the most diverse influencing factors. Owing to the complexity of its mechanisms and the limitations of data acquisition, academics have yet to draw uniform and convincing conclusions, making residential segregation a cutting-edge issue that continues to be explored by academics. The research on residential segregation not only profoundly reveals its extensive and profound impact on social structure, urban planning, community development, and public health, but it also further enhances our profound understanding of social stratification. It provides a valuable foundation for exploring and seeking effective strategies to address residential segregation issues, effectively promoting the urban society towards a harmonious and stable future.

The research on this topic involves multiple disciplines, such as urban geography, urban economics, urban sociology, urban management, psychology, institutional economics, and public economics. Scholars have conducted a substantial amount of theoretical and empirical research on this topic since the 1920s. Generally, it can be divided into two stages: the theoretical innovation research from the 1920s to the 1980s, and the theoretical refinement and perspective supplementation research from the 1990s to the present. Both phases are accompanied by the emergence of several empirical research results. During the stage of theoretical innovation research, this field employed various theoretical perspectives, such as ecological theory, consumer behavior theory, family life cycle theory, political economy and public economics theory, neoclassical economics theory, environmental perception theory, the "utility space" perspective, psychological theory, Marxist theory, and urban management theory, to conduct new theoretical research. The following are examples of the models that have been established in the process of theoretical exploration: the "invasion-succession" model, housing filtering theory, life course theory, the "voting with feet" theory (including the Tiebout model), exchange theory, residential utility value theory, housing career theory, and the "migration + search" relocation decision model [1], residential discrete choice modeling, socio-spatial unity theory, and others. Schools such as the human ecology school, the behavioral school, the neoclassical economic school, the neo-Marxist school, the structural school, the urban management school, and so on, have been formed. Subsequent empirical research focuses on the above theoretical perspectives and disciplinary lineage.

Residential segregation leads to the differentiation of different social groups in terms of living space and geographic location. This spatial differentiation is not only reflected in housing types, architectural styles, and facility allocations, but also involves aspects such as residents' lifestyle [2], socioeconomic status [3], and cultural background [4]. Meanwhile, in terms of spatial characteristics, urban residential segregation mainly manifests as a spatial distribution pattern of homogeneous clustering and heterogeneous segregation. The factors and mechanisms of intra-urban residential segregation are shown to be diversified and complex, involving not only the influence of external environmental characteristics such as location, traffic, landscape, built environment, public services, neighborhood characteristics, safety, social space, policies and regulations, and market system [5–8] but also the influence of residents' characteristics (households or individuals) such as the age of residents, gender, occupation, income, education, employment, family composition, lifestyle preferences, family life cycle, psychological factors, and other characteristics of the households (families or individuals) themselves [9–12]. In addition, institutional [13,14] and market factors [15] in the city generally have a non-negligible moderating effect on residential segregation, jointly constituting its complex driving mechanism. The existence of urban residential segregation leads to issues such as inequality in housing wealth, resource scarcity, and the solidification of class identity [16], further exacerbating social inequality. These issues are also interconnected, forming a complex social phenomenon. However, existing research lacks a systematic analysis of the manifestations of residential segregation in multiple dimensions.

Scholars have conducted in-depth discussions on residential segregation from multiple dimensions. They not only carefully analyzed the differentiation trends in population types and spatial characteristics of residential segregation within cities, but also revealed its complex context and multi-perspective features in the study of its formation mechanism. Given this, a systematic review of theoretical and empirical research on residential segregation in different countries is particularly important, and will help us to summarize research trends and provide inspiration for future research. This research not only has reference value for deepening the academic discussion on the formation mechanism of residential segregation within cities but also provides an important basis for the precise supply of urban space housing and the effective formulation of housing policies. Therefore, the core focuses of this study include: (1) tracing the historical evolution of the theory of residential segregation to understand the evolution and development of its theoretical foundation, providing solid theoretical support for current research; (2) analyzing, in depth, the main characteristics of urban residential segregation, especially the significant differences in population types and spatial distribution, laying the foundation for subsequent mechanism exploration and effect analysis; (3) exploring, in depth, the driving mechanisms and effects of urban residential segregation, revealing the multiple factors and complex relationships behind it; and (4) summarizing research trends and discussing future research directions prospectively, providing directional guidance and inspiration for future research.

The structure of this study is as follows. First, it systematically sorts out the development context of early theories on residential segregation. Second, it summarizes the main characteristics of urban residential segregation, which are mainly reflected in the differentiation of social groups and the uneven spatial distribution. Furthermore, it explores the main driving mechanisms of residential segregation from the dual perspectives of structural and individual factors. Finally, we summarize and conduct in-depth discussions on future research directions and possible limitations. This research aims to provide useful references and insights for academic research and policy formulation on residential segregation within cities.

2. Early Theoretical Developments and Analytical Methods

2.1. Theoretical Development of Residential Segregation

The phenomenon of residential segregation was revealed as early as 1872 in Engels' "*The Housing Question*". In the 1920s, members of the Human Ecology School of Urban Location Research paid attention to the issue of residential segregation. Among them, Burgess (1924) constructed the "invasion-succession" model from the perspective of ecological theory to explain and describe the segregation of different groups and classes in cities [17]. Hoyt (1939) developed the housing filtering theory, which argues that the migration of high-social-status households and the resulting vacant housing is a prerequisite for the choice of housing location and a driving force for residential migration among lower-status classes, emphasizing the dynamics of the housing market, differences in residents' economic capabilities, and the role of government policies in the formation of residential segregation [18]. However, all their studies remained at the stage of macro-level description and lacked a detailed analysis of the decision-making process at the individual level. In the 1950s–1960s, the public economics/political economy school, the neoclassical economics school, and the behavioral school explained the mechanism of urban residential segregation from different theoretical perspectives. Shevky and Bell (1955) summarized, through the study of the social districts, that economic status, family type, and ethnic background are the three main characteristic elements that influence the residential segregation of urban residents [19]. Rossi's (1955) study of individual housing choices, based on the perspective of consumer behavior, initiated the behavioral school's research paradigm of micro-housing segregation. More importantly, he considered the influence of the "family life cycle" in his study and proposed a life course perspective of analysis [20]. Tiebout (1956) put forward the theory of "voting with feet" from the perspectives of political economy and public economics and argued that differences in the level of supply of "local public goods" and the tax systems of different regions determine residential segregation due to differences in the ability to pay and preferences for local public goods, and the classic Tiebout model was constructed [21]. Based on the market equilibrium theory of neoclassical economics, Herbert and Stevens (1960) analyzed residents' choice of residential location from the perspective of macroeconomic equilibrium under the assumption of "maximization of rental balance" and believed that residents with the highest ability to pay for rent would be given the optimal residential location, which led to the optimal layout of residential space for residents with different abilities to pay [22]. The study primarily explored the probability of residents' overall housing choice/relocation behavior and its correlation with housing characteristics, demographic characteristics, and socioeconomic factors. Wolpert (1965) argued that location choice originates from environmental perception and proposed the basic concepts and research perspectives of "behavior space" and "place utility". He introduced environmental perception into the analytical framework of location decision-making, suggesting that residential segregation can be viewed as the outcome of location choices made by different individuals or groups based on their diverse perceptions of the environment and assessments of place utility [23]. The American scholar Kain (1968) proposed the spatial mismatch hypothesis, which focuses on the geospatial separation between employment opportunities for low-income groups in cities, especially minority residents, and their place of residence [24]. Based on the bid–rent theory proposed by Alonso (1964) [25], another representative of the neoclassical economics school, Muth (1969), put forward the "exchange theory" of housing location choice by studying the relationship between urban housing rents and transportation costs. He believed that minimizing the sum of rent and transportation costs can maximize household utility while minimizing costs, which represents the "optimal location" for residential choice. The location choice mechanism, based on the cost–utility tradeoff, has led to the uneven distribution of different income groups in urban space, thus forming the phenomenon of residential segregation [26]. Based on a filter theory perspective, Lansing et al. (1969) analyzed the differential impacts of urban macro-level market environments on the housing choice process of different income classes, where differences in choices based on affordability led to the spatial separation of residents of different socio-economic statuses in terms of living space [27].

In the 1970s–1980s, the Marxist, structural, and Weberian schools explained urban residential segregation at the level of social systems and institutions. Brown and Moore (1970) drew on psychological concepts to study the behavior of housing location choice; based on the perspective of "utility space", they proposed a two-stage model of "migration + search" for relocation decisions. This selection process, based on individual utility maximization, often leads residents of different socioeconomic statuses to choose different residential areas, thus creating residential segregation [1]. Pahl (1970), of the urban management school, put forward the doctrine of "city managers", arguing that the pattern of residential segregation in a city is determined by "city managers" who control important social and market resources, including land market managers, construction market managers, capital market managers, transaction market managers, local government agency managers, and so on [28]. Schelling's segregation model, proposed by the American economist Schelling (1971) to explain and model the process of formation of residential segregation (or residential differentiation) between different groups in a city, highlights the fact that the formation of residential segregation may not require extreme preferences or discrimination, but can be explained by simple individual behavior and decision-making processes [29]; McFadden (1973) incorporated the theory of the random utility model into the discrete choice problem of consumers and applied it to the study of the residential location choice problem, forming the classic discrete choice model methodology in the field of residential choice, which argues that the housing location choice behavior of households can be abstracted as the set of choices with different characteristics faced by consumers, and that differences in choices based on household preferences and needs make the families of different socio-economic status spatially segregated [30]. Harvey (1973), an iconic Marxist scholar, argued that the housing market is a site of social class conflict, which in turn leads to the segregation of living spaces for different classes of people [31]. Starting from the utility function and the degree of hedonic enjoyment derived from housing, Rosen (1974) proposed a theory of residential utility value based on the perspective of the characteristics of housing supply, arguing that this combined utility value determines the housing choices of the population, and then constructed the hedonic pricing model (also known as the hedonic model) [32]. Gray (1975), of the structural school, argued that the social structural system is the root cause of the individual's residential location choice behavior and a reflection of the contradictions of capitalist society on the spatial system [33]. From a behavioral environment perspective, Färe and Lovell (1978) argued that in the housing choice process, apart from the consumer's household characteristics, subjective factors, such as his or her previous home-buying experience, culture and values, emotions, and preference profiles, influence his or her residential choice behavior [34]. Since the 1980s, globalization, labor market restructuring, and economic liberalization have led to the polarization of residents' incomes, increased residential segregation [35], and more complex residential segregation structures. Based on studies such as life course and residential trajectory, Kendig (1984) proposed the theory of housing career by integrating the theories of filter theory, residential mobility, and housing hierarchy, reflecting the stage characteristics of people's residential choices. The theory suggests that housing choices are not only related to the characteristics of the housing itself but are also influenced by factors such as career changes, major events, life status brought about by the family life cycle, and residential concepts. Housing choices based on the needs and preferences of different life stages lead to the spatial separation of different social groups, and the formation of residential segregation is the result of different choices and decisions made by individuals during their housing careers [36]. Cassel and Mendelsohn (1985), who typified socio-spatial unity theory, argued that residential location choices and socio-spatial segregation have an interactive relationship; for example, the values and behavioral characteristics of a group of people living in the same community are easily influenced by other neighbors in that community; in the process, the characteristics of the community are, in turn, created and influenced by those groups [37]. Based on the correlation between socio-economic status and living space, Massey, a famous demographer in the United States, put forward the spatial assimilation theory (1985), which focuses on the integration of different ethnic groups in the social, economic, cultural and other aspects, and the resulting adjustment of living space, and argues that people use their social and economic achievements in exchange for living in a better neighborhood [38]; Aitken (1987) emphasized the influence of social background and social differences on housing search behavior [39].

Since the 1990s, with the acceleration of globalization and the deepening of urbanization, the phenomenon of residential segregation has become more com-plex and varied, prompting academics to study and expand the theory of residential segregation in greater depth. Louviere and Timmermans (1990), who disaggregated their study according to differences in residential preferences, are more representative in their line of segmentation research [40]. European geographers Klassen and Paelinck, based on the law of population mobility in the development and evolution of urbanization, divided the whole process of urbanization into three periods and four phases, putting forward the theory of urban development phases of metropolitan areas from growth to decline. Population migration is the most direct impetus for the formation of residential segregation, so it is feasible to study residential segregation based on the theory of stages of urban development. In 1996, based on the housing filters theory, O'Flaherty developed a model of housing filters, focusing on the cost of housing [41].

Since the 2000s, the classical theories, doctrines or models on residential differentiation have been continuously improved and developed. Wu (2001) proposed that the social–spatial dialectic theory of the radical Marxist school is the basis for the study of residential spatial differentiation in Chinese cities, arguing that "there exists a dialectical and unified interaction and interdependence between the social and the spatial [42]. Li and Zhu (2003) proposed a study of residential differentiation based on the extended ecological niche theory, which not only can better depict the connection between residential factors and the objective environment of residence, but also has more comprehensive results than the previous residential evaluation results, which only utilized the index system [43]; Feitosa (2007) and others argue that the urban segregation index is an important tool for analyzing the spatial distribution of populations and the patterns and trends of changes in urban segregation [44]. Clark (2009) combined a behaviorist perspective that focuses on the residential decisions of individual residents or families, based on family preferences, considering the role of factors such as the family life cycle, family member attributes, and housing characteristics, and focusing on the process of residential space formation [45]; the theory of residential segregation focuses more on the macro level, viewing residential segregation as a process related to racial consciousness, and argues that residential patterns do not merely reflect socio-economic achievements, but are more the result of a racialized residential market [46]. A study by Wang et al. (2012) is based on an activity space perspective, from the perspective of people's daily activities and behavioral patterns, to a more dynamic perspective on the urban socio-spatial differentiation problem [47]. Marcinczak et al. (2013) suggested that the degree of differentiation between whole cities or different social groups is manifested in the traditional segregation index as no increase or even a decrease in the degree of segregation, the so-called segregation paradox [48]; Hennerdal et al. developed a k-nearest-neighbor-based method to measure exposure dimensions for different racial groups [49]. Huang et al. (2023) proposed a theoretical framework of dialectical unity of the "social-material-information" ternary space, arguing that urban residential space is a specific embodiment of the ternary composite space of society, material, and information at the level of the community residence. Residential differentiation under different geographical spatial scales may present varying degrees and patterns, and artificial division of continuous geographical space will have a significant impact on the analysis results [50] (Table 1 and Figure 1).

Table 1. A classical theoretical study of urban residential segregation.

Year	Theory, Doctrine, or Model	Theoretical Sources and Research Perspectives	Representative Scholars
1924	"Invasion-succession" model	Based on human ecology, high-income class migration stems from the pressure of low-social-status migrants	Burgess [17]
1939	Housing filtering theory	Based on human ecology, the migration of high-social-status households is a prerequisite for the choice of housing location and a driver of residential migration for lower-status classes	Hoyt [18]
1955	Social district research paradigm	Based on the concept of social districts, economic status, family type, and ethnic background influence residential choices	Shevky and Bell [19]
1955	Life course	Based on consumer behavior and household life cycle theories, individual behavioral choice characteristics and the stage of the household they are in determine residential choices	Rossi [20]
1956	"Voting with feet" and the Tiebout model	Local public goods determine residential choices based on political economy and public economics perspectives	Tiebout [21]
1960	Optimal residential location	Based on the market equilibrium theory of neoclassical economics, with the assumption of "maximization of rental balance".	Herbert and Stevens [22]
1965	Place utility and action space	Introducing environmental perception into location decision analysis based on environmental perception theory	Wolpert [23]
1968	Spatial mismatch hypothesis	Based on traditional location theory, urban spatial structure theory, etc., focusing on the geospatial separation between employment opportunities and places of residence in cities for low-income groups and ethnic minorities in cities	Kain [24]
1969	Exchange theory	Based on Alonso's bid-rent curve theory, oriented to maximize household utility and minimize transportation costs	Muth [26]
1969	Macro housing market environment impacts of residential choices	Based on a filter theory, housing-oriented, focusing on the impact of macro housing market environments and conditions on different segments of the population	Lansing and Marans [27]
1970	Two-stage relocation decision model "migration + search"	Psychology-based study of residential choice from the perspective of utility space	Brown and Moore [1]
1970	City Managers Doctrine	Based on urban management science, "city gatekeepers" determine housing choices	Pahl [28]

Table 1. *Cont.*

Year	Theory, Doctrine, or Model	Theoretical Sources and Research Perspectives	Representative Scholars
1971	Schelling's Segregation Model	For explaining and modeling the formation of residential segregation (or residential differentiation) between different groups in cities	Schelling [29]
1973	Discrete choice model in the residential choice domain	Based on the random utility model and the theory of discrete consumer choice, location choice is abstracted as the set of choices faced by consumers with different characteristics	McFadden [30]
1973	Socio-environmental factors in residential choices	Based on Marxism, the social environment is an important factor in the residential decision-making process	Harvey [31]
1974	Residential utility value theory and hedonic price model	Based on Lancaster's theory of consumer preferences, the combined utility function and value that housing brings determines residents' housing choices	Rosen [32]
1975	Influence of social structural systems on residential choices	Structural school of thought, where the social structural system is at the root of an individual's residential site selection behavior	Gray [33]
1978	Influence of subjective factors in residential choices	Based on the behavioral environment perspective, consumers' subjective factors govern their residential choice behavior	Färe and Lovell [34]
1984	Housing career theory	Based on the life course and residential trajectory perspectives, housing choices are influenced by family status, workplace career, housing perceptions, and major events.	Kendig [36]
1985	Socio-spatial unity theory	Residential location choice and social space have an interactive relationship	Cassel and Mendelsohn [37]
1985	Spatial assimilation theory	Based on the correlation between socio-economic status and living space, it is argued that the social, economic, and cultural integration between different ethnic groups and the resulting adjustment of living space	Massey [38]
1987	Social impacts of residential choices	Based on the theoretical perspective of housing search decision-making, social background, and social differences have a significant impact on housing search behavior.	Aitken [39]
1990	Decomposition of residential preferences	Disaggregated studies are needed for populations with different housing preferences	Louviere and Timmermans [40]
1996	Housing filter modelling	Develop a housing filtering model based on housing filtering theory, focusing on the cost of housing.	O'Flaherty [41]
2001	Social-spatial dialectic theory of the radical Marxist school	It is the basis for the study of spatial differentiation in urban living in China, which argues that "there exists a dialectical and unified interaction and interdependence between society and space".	Wu [42]
2003	Based on the extended ecological niche theory	Not only can the link between residential factors and the objective environment of residence be better portrayed, but also the results of the study are more comprehensive than the results of previous residence evaluations that utilized the indicator system alone.	Li and Zhu [43]
2007	Spatial segregation index	Explain the spatial layout of the population and show how segregation changes throughout the city	Feitosa, Câmara and Silva [44]

Table 1. *Cont.*

Year	Theory, Doctrine, or Model	Theoretical Sources and Research Perspectives	Representative Scholars
2009	Behaviorist perspective	Focusing on the residential decision-making of individual residents or families, based on family preferences, taking into account the role of family life cycle, family members' attributes, housing characteristics and other factors, and focusing on the formation process of residential space;	Clark [45].
2011	Residence differentiation theory	The theory of residential segregation, which focuses more on the macro level, views residential segregation as a process related to racial consciousness and argues that residential patterns do not merely reflect socio-economic achievements, but are more the result of a racialized housing market.	Bennett [46]
2012	Activity space perspective	From the perspective of people's daily activities and behavioral patterns, a more dynamic perspective on the social and spatial differentiation of the city.	Wang et al. [47]
2013	The segregation paradox	The degree of differentiation between the city as a whole or between different social groups is reflected in the traditional segregation index as no increase or even a decrease in segregation.	Marcinczak et al. [48]
2017	Exposure dimensions	Measuring the exposure dimensions of different ethnic groups based on the k-nearest neighbor method.	Hennerdal and Nielsen [49]
2023	The theoretical framework of the dialectical unity of the "social-material-information" ternary space	Urban residential space is a specific embodiment of the ternary composite space of "social-material-information" at the level of community living, and residential differentiation under different geographical spatial scales may present varying degrees and patterns.	Huang et al. [50]

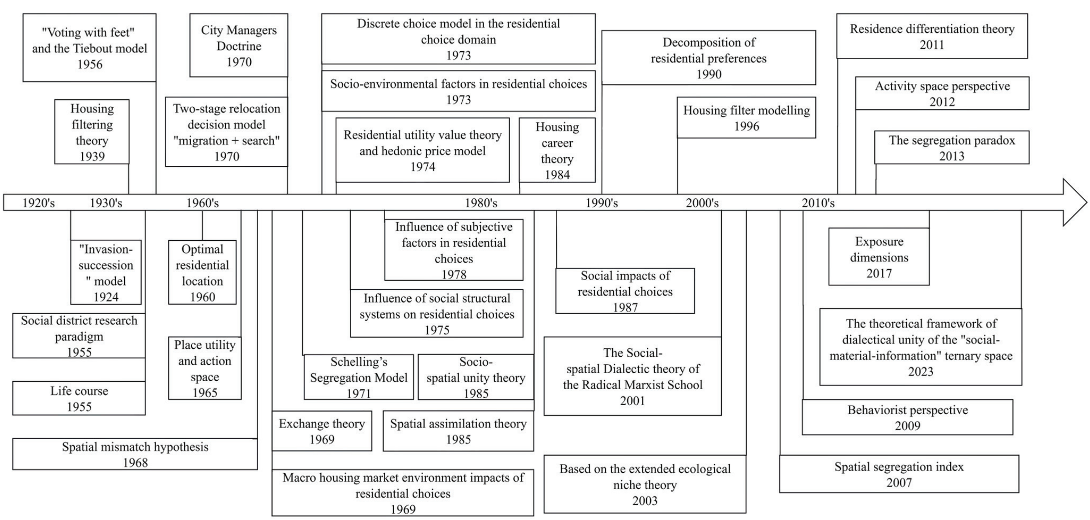

Figure 1. The early theoretical thread of residential segregation.

These early housing theories have been further expanded and improved in subsequent studies. For example, after the 1990s, housing filtering theory has been widely applied to urban planning and housing policymaking, and policymakers have begun to pay attention to methods of reducing residential segregation and improving the fairness and inclusiveness of urban living through rational residential planning and housing policies. The theory of spatial assimilation has been widely discussed in other countries and regions and has played an important role in promoting migration research and policymaking in various countries [51]. As a result of Schelling's model, researchers have begun to focus on more types of residential preferences and influencing factors, such as income level, type of occupation, and cultural background, which can affect residents' residential choices and the formation of residential segregation. The spatial mismatch hypothesis is another important framework for studying the phenomenon of residential segregation in recent years. The theory emphasizes the influence of factors, such as commuting time, income, and employment on residential segregation, and tries to explain why different social groups are spatially separated in terms of residential space. Some studies have found that spatial mismatch not only leads to residential segregation but also further exacerbates social inequality and stratification.

2.2. A Review of Analytical Methods for Residential Segregation

In the research methodologies of residential segregation, scholars tend to delve into the complexities and diversities of the phenomenon by examining various dimensions. Specifically, they investigate residential segregation based on factors such as immigrant background [52], income [53], gender [54], education [55], and policy [56]. On a more comprehensive level, the patterns of housing segregation are often characterized by three dimensions: intensity, segregation, and scale [57]. Gastón-Guiu et al. analyzed the residential segregation of African immigrants in Spain from the triple perspectives of age, period, and cohort [58]. Consolazio et al. explored dimensions, such as homogeneity, exposure, concentration, centralization, and clustering, using theories and methods from the residential segregation literature [59]; Buck et al. evaluated the relationship between the three dimensions of sustainability (environmental, economic, and social) and widespread residential segregation in urban areas of the United States [60].

To quantify and analyze the spatial distribution and social impacts of residential segregation, scholars have employed various index methods. These methods not only aid in understanding the complexity of residential segregation but also provide significant foundations for optimizing residential environments. Among them, segregation indices and disparity indices are widely used in residential segregation research [52,61]. For instance, Marcinczak et al. revealed the level of residential segregation within Polish cities by measuring disparity indices related to social and occupational status [62]. Boterman et al. calculated segregation indices using a multinomial logistic regression model, thereby exploring the economic and cultural dimensions of residential segregation in the Amsterdam metropolitan area [63]. Lee et al. systematically assessed the spatial segregation of the following four social groups: foreigners, low-income groups, young single-person households, and elderly single-person households, between 2010 and 2019, using disparity indices and segregation indices [64]. However, traditional segregation indices often rely on areal units in their calculations, which may lead to measurement and interpretation errors. To address this issue, Fineman introduced the shortest path isolation (SPI) index, a new individual-level segregation measurement method that accurately reflects the extent of racial isolation individuals experience in terms of distance and interpersonal contact [65]. Additionally, Katumba et al. combined spatial information theory indices with spatial exposure/isolation indices to measure racial residential segregation faced by residents in Gauteng Province, South Africa, across multiple spatial scales [66]. Furthermore, as traditional segregation indices primarily focus on two groups (Blacks and Whites) [67,68], they are increasingly insufficient in describing the complex spatial segregation and integration patterns in a diversified society. In response, multi-group segregation indices have emerged, such as the one pioneered by Song et al., who analyzed the differences in the degree and evolution of residential differentiation under different city, scale, and segregation indices. They applied a segregation decomposition method to calculate the contributions of spatial structure components and cluster attribute components to the differences in residential segregation between Nanjing and Hangzhou [69]. Additionally, scholars have also used other indices, such as similarity indices and delta indices, to measure the degree of residential segregation [70].

By utilizing index methods combined with various analytical approaches, scholars have gained a comprehensive and in-depth understanding of residential segregation phenomena. Martori innovatively applied multi-level analysis of disparity indices to Spanish cities, providing a new perspective for understanding residential segregation within cities [71]. Carvalho utilized Spearman's rank correlation test and a combination of socio-urban infrastructure variables, along with hierarchical cluster analysis and 'spatial ellipse' analysis, to assess the segregation levels of cities and slums. He also compared the residential segregation levels of cities and slums nationwide using Moran's *I* index [72]. Additionally, Lu et al. employed a generalized propensity score matching method to quantify the actual impact of residential segregation on the provision of public services in both the public and private sectors, providing a scientific basis for policy-making [14]. Regarding the study of residential differentiation among migrant populations, Sun et al. took Beijing, Shanghai, Guangzhou, and Shenzhen as research objects and combined global spatial autocorrelation, location entropy, factor analysis, multiple linear regression, geographically weighted regression, and geographical detectors to deeply explore the influencing mechanisms of migrant populations' residential differentiation [73]. In the study of residential segregation, qualitative analysis methods also play an important role. Dove-Medows explored issues of racial segregation and community racial distribution among pregnant Black women through qualitative interviews [74]. Asibey et al. comprehensively investigated the residential segregation of ethnic minorities by combining household surveys, focus group discussions, secondary data, and institutional interviews [75].

In the study of residential segregation, the theoretical model proposed by Schelling has become a classic paradigm in the field of social sciences and is widely used to reveal the formation mechanism of residential spatial segregation [29]. With its excellent explanatory power, the Schelling model enjoys a high citation rate in the urban research literature and is one of the most influential models in this field. However, despite its widespread applicability, the Schelling model is also considered oversimplified and unable to fully simulate the mixed, coexisting patterns of segregation and integration that exist in cities [76,77]. Kusumah expanded the agent-based Schelling model by combining random discrete utility choice methods to simulate residents' relocation decisions and study relocation phenomena in residential segregation [78]. Furthermore, the SimSeg model developed by Fossett et al. is an extension of the Schelling model that uses agent-based methods to explore the potential of theories of residential segregation in urban areas [79]. Li et al. proposed an agent-based sorting and repeated game model to quantify segregation patterns [53]. Song et al. established a multi-scalar segregation profile and comparison model based on different geographic scales and residential types to further investigate the phenomenon of residential segregation [69]. Harting et al. constructed a modeling framework that includes population, rental markets, and household utility to explore the economic and diversity-related factors of residential segregation [80].

Traditionally, the data relied on in residential segregation studies mainly comes from various census data [4,55,81], official records, and geocoded data [63,82]. However, with the rise of multi-source data, the application of multi-source data in residential segregation research has become increasingly widespread. Cao et al. combined multiple data sources, such as housing price data, planning permit data, and points of interest (POIs), and employed stepwise regression models and t-tests to explore the impact of urban renewal on local and regional residential segregation in Shenzhen [83] As technology continues to advance, new trends are emerging in data selection and application. Using public transportation smart card data, researchers can measure social segregation based on activities among different groups, providing a new perspective on the degree of urban segregation [84]. The progress of geographic data, such as mobile signaling data (MSD), has provided valuable opportunities to gain insights into residential segregation from a spatiotemporal context at the level of transportation analysis zones (TAZ) [85]. In addition, Hedman et al. used mobile phone data to track daily travel patterns related to residential segregation [86], enabling researchers to observe the specific impact of residential segregation on residents' daily lives in a more intuitive manner.

3. Main Characteristics of Urban Residential Segregation

To delve into the main characteristics of urban residential segregation, this study adopted the Web of Science (WOS) Core Collection database as the source of information, particularly focusing on relevant studies published after January 2020. In the screening process, we precisely used the keyword "residential segregation (and its synonyms)" as the primary keyword and combined it with "characteristics" as the secondary keyword to ensure the pertinence and accuracy of the search. Through systematic retrieval, we comprehensively collected the kinds of studies related to the characteristics of urban residential segregation, covering two dimensions: population types and spatial characteristics. Then, we conducted a detailed analysis and screening of this literature, aiming to select high-quality ones that can directly reflect the main characteristics of urban residential segregation. In the screening process, we classified the search results according to the research objectives and strictly excluded articles that did not meet the established standards to ensure the accuracy and effectiveness of the final analysis. Finally, we successfully selected high-quality studies, which provided a solid foundation for us to clearly describe the main characteristics of urban residential segregation.

3.1. Dimensions of Population Type in Residential Segregation

In terms of the population type division dimension of residential segregation, the current research has been conducted in terms of racial status, immigrant background, socioeconomic conditions, and age status. Racial residential segregation between Whites and Blacks is a persistent feature of residential segregation in U.S. cities [67,87,88]. Additionally, the segregation of the Black community is more pronounced than in the UK [89]. Caste segregation is the most typical feature of residential segregation in India [90]. In the context of globalization, residential segregation between immigrants and native residents has become a current research hotspot and frontier. For example, the phenomenon of immigrant residential segregation in British cities is particularly significant [91]. African immigrants have increased the spatial segregation of settlements in six major Spanish cities [58]. Dutch cities, for their part, have experienced diverse residential segregation due to the diversity of immigrants [57]. In addition, foreign immigrants have shaped a unique pattern of residential segregation in the urban periphery of the Italian city of Milan [59]. Transnational migrants (especially professionals from multinational corporations) have triggered diverse spatial patterns of living in Tokyo [92]. In Seoul, South Korea, immigrants from different income levels shape the city's pattern of residential segregation [12]. Immigration status plays a role in determining residential segregation even beyond the occupational factor [93]. However, in most cases, migrants with higher levels of education have access to better housing and living conditions [94].

Differences in socioeconomic status (including income, property, education occupation, etc.) are one of the major causes of residential segregation. When significant differences exist in the socioeconomic status between different social groups, they tend to be spatially segregated [95]. The visible spatial segregation of the high-income population (living in city centers) from the low-income population is increasing in the current global cities (New York, London, Tokyo) [96]. Notably, the phenomenon also occurs in some European cities [97]. For example, graduates of the University of Amsterdam in the Netherlands are more likely to be segregated than high-income people [63]. Residential segregation based on educational and occupational groups has generally increased in Australia's core cities [4]. Age differences are driving socio-spatial polarization, especially in aging societies [11]. As more and more communities become extremely polarized by age and generational differences, age differences in the UK lead to unequal housing affordability, which in turn exacerbates residential polarization [10]. Residential segregation between the young and older adults continues to rise in the United States [98]. Age segregation in Hong Kong is expected to intensify as the population ages and as young people move to the suburbs [99]. Migrant and rural populations experience higher levels of residential segregation than urban residents [100–102]. In Longgang City, China, although both the working and residential populations exhibit high levels of segregation, the working population is relatively less segregated [103], suggesting that additional housing options and better living conditions should be provided for the mobile and rural populations.

3.2. Spatial Characteristics of Residential Segregation

Residential segregation is a complex and multidimensional phenomenon with different contexts and intrinsic mechanisms of residential segregation exhibiting their own unique characteristics [104]. A general trend toward residential segregation emerges in cities worldwide, characterized by a gradual shift in high-income populations toward city centers or attractive waterfront areas, whereas low-income populations are moving to the urban fringe (e.g., London) [105]. This pattern of migration has led to a marked spatial segregation of settlements between urban centers and peripheral areas, with high-income populations clustered in city centers and low-income populations mostly located on the urban fringes. In addition, in some low-income countries, high-income populations not only choose to live in the city center but may also tend to construct their own living space in enclaves or gated communities outside the city center, which often contrasts with low-income neighborhoods, creating a kind of privatized living space that is segregated from low-income residents [96]. For example, in Lima, Peru, a 10 km long wall in the eastern region separates wealthy neighborhoods (e.g., La Molina and Santiago de Surco) from poorer neighborhoods (e.g., San Juan de Miraflores and Villa María del Triunfo) [106]; it is a clear sign of economic and social segregation, highlighting extreme forms of residential differentiation and directly reflecting the socio-economic state in the spatial layout of the city.

People with different incomes and occupations show significant differentiations in their choice of living space; in Hangzhou, for example, the city's elite still tend to live in the central city surrounding the CBD [107]. In Nanjing, on the other hand, residents with higher education and occupational statuses are predominantly clustered in the city center [108], and this difference in residential choices further exacerbates the spatial segregation of residences within the city. In terms of the degree of residential segregation within the city, peri-urban (low-density) areas tend to be the most obviously segregated areas in terms of residential space [109]; this phenomenon has occurred with the expansion of the city scale and out-migration of the population; peri-urban areas have gradually become the main gathering places of low-income groups, forming a very different residential space characteristic from the city center. Especially in large cities, the phenomenon of residential segregation is more prominent due to the complexity of the economic structure and the diversity of social classes. Several case studies (e.g., the Netherlands, Poland, etc.) have shown a highly positive correlation between city size and the degree of residential segregation [57,62]; this suggests that living space segregation is generally higher in large cities than in small- and medium-sized cities [110]. Immigration is one of the key topics in the field of residential segregation research. At the international level, foreign migrants in specific areas of the city (peripheral zones) have shaped the pattern of residential segregation in the city of Milan; to illustrate, the Chinese are clustered in several peripheral zones to the north of the historic center, and Egyptians are dispersed all over the city [59]. Similarly, immigrants from low- and lower-middle-income and lower-income economies are more likely to reside in the rural and industrial zones outside of the Seoul metropolitan area [12]. In some of China's megacities, such as Beijing, Shanghai, Guangzhou, and Shenzhen, immigrants are disproportionately located in the suburbs, mainly because of the large number of manufacturing firms and employment opportunities in the suburbs, which have attracted a large concentration of new immigrants [15,111,112]. In Shanghai, the most severe segregation occurs in the suburbs [113], where rural migrants tend to congregate spatially in peri-urban areas far away from the local population, while the migrant population prefers to live in the peripheral areas of the central city [114]. However, unlike Shanghai, Guangzhou's migrants are gradually moving to the suburbs due to the substantial increase in housing prices in the city center [15]. Overall, China's migrant population usually lives in the peripheral areas of cities [8]. However, migrants are less likely to live on the fringes of the city than in the center of Shijiazhuang [93]. In Hong Kong, migrants from South or Southeast Asia are mainly concentrated in densely populated areas in the northern part of the New Territories and Kowloon, while migrants from developed countries tend to live on Hong Kong Island and certain parts of Lantau Island [115]. Age structure is an important factor in shaping the spatial characteristics of urban residential segregation, with the residential needs and lifestyles of older persons changing as they age, often causing them to prefer to live in familiar neighborhoods or urban residential areas. By contrast, younger people are in search of new lifestyles and living environments, choosing to migrate to the outskirts of the city or to new public and private housing units. Changes in age structure may affect the character of neighborhoods and urban residential patterns. While older persons in Hong Kong are concentrated in urban residential areas, younger persons will move into new public and private housing units in sprawling urban or suburban areas and become increasingly segregated from older persons [99]. By contrast, Berlin has a concentration of older people in peripheral areas, spatially surrounding other groups in the city [116]. The household registration system has had a profound impact on the spatial characteristics of residential segregation in China. Owing to the restrictions of the household registration system, migrants often have difficulty accessing low-cost public housing services and other social benefits in cities [117]. In addition, most rural-urban migrants congregate in urban villages or poor urban neighborhoods [111] with institutional segregation exacerbating socio-economic inequalities and spatial segregation of residence within cities. In many countries, especially in multiracial societies, race is often an important factor influencing the spatial characteristics of residential segregation, such as in Atlanta, USA, and the majority of Blacks living in the suburbs [118]. Minority populations in U.S. cities live in highly walkable neighborhoods more often than non-minority populations [119]. Apart from horizontal segregation, vertical segregation at the micro scale also exists in cities. studies in cities such as Athens and Budapest have also found that higher-status groups tend to occupy the upper spaces of apartments, whereas people from lower classes are more concentrated in the lower spaces; this segregation continues to exacerbate the sense of social inequality and divisions within neighborhoods [120] (Table 2).

Table 2. Spatial characteristics of urban residential segregation.

City/Country	Spatial Characteristics
London	Low-income groups live in less accessible areas of outer London [105]
Lima	Segregation of the rich and the poor exists in the east, with La Molina and Santiago de Surco (the rich) separated from San Juan de Miraflores and Villa María del Triunfo (the poor) [106]
Netherlands	City size is highly positively correlated with the degree of residential segregation [57]
Poland	Large cities are more segregated than small cities [62]
Milan	Foreign immigrants have shaped the spatial segregation of Milan's settlements in specific areas of the city (peripheral zones), with the Chinese clustered in some peripheral areas north of the historic center, the Egyptians dispersed throughout the city, and immigrants working in domestic service as the only foreign group present in the city center [59]
Seoul	Migrants from low- and middle-income economies are more likely to live in rural and industrial areas outside the Seoul metropolitan area [12]
Berlin	Older people are concentrated in the peripheral areas of Berlin, spatially surrounding the other groups within the city [116]

Table 2. *Cont.*

City/Country	Spatial Characteristics
Atlanta	Black suburbanization [118]
U.S. Cities	Minority populations live in highly walkable neighborhoods more often than non-minority populations [119]
Athens & Budapest	High-status groups tend to occupy the upper floors of apartments, while lower-class people are more concentrated in the lower floors [120]
Hangzhou	The urban elite still tend to live in the central city surrounding the CBD [107]
Nanjing	Residents with higher education and higher occupational status mainly live in downtown Nanjing [108]
Shenzhen	Suburban migrants are overrepresented; most rural-urban migrants are clustered in urban villages or poor neighborhoods [111]
Shanghai	Migrant populations are willing to live in peripheral areas of central cities [114]
Guangzhou	Gradual movement of migrants to the suburbs [15]
Shijiazhuang	Migrants are not more likely to be found on the periphery of Shijiazhuang [93]
Hong Kong	Older people are concentrated in urban residential areas, while younger people will move into new public and private housing units in extended urban or suburban areas [99]; migrants from South or Southeast Asia are mainly concentrated in densely populated areas in the northern part of the New Territories and Kowloon, while migrants from developed countries tend to live on Hong Kong Island and certain parts of Lantau Island [115]

4. Key Driving Mechanisms of Urban Residential Segregation

Relying on the Web of Science (WOS) Core Collection database, this study conducted a thorough investigation into the core driving mechanisms of urban residential segregation, particularly focusing on the latest research findings published after January 2020. During the literature search phase, we carefully selected "residential segregation (and related terms)" as the primary keyword and combined it with "driving mechanisms" as the secondary keyword to ensure the precision and relevance of the search results. Through systematic literature retrieval and screening, we successfully collected a large number of research papers closely related to the driving mechanisms of urban residential segregation.

Subsequently, we conducted an in-depth analysis and scrutiny of this literature, aiming to identify the core elements and dynamics that influence urban residential segregation. To ensure the rigor and validity of the study, we finely categorized the selected kinds of literature based on the research objectives and strictly excluded articles that did not meet the established criteria.

Finally, we carefully selected several high-quality and highly relevant studies in the literature as the basic data for this study. These studies not only provide us with a comprehensive description of the driving mechanisms of urban residential segregation but also offer rich data support for us to deeply understand the complex mechanisms behind it. Based on the in-depth analysis of this literature, we hope to provide valuable references and insights for addressing the issue of urban residential segregation.

4.1. Structural Factor Perspectives

From the perspective of structural factors, the main driving mechanisms of current urban residential segregation are multidimensional and complex. In specific cities, such as Toronto, Canada, discrimination in the labor market and the resulting disparities in economic income opportunities have been a major driver of residential segregation for colored people [121], which is not only reflected in employment opportunities but also leaves a deep imprint on residential choices. In addition, the process of gentrification, the upscale nature of housing development, and exclusionary housing markets are important reasons for the persistence or exacerbation of residential segregation in some cities in the United States of America [122–124]. Green gentrification exacerbates residential segregation and social polarization and hinders community integration [125]. The predominance of low-density residential neighborhoods and the implementation of their zoning regulations have exacerbated the housing affordability divide and reinforced the degree of residential segregation [126], a phenomenon that is prevalent globally and has been validated in specific cities, such as Nanjing, where house prices have become a key factor in shaping the pattern of residential segregation [69]. In London, due to high housing prices, low-income groups have been pushed into less accessible areas of the outer city, which intensifies the residential segregation between urban centers and peripheral areas [105]. Racial consciousness is a dominant determinant of residential segregation [53]. Differences in access to homeownership among different racial groups in different regions contribute to residential segregation at the city level [127]. Moreover, narrowing the ethnic income gap may instead exacerbate residential segregation, as such processes may be accompanied by more pronounced solidification of social class [80]. Policy orientation and management systems have a far-reaching impact on residential segregation. For example, neoliberal policies have increased residential segregation (especially ethnic segregation) in Chile's major cities [128]. Although urbanization in developing countries may be driven by different social and political processes from those in Western countries, it is accompanied by residential segregation that is equally as serious. [129]. The combination of China's school district system and housing marketization not only aggravates urban residential segregation and inequality but also deepens social isolation within the unit [130]. The impact of housing policy on residential segregation is particularly significant. The Liberal housing policy is one of the main drivers of residential segregation in the Marseille metropolitan area of France [131]. Hong Kong's housing policies and aging-in-place have led to the spatial segregation of older and younger people [99]. More public housing construction has led to more pronounced residential segregation in Poland [66] and France [132]. Furthermore, large-scale land zoning and public housing policies for immigrants in the Pearl River Delta region can lead to severe residential segregation [9]. As a unique population management system in China, the household registration system strictly limits people's freedom of migration and intensifies the social spatial segregation within cities [133]. Policy decisions and urban planning have a profound impact on settlement patterns and community structure, such as the strategy of building highways in the United States, which exacerbates the fragmentation and isolation of communities by cutting through low-income and minority neighborhoods [134]. State–market participation and socialist identity-driven urban planning are key reasons for extreme residential segregation in six key development zones in the Pearl River Delta [13].

The trend toward labor specialization in globally renowned megacities has led to the polarization of occupational structures and socioeconomic inequalities, which has in turn led to increased spatial segregation of dwellings [96]. Socio-economic inequality is a pervasive factor in urban residential segregation, which is not only a predictor of racial residential segregation in Munich [52] but is also closely related to the residential segregation patterns of different minorities in Hong Kong [115]. A survey of 40 Brazilian metropolitan areas demonstrates a positive correlation between residential segregation and socio-economic status [68]. Income inequality within counties of metropolitan areas in the United States exacerbates racial residential segregation [135]. This inequality exists not only within countries but also internationally; residential segregation is strongly correlated with income inequality in countries such as the Netherlands, Sweden, the United Kingdom, and Estonia; to illustrate, the intensity of residential segregation and separation of all cities in the Netherlands is related to income inequality and the share of interest groups in the urban population [57]. High-income inequality and segregation also lead to difficulties in social spatial mobility in four European countries, including Sweden, the Netherlands, the United Kingdom (England and Wales), and Estonia, with different socioeconomic groups settling in different types of neighborhoods [136]. Residential mobility is a crucial determinant in reshaping urban social space and promoting spatial differentiation and segregation within cities [108]. Research has shown that residential segregation is associated with a smaller immigrant population and poor socio-economic conditions in 16 functional urban areas in

Italy and Spain [137]. In the context of globalization, the influx of immigrants (especially from different socio-cultural and ethnic backgrounds) is undoubtedly an important driver of current academic concern [12,71,75,138]. The influx of foreign white-collar professionals in Bahrain has driven the development of gated communities, exacerbating residential segregation [125,139]. Meanwhile, suburbanization, as a specific stage or phenomenon in the process of urbanization, has intensified social stratification and spatial imbalance in China [140]. These studies indicate that the current mechanisms of residential segregation primarily stem from labor market specialization and its discrimination, high housing prices and housing shortage, neoliberal policies, economic restructuring, gentrification, and so on, which interact to shape the complex pattern of urban residential segregation. We drew a keyword map (Figure 2) and organized it into a table (Table 3).

Figure 2. Keyword map of structural factors of residential segregation.

Table 3. Driving mechanism of residential segregation—from structural factor perspectives.

Mechanism	Cases
Labor market discrimination	In Toronto, Canada, discrimination in the labor market and the resulting disparities in economic income opportunities have been a major driver of residential segregation for colored people
Gentrification, housing development, and housing markets	The process of gentrification, the upscale nature of housing development, and exclusionary housing markets are important reasons for the persistence or exacerbation of residential segregation in some cities in the United States of America [122–124].
	Green gentrification exacerbates residential segregation and social polarization and hinders community integration [125].
	The predominance of low-density residential neighborhoods and the implementation of their zoning regulations have exacerbated the housing affordability divide and reinforced the degree of residential segregation [126]
	In Nanjing, where house prices have become a key factor in shaping the pattern of residential segregation [69]. In London, due to high housing prices, low-income groups have been pushed into less accessible areas of outer city, which intensifies the residential segregation between urban centers and peripheral areas [105]

Table 3. *Cont.*

Mechanism	Cases
Racial and ethnic factors	Differences in access to homeownership among different racial groups in different regions contribute to residential segregation at the city level in Czech [127]
Policy orientation and management system	Neoliberal policies have increased residential segregation (especially ethnic segregation) in Chile's major cities [128].
	Educational policy: The combination of China's school district system and housing marketization not only aggravates urban residential segregation and inequality but also deepens social isolation within the unit [130].
	Housing policy: Liberal housing policy, is one of the main drivers of residential segregation in the Marseille metropolitan area in France [131]. Hong Kong's housing policies and aging-in-place lead to spatial segregation of older and younger people [99]. More public housing construction has led to more pronounced residential segregation in Poland [62] and France [132]. Furthermore, large-scale land zoning and public housing policies for immigrants in the Pearl River Delta region can lead to severe residential segregation [13].
Socio-economic inequality	Population management system: As a unique population management system in China, the household registration system strictly limits people's freedom of migration and intensifies the social-spatial segregation within cities [133].
	Urban planning: The strategy of building highways in the United States, exacerbates the fragmentation and isolation of communities by cutting through low-income and minority neighborhoods [134]. State-market participation and socialist identity-driven urban planning are key reasons for extreme residential segregation in six key development zones in the Pearl River Delta [13].
	Socio-economic inequality is not only a predictor of racial residential segregation in Munich [52] but is also closely related to the residential segregation patterns of different minorities in Hong Kong [115].
	A survey of 40 Brazilian metropolitan areas demonstrated (demonstrate) a positive correlation between residential segregation and socio-economic status [68];
	Income inequality within counties of the U.S. metropolitan area exacerbates racial residential segregation [135]. This inequality exists not only within countries but also internationally; residential segregation is strongly correlated with income inequality in countries such as the Netherlands, Sweden, the United Kingdom, and Estonia; to illustrate, the intensity of residential segregation and separation of all cities in the Netherlands is related to income inequality and the share of interest groups in the urban population [57]. High-income inequality and segregation also lead to difficulties in social-spatial mobility in four European countries, including Sweden, the Netherlands, the United Kingdom (England and Wales), and Estonia, with different socioeconomic groups settling in different types of neighborhoods [136]
Residential mobility and migration phenomenon	Residential segregation is associated with a smaller immigrant population and poor socio-economic conditions in 16 Functional Urban Areas in Italy and Spain [137]
	The influx of foreign white-collar professionals in Bahrain has driven the development of gated communities, exacerbating residential segregation [125,139]
Urbanization phenomenon	Suburbanization, as a specific stage or phenomenon in the process of urbanization, has intensified social stratification and spatial imbalance in China [140].

4.2. Individual Selection Factors Perspectives

Individual choice is one of the key driving mechanisms shaping urban residential segregation. Based on a complex interplay of factors such as personal preferences, social networks, cultural affinity, or a sense of belonging to a specific community, people tend to choose to live in communities with similar backgrounds (e.g., ethnicity, culture, or economic status) when selecting a residence. Homogeneity is an important consideration for both local and non-Western immigrant families in their housing choices [141]. The lack of integration among different ethnic groups at the household level further exacerbates the trend of residential segregation [142]. Age, as a key factor in residence choice, is not only closely related to housing affordability but also exerts differentiated impacts on residential segregation through its cyclical social effects. For instance, in the United Kingdom, the strong correlation between age and housing affordability is particularly prominent in affluent areas, highlighting the complex interplay between socioeconomic status and age structure [10]. Age differences have significant impacts on the level of segregation experienced by African immigrants in Spain, and the trend of segregation becomes pronounced as age increases [58]. In the United States, the age differentiation characteristic of urban spaces, especially in affluent areas, where high housing prices and clear socioeconomic and age boundaries coexist, jointly exacerbates the spatial polarization at the intersection of wealth and age [10]. Educational level also plays a crucial role in residential choice [63]. Education composition is the main driving factor of income inequality before tax on residential segregation [143]. Those with high educational levels tend to choose sites freely in various areas of the city, promoting the gentrification of the originally homogeneous low-class areas [144]. By contrast, the poorly educated face more residential segregation due to economic constraints, accepting poorer housing conditions, or migrating to affordable areas, further exacerbating the suburbanization of poverty [145]. The inequality in school choice further reinforces income-based residential segregation in cities such as those in Germany [146]. Additionally, school catchment areas have a significant impact on high-income Finnish-dominated families [147]. Convenience facilities, as another consideration in residential choice, are closely related to residential mobility [6]. Studies have found that groups with higher socio-economic status tend to prefer neighborhoods with well-developed infrastructures [5]. The pursuit of environmental quality also affects immigrants' decisions to choose ethnic Chinese neighborhoods [6]. Research in Hangzhou has found that employment, schooling, and neighborhood accessibility have significant effects on residential differentiation [107]. Ethnicity and nationality play an important role in partner choice and residence decisions, which exacerbate the segregation and division among communities, leading to a more entrenched urban social structure. In Sweden, the tendency to partner with single people who live nearby and have the same race and birthplace has aggravated segregation [148]. Cultural characteristics (e.g., language and religion) are probably the core elements in the choice of group identification and residence [149]. To integrate into the mainstream, minorities may choose to live in a neighborhood with fewer speakers of their language [150]. However, research in Sydney reveals significant segregation among different linguistic groups within communities [149]. The impact of economic status on residential segregation is particularly significant. In Shanghai, high-income groups have local household registrations, where income levels and family size enhance their tendency to avoid living next to neighbors with different economic or household registration backgrounds [151]. Relatively high-income earners are more inclined to relocate when individuals perceive a mismatch between their household income and their neighborhood. This tendency also exists among groups with a higher socio-economic status, whereas those with a lower socio-economic status are less likely to consider relocating even if they feel their status is lower [152]. Furthermore, the individuals' life course, family cycle, and ownership type are closely linked to housing choices. Particularly in urban centers, the proportion of residential choices is closely related to urban population dynamics, changes in family structure, population density, specialization in tourism activities, and social inequality [9]. In summary, understanding the multidimensional aspects of individual choice is critical to revealing and responding to the phenomenon of urban residential segregation. We drew a keyword map (Figure 3) and organized it into a table (Table 4).

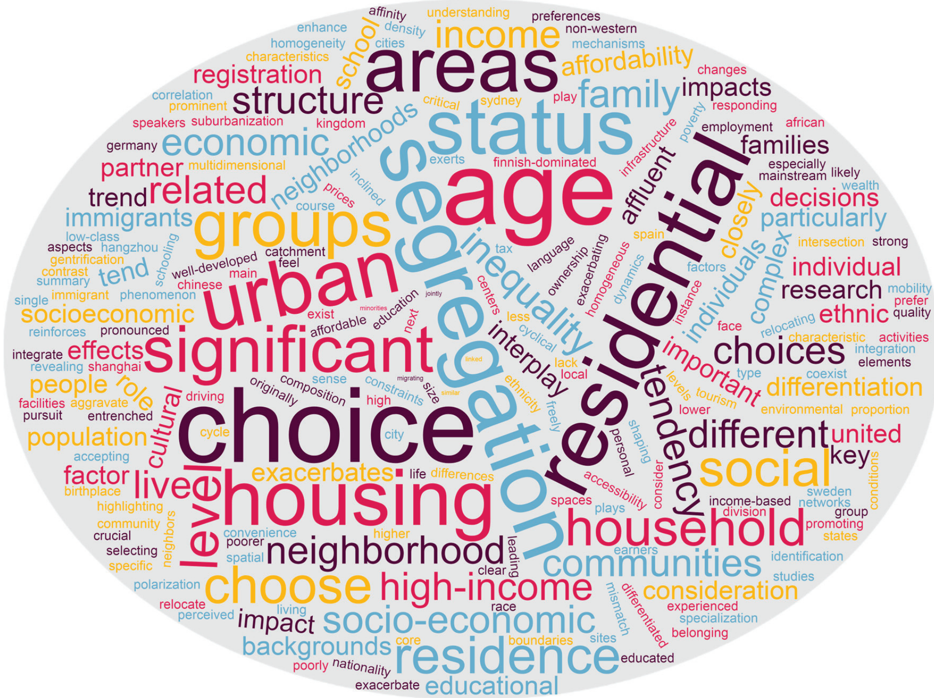

Figure 3. Keyword map of individual selection factors of residential segregation.

Table 4. Driving mechanism of residential segregation—From individual selection factors perspective.

Mechanism	Cases
Age factor	In the United Kingdom, the strong correlation between age and housing affordability is particularly prominent in affluent areas, highlighting the complex interplay between socioeconomic status and age structure [10]. Age differences have significant impacts on the level of segregation experienced by African immigrants in Spain, and the trend of segregation becomes pronounced as age increases [58]. In the United States, the age differentiation characteristic of urban spaces, especially in affluent areas, where high housing prices and clear socioeconomic and age boundaries coexist, jointly exacerbates the spatial polarization at the intersection of wealth and age [10].
Educational level and Economic level	The poorly educated face more residential segregation due to economic constraints, accepting poorer housing conditions, or migrating to affordable areas, further exacerbating the suburbanization of poverty [145]. School catchment areas have a significant impact on high-income Finnish-dominated families [147]. In Shanghai, high-income groups have local household registration whose income level and family size enhance their tendency to avoid living next to neighbors with different economic or household registration backgrounds [151].
School choice and convenience facilities	The inequality in school choice further reinforces income-based residential segregation in cities such as Germany [146]. In Hangzhou has found that employment, schooling, and neighborhood accessibility have significant effects on residential differentiation [107].
Race, nationality and cultural characteristics	In Sweden, the tendency to partner with single people who live nearby and have the same race and birthplace will aggravate segregation [148]. Cultural characteristics (e.g., language and religion) are probably the core elements in the choice of group identification and residence [149]

5. Effects or Consequences of Urban Residential Segregation

This study, based on the Web of Science (WOS) Core Collection database, conducted an in-depth exploration of the latest research findings published after January 2020, focusing primarily on the effects or consequences of urban residential segregation. During the literature search process, we precisely selected "residential segregation (and related terms)" as the primary keyword and combined it with keywords such as "effects" and "consequences" as secondary screening criteria to ensure the precision and relevance of the search results.

After systematic literature retrieval and rigorous screening, we successfully collected a large number of research papers closely related to the effects or consequences of urban residential segregation covering two significant dimensions: resource inequality and social impact. Subsequently, we conducted an in-depth and careful analysis of these papers, aiming to uncover the core elements and driving forces that influence urban residential segregation.

To ensure the rigor and validity of the study, we refined the selected literature based on the research objectives and strictly excluded articles that did not meet the established criteria. Ultimately, we carefully curated many high-quality, highly relevant documents as the solid foundation data for this research. These documents will provide strong support for us to gain a deeper understanding of the effects or consequences of urban residential segregation.

5.1. Residential Segregation and Resource Inequality

Residential segregation within cities reflects not only the differences in settlement patterns but also the deeper imbalances in social equity, economic development, and community well-being; additionally, residential segregation has important implications for inequality [153]. Research on the effects of segregation of urban living spaces is predominantly negative. Research has shown that severe residential segregation within cities can lead to inequalities between advantaged and disadvantaged groups in terms of educational resources [154], public resources [69], employment opportunities [54], environmental quality [155], health levels [156,157], access to healthy food options [158], availability of infrastructure [72], social security [7], social status and living conditions [159], and other inequalities. This situation further leads to a spatial mismatch of resources [69], exacerbating social differentiation and thus affecting the spatial equity and sustainable development of cities.

Residential segregation leads to the unequal distribution of educational resources. Typically, schools located in higher-income neighborhoods tend to have access to richer educational resources, whereas schools in peripheral areas are relatively poorly resourced, an uneven distribution of resources that leads directly to inequities in education. Residential segregation not only determines where students live but also has a profound impact on their access to education and employment opportunities [160]. Studies have shown the significant geographical imbalances in the population with tertiary education, particularly in peri-urban and other marginalized areas [113]. In regions with a high level of urbanization, families often face a wider range of choices when selecting schools; however, such choices are often constrained by the socio-economic context of their place of residence [161]. Neighborhood segregation and poverty lead directly to ethnic isolation and the concentration of poverty in schools, resulting in significant inequalities in access to education [162]. In geographically segregated communities, non-Hispanic Black groups face dual inequalities in educational and economic opportunities due to physical segregation [163]. The impact of segregation on education is particularly significant for students with immigrant backgrounds. In Sweden, pupils from immigrant backgrounds are often associated with the so-called "segregated neighborhoods" and underperforming suburban schools. Despite the possible formal value they receive and inclusion, they are often subtly excluded socially by their peers; the latter results in lower chances of integration [164]. Such exclusion not only affects their academic performance but can also have long-term consequences for their mental health and social adjustment. They often have difficulty accessing high-quality educational resources, which not only limits their personal development but also exacerbates social inequalities. In China, the uneven distribution of quality education resources has become a prominent issue, which has not only led to the capitalization of school district housing premiums but also exacerbated inner-city residential segregation, making housing a visible symbol of class differentiation [130]. Advantageous families in cities contribute to the reproduction of class differentiation by owning housing near quality educational resources, allowing inequalities in resources and development opportunities to be transmitted between generations [16].

Differences in living space can also lead to problems such as public resource deprivation and class identity solidification [16]. The context of China's property market somewhat enables residential segregation to reflect socio-economic characteristics by influencing house prices [165]. Middle- and high-income families can reside in prime residential areas with convenient transportation and complete facilities, whereas low-income families are often marginalized in communities with low accessibility and scarce resources [166]. In areas with high levels of racial or ethnic segregation, communities in these areas often lack affordable and safe access to recreation, work, education, and healthcare for sporting activities due to widespread transport vulnerability [167]. Communities with high levels of segregation often do not enjoy a better quality of life and have limited access to basic services such as schools, hospitals, or transportation.

While evidence proves that in some cases, segregation can benefit migrants by encouraging social networks that provide employment opportunities [4], several potential disadvantages exist. Segregation has adverse spatial mismatch effects on labor market participation rates [54]. Regardless of the floating population or the registered population, people living in isolated areas often have poor job opportunities [114], and residential segregation has a significant negative impact on employment stability [168]. Apartheid areas tend to be more disadvantaged in terms of a range of neighborhood-level situational attributes, including higher unemployment rates [169]. The rural migrant workers, living in the suburbs, face a high risk of segregation from the local population, both in the neighborhood and workplace; in particular, migrant workers working in the manufacturing sector in the suburbs are more likely to be in a closed working environment, where coming into contact with and getting to know other social groups are difficult for them, thus exacerbating their social segregation [170].

In terms of the environment, residential segregation has a significant impact on the health status of residents in low-income residential neighborhoods. Studies have found that these neighborhoods have significantly lower green space accessibility [171], meaning that residents lack sufficient green spaces for recreation and exercise, which may negatively impact their physical and mental health. Socioeconomically disadvantaged residents tend to live in neighborhoods with poorer environmental quality, and these areas typically have higher PM2.5 concentrations and poorly built environments [172]. This environmental exposure directly increases their health risks for respiratory and cardiovascular diseases, further exacerbating health inequalities. Residential segregation also affects the availability of healthy food options to residents. In more segregated neighborhoods, relatively fewer healthy food outlets exist, and residents travel longer distances to these outlets [173]; have a poorer perception of the food environment (low food environment perception); and consume fewer fruits, vegetables, fish, and so on [174]. The unequal distribution of healthcare resources is also influenced by residential segregation. In areas with high levels of residential income segregation, hospitals often lack specific diagnostic or therapeutic technologies [175], which renders access to high-quality healthcare difficult for locals when facing serious illnesses. In China, owing to the uneven distribution of public hospitals and other healthcare resources, communities on the outskirts of cities with abundant healthcare resources are at a relatively lower risk of having residents with health conditions than other communities [172].

5.2. Residential Segregation and Social Impact

Residential segregation is associated with health inequalities, with higher levels of racial residential segregation being associated with poorer health [176]. It exacerbates cardiovascular disease (CVD) mortality [177], and the prevalence of hypertension [170], and the negative impact of residential segregation on virological suppression is greater in counties with lower levels of community health resources [178]. As a result of persistent residential segregation in society, Black citizens are often forced to live in areas adjacent to major roads or motorways and are also disproportionately exposed to carbon monoxide emissions from car exhausts [179]. Residential racial segregation is negatively correlated with the incidence of chronic obstructive pulmonary disease (COPD) among urban Blacks, suggesting that racial segregation plays a role in contributing to health inequalities in Black communities [180]. Long-term residence in segregated communities may exacerbate the degree of brain aging [181], indirectly contributing to an increased risk of Alzheimer's disease and related dementia (ADRD) [182]. Older people living in segregated neighborhoods are vulnerable to loneliness and health threats at both the physical and psychological levels in poor housing conditions [183]. The scarcity of entertainment venues in highly segregated areas increases the risk of cardiovascular diseases [167] and obesity among the youth [184]. Residential segregation leads to inequalities in anxiety related to neighborhood violence and obstacles, and policies that reinforce segregation may impact neighborhood mechanisms (unequal socioeconomic status, overall discrimination, and low social cohesion) [185].

Residential segregation significantly increases the risk of theft and violence [7]. Low-income neighborhoods are excluded from the urban system and are located in areas with low land values and are far from the core, leading to social problems such as crime and drug abuse [186]. Research has shown that in racially segregated residential areas, the risk of gun-related deaths is 1.3 times higher than in areas with lower levels of segregation [187]. This phenomenon is particularly evident in Brazilian cities, where a clear positive correlation exists between racial segregation and homicide rates. The spatial degradation and lack of physical, economic, and social infrastructure resulting from residential segregation further exacerbate the risks of discrimination and interpersonal violence faced by residents in poverty-stricken areas [188]. In the United States, Black males are likely to be victims of violence and exclusion due to residential segregation; even within the same county, Black and White residents may face different policing support, security infrastructure, and unequal distribution of public and private investment in their communities [189].

Residential segregation has a profound impact on social inequality, which is reflected in three ways. First, residential segregation exacerbates gender inequality in less-educated households, exposing females in these households to additional barriers to education and career development. Second, as women with higher educational attainment increasingly participate in the labor market, residential segregation further amplifies the socioeconomic inequality between low-income and affluent families. Finally, residential segregation deepens the geographic separation between marginalized and non-marginalized households, leading to increased difficulties in accessing resources and services for these households [54]. For example, segregation can prevent migrants from integrating into the city and limit opportunities for social mobility [190]. In cities such as Shanghai, individuals have become increasingly socio-economically differentiated as upmarket neighborhoods and migrant communities have formed [94]. This differentiation not only exacerbates social inequality but also makes it difficult for migrants to cross social classes and achieve upward mobility. Residential segregation not only exacerbates material inequalities between populations but can also undermine the foundations of trust needed to build and maintain the public good, thus weakening the ability to overcome collective action problems [160]. In Korea, poor residents in permanent rental flats have weakened social networks due to residential segregation, external stigmatization, and the existence of slums, further exacerbating their social isolation [191].

Residential segregation is a multidimensional social problem that not only reduces the quality of life of residents but also exacerbates social inequalities. In a social environment where segregation is prevalent in communities, schools, and workplaces, the likelihood of people establishing deep personal friendships with those from different backgrounds will significantly decrease [132]. Social integration has the following three dimensions: willingness to settle permanently, cultural integration, and psychological integration [192]. Notably, it can encourage migrants living in formal communities to work hard, have a strong willingness to settle, and actively integrate into mainstream society by building localized social capital [193], which is essential to alleviate the negative impacts of residential segregation. Joint efforts from the government, social organizations, and residents are necessary for taking effective measures to reduce residential segregation, optimize resource allocation, and enhance community well-being to promote social equity and sustainable development.

6. Research Trends and Prospects

In terms of research trends, the study of residential segregation in cities worldwide has been receiving increasing attention owing to the acceleration of the urbanization process. In addition, the increase in population migration has prominently increased the problem of the differentiation and segregation of urban residential space. By reviewing the above research progress, the following shifts have occurred in residential segregation research. First, the focus has shifted from the physical environment to the social environment. Second, residential segregation research is likely to pay extra attention to the impacts of ethnicity, income, and socio-economic status and to explore how to promote racial and economic integration through policy interventions. Third, it pays extra attention to the impacts of macro-contextual factors such as the system and the market. Fourth, it pays extra attention to the targeting of specific populations in segmented studies. In addition, based on China's unique household registration system, the issue of spatial segregation of migrant and rural populations has received increasing attention. "Social environment", "soft factors", "system", "population segmentation research", and so on are hot keywords in the current research on housing location choice. Certainly, it is also manifested in the following shortcomings. First, the coverage in population segmentation remains incomplete. Second, although the influence of the social environment has begun to receive extra attention from researchers, the study of the driving mechanism of social space on urban residential segregation persistently needs further supplementation and improvement. Drawing on the research trend of intra-city housing location choice, future research can be further developed from social factors represented by social space, time process factors represented by housing career, and lifestyle factors represented by life tendency and psychological characteristics, paying extra attention to the research perspectives of society, time, and lifestyle to further enrich the research outcomes in this field.

The study of urban residential segregation is moving toward a new stage of diversification and depth, and the global study of urban residential segregation will continue to develop in depth. Future research urgently needs to delve deeper into the core roles and underlying mechanisms of different population types in residential segregation without overlooking the intricate interplay and influence of various factors to propose comprehensive and effective solutions. In addition, vertical spatial segregation, which reflects socio-economic differences and unequal distribution of resources, will be one of the foci of future research as another important dimension of residential segregation. With the rapid development of digital technology, researchers can increasingly utilize big data, GIS, and other technological means to study residential segregation. These technologies not only provide more comprehensive and accurate data support but also reveal the dynamic changes of residential segregation in terms of space and time. To promote social equity and sustainable development, the government, social organizations, and residents must work hand in hand to take practical and effective measures to reduce residential segregation, which includes optimizing the allocation of resources to ensure that all residents have equal access to quality public services, such as education, healthcare, and employment. A need also arises to strengthen community building, enhance community well-being, and create a more inclusive and harmonious social environment.

7. Conclusions

After extensive research and analysis of urban residential segregation, we developed the following main conclusions, which are intended to provide us with new perspectives and strategies for understanding and responding to the urban residential phenomenon in depth.

First, in terms of the evolution of the theoretical lineage, the study of urban residential segregation has undergone a development process from simple to complex and from single to multiple since it was first revealed in 1872. The trajectory of this theoretical development not only reflects the deepening and expansion of academic research but also the complexity and multidimensionality of the urban residential segregation phenomenon itself. With the increase in disciplinary crossover and in-depth research, future research on residential segregation will be more comprehensive, systematic, and innovative, providing us with more comprehensive and accurate theoretical support.

Second, from a methodological perspective, the study of residential segregation has achieved a leap from socioeconomic factors to spatial distribution, transitioning from a single viewpoint to a comprehensive and all-round consideration. Quantitative tools such as segregation indices and disparity indices provide robust support for in-depth research into the phenomenon of residential segregation. In terms of analyzing these indices, methods like regression analysis and dynamic cluster analysis not only enable the identification of key factors influencing residential segregation and their mechanisms but also help to reveal the spatial distribution and dynamic changes. The establishment of research models such as the Schelling model and its extensions contributes to understanding the dynamic mechanisms and trends of residential segregation. Meanwhile, qualitative research methods, including interviews and observations, delve deeply into the social and cultural factors behind residential segregation. With the advancement of data technology, big data and real-time data provide a new perspective for the study of residential segregation. These methods collectively constitute a solid foundation for research on residential segregation.

Third, the main characteristics of urban residential isolation are diversified. In geographical space, there is an obvious phenomenon of residential agglomeration, and people with similar socio-economic characteristics tend to live in the same area and form homogeneous communities. However, people with great differences in socio-economic characteristics are often separated in different regions, forming a heterogeneous isolation state. Racial status, immigrant background, socio-economic conditions, and age status are all important factors influencing residential segregation in terms of the population typology dimension. These different contexts and inherent mechanisms of residential segregation exhibit unique characteristics, making it necessary to consider a wider range of variables and factors in understanding and responding to this phenomenon.

Furthermore, the mechanisms driving urban residential segregation are manifold. Structural factors, such as policy orientation, economic structure, and sociocultural factors, play an important role in urban residential segregation, and these factors are interrelated and interact with each other to form the macro-context of urban residential segregation. At the same time, individual choice factors are one of the driving mechanisms that cannot be ignored. Based on personal preferences, social networks, cultural proximity, or identification with a particular neighborhood can also have an impact on residential segregation. Individual choice factors manifest as imbalances in spatial distribution, pronounced differentiation of social groups, and unequal access to resources. These factors all influence people's choice of residence, thereby further intensifying the degree of residential segregation to a certain extent. This interaction between individuals and structures increases the complexity and multifaceted character of the driving mechanism of urban residential segregation.

Finally, research on the effects triggered by urban residential segregation is predominantly negative. Numerous studies have pointed out that residential segregation has a significant impact on social inequalities. Due to the obvious differentiation in residential spaces, issues such as uneven resource allocation and rising unemployment rates have exacerbated social division and inequality, affecting social stability. These effects involve multiple aspects, including educational resources, public resources, job opportunities, environmental quality, health levels, access to healthy food options, infrastructure utilization, social security, social status, and living conditions.

In summary, we need to recognize the profound impact of urban residential segregation on social development. It exacerbates social inequality and class solidification, restricts social mobility and integration, hampers the development of urban cultural diversity and inclusiveness, and may even trigger social conflicts and contradictions. Therefore, we need to formulate effective policies and measures to address the phenomenon of segregation of urban living space at multiple levels, including strengthening urban planning and management, promoting social equity and justice, and facilitating exchanges and integration among different social groups. Second, to promote the social integration of residents and reduce social inequality, we need to take measures to break down the barriers of segregation to encourage exchanges and interactions between different social groups and promote social fairness and harmony.

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Exploring Gentrification Architecture Pursuit in Individuals with Childhood Left-behind Experiences—Empirical Analysis Based on the Perspective of Sports Participation

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Abstract: Using a quantitative method, this paper examined the role of physical activity well-being before physical activity participation and gentrification architecture pursuit in 481 respondents (including 377 with childhood left-behind experiences) in Xi'an City, China, and tested the effect of the metacognition level of the group with childhood left-behind experiences on this pathway. The results showed that (1) physical activity participation of the group with childhood left-behind experiences had a significant positive predictive effect on gentrification architecture pursuit; (2) the level of physical activity participation of the group with childhood left-behind experiences could exert an indirect effect on gentrification architecture pursuit through physical activity well-being; (3) metacognition played a negative role in the pathway of physical activity participation predicting gentrification architecture pursuit of the group with childhood left-behind experiences; (4) the level of metacognition played a negative role in the pathway of physical activity participation and gentrification architecture pursuit of the group with childhood left-behind experiences; (5) metacognition also played a negative role in the path of physical activity well-being in predicting gentrification architecture pursuit in groups with childhood left-behind experiences. This paper is important in analyzing the complex effects of childhood left-behind experiences on individual consumption perceptions and develop a deeper understanding.

Keywords: gentrification; sports participation; well-being; childhood experiences of staying behind; metacognition

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1. Introduction

Gentrification is a common phenomenon in today's society, especially in the field of urban renewal and construction [1]. As shown in Figures 1 and 2, Xi'an, China, has seen a significant reduction in cultivated land in nine years due to the expansion of building land as a result of its urbanization; and the distribution and size of buildings in Xi'an has undergone significant changes in the past 10 years, with a tendency to expand from the center to the periphery, where urbanization and economic growth have driven the demand for gentrified buildings and land development, and, more importantly, the government-driven urban renewal and renovation projects for old neighborhoods, as well as the preservation of historical cultural heritage and organic micro-renewal, have all had a significant impact on the cityscape and distribution of buildings. Renovation projects in older neighborhoods, as well as the preservation and organic micro-renewal of historical and cultural heritage, have all had a significant impact on the urban landscape and building distribution.

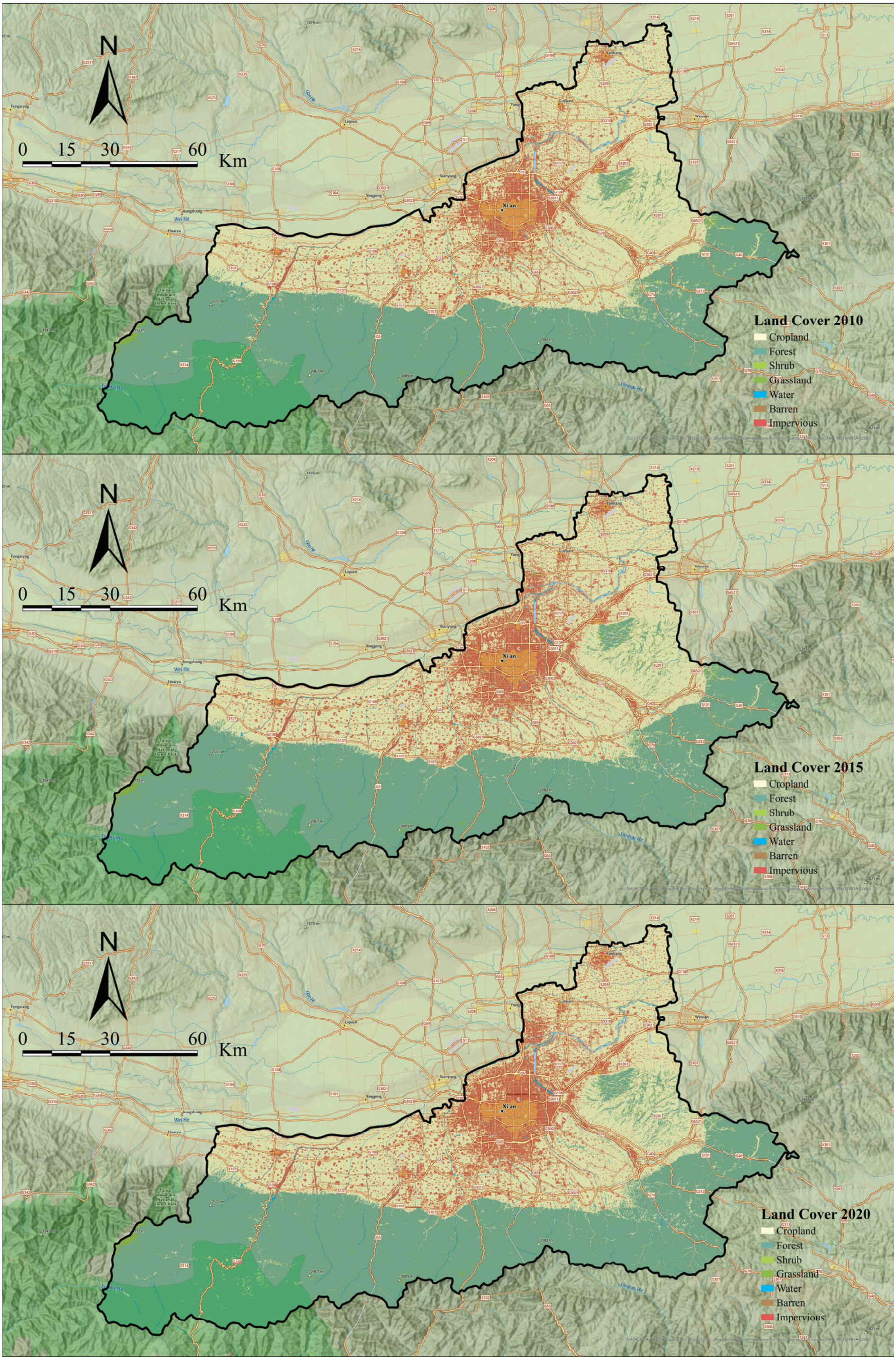

Figure 1. Illustrative map of land cover in Xi'an, China.

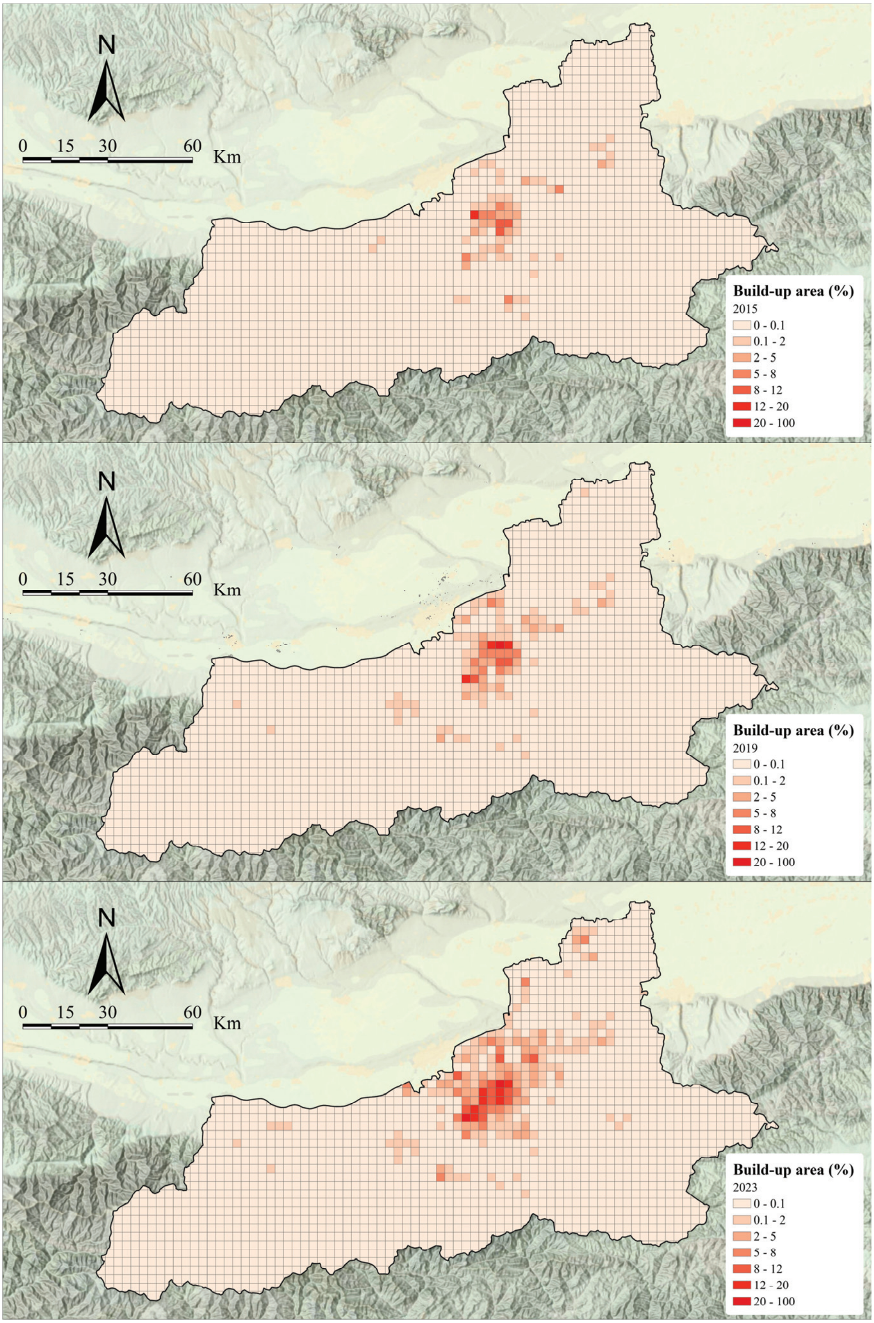

Figure 2. Illustrative map of building changes in Xi'an, China.

Gentrification usually refers to the process of transforming older residential areas of a city into middle- and high-income neighborhoods through renovation and upgrading, which is often accompanied by an exodus of low-income residents and an influx of diverse outsiders [2,3]. Gentrification has become an unavoidable phenomenon in many cities around the world, and while it brings strong economic impetus to cities, it also brings social problems that cannot be ignored [4]. For example, gentrification has exacerbated the polarization of the housing market, with an increase in the supply of high-end housing and a growing scarcity of affordable housing, which not only squeezes the living space of low-income people in cities but also puts more pressure on the middle-income group under the rapid upgrading of urban services. The phenomenon of urban gentrification not only diminishes the living space for low-income groups in cities but also exacerbates the pressures faced by middle-income groups due to the rapid upgrading of urban services. One of the notable challenges associated with this trend is the burden of "mortgage repayment", which particularly affects young and middle-income groups in China. For this reason, some countries and cities have adopted housing policies and other measures to curb the negative effects of gentrification, such as the rent freeze implemented in Berlin, Germany.

Gentrification, on the other hand, refers to the renewal or redevelopment of buildings that occurs as part of the process of urban gentrification, which usually involves the transformation of older, low-cost residential areas into higher-end residential, commercial, and recreational facilities catering to the needs of middle- and upper-income residents. This transformation is often accompanied by cosmetic renovation, modernization of facilities, and the introduction of new architectural styles, with the aim of increasing the economic value and visual appeal of the urban area [5]. There are three reasons for the rapid development of gentrification [6–8]: firstly, there are economic motives, such as governments promoting gentrification through increased tax revenue and regional economic activation, and real estate developers seeking large profit margins and investing in downtowns or other potential areas through renovation to quickly build gentrified buildings to "attract attention"; secondly, market demand, such as with urbanization and the increase in the income level of the general public; the middle-class people's demand for high-quality living space continues to increase, such as people's lifestyles and "personalized" changes in the residence around the convenient transportation; facilities are the consumer's choice; thirdly, cultural trends, such as the rise of new art forms and creative industries, are driving the transformation and upgrading of old industrial areas.

It has to be emphasized that there has always been a passion and popularity for the pursuit of commodity symbols in all groups of society, especially in the context of the rapid development of information technology; the concept of symbolic consumption, which takes the pursuit of commodity symbolic meanings as the main purpose of consumption, is also spreading in all groups of society [9]. This symbolic consumption has the nature of the times and will develop and change with the development of the social economy, politics, culture, and other factors. In this context, "status manifestation" has become one of the main forms of symbolic meaning of gentrified architectural properties. For example, Kreuzberg in Berlin, Germany, is known worldwide for its rich cultural diversity and counter-culture. With the recent rise of new-age art and diverse creative entrepreneurial dynamics, the area has attracted a succession of young professionals and middle-class families. The pursuit of gentrification architecture is not only about changing architectural styles and cityscapes but also deeply touches on shifts in social structure, cultural expression, and identity [10].

Reviewing the current research on gentrification architecture pursuit can be divided into five categories; namely, urban planning and property policy response research [11], global comparative research on gentrification architecture [12], research on gentrification architecture and physical and mental health of the general public [13], research on the environment and the sustainable development of urban architecture [14], and research on culture and identity change [15]. In the study of culture and identity change, some studies have explored the gentrification architecture pursuit intention of immigrant groups, high-, middle-, and low-income groups, ordinary people in different stages of life, and people with different educational backgrounds and occupations [16]. However, no study has focused on people who experienced being left behind in their childhood. The uncertainty and loneliness of the left-behind children's experience may make them more eager for stability and security in adulthood. As a result, this group may be more inclined to seek residential environments that offer long-term security. At the same time, the childhood left-behind experience may stimulate a strong need for social identity and a sense of belonging, and gentrified areas, which are usually associated with social status enhancement, may better satisfy their quest for social identity. Physical activity participation has been shown to be effective in reducing stress, anxiety, and depression, with positive effects on mental health. For consumers with the experience of being left behind, the availability of sports facilities and space for sports activities may be an important factor in their choice of housing, and the unstable family environment of prolonged separation may make this segment of the population have a higher pursuit of the stability and health of the living environment, and gentrification areas usually develop housing projects that include gyms, swimming pools, or other sports facilities. Such amenities may be attractive to consumers with a history of staying behind who want to enhance their well-being through physical activity.

Based on this, this paper, in the process of researching gentrification, effectively focuses its perspective on the group with childhood left-behind experiences. Based on the integration and analysis of previous scholars' dissertation materials, with identity construction theory as the theoretical guideline, and on the basis of physical activity participation, two emerging variables, namely, physical activity happiness and metacognition, are introduced to explore the impact of childhood left-behind experience on consumers' pursuit of architecture in adulthood. Through SPSS and PROCESS, we introduced interdisciplinary variables, such as "sports participation" and "left-behind childhood experience", and for the first time, explored the internal perception and influencing factors of this group in the process of urbanization from a non-dimensional perspective. This study illustrates the unique understanding and pursuit of gentrification architecture by this special group of left-behind sports participants, which promotes the understanding of this group and provides real estate developers and other stakeholders with unique suggestions from the perspective of special consumers, which will help them to design, build, and publicize real estate projects that are more suitable for the general public by more comprehensively taking into account the psychological state of different groups.

2. Literature Review and Hypothesis

2.1. Physical Activity Participation and Gentrification Architecture Pursuit

Physical activity participation refers to the extent to which an individual participates in physical activity and the manner in which he or she participates, which usually involves the individual's input at the physical, psychological, social, and cultural levels. The study by Beaton et al. defines physical activity participation as a multidimensional construct that represents the centrality of physical activity in the life of an individual as well as the hedonic and symbolic value it provides [17]. The development of physical activity participation is influenced by a variety of factors, including the socio-cultural context, the educational system, increased health awareness, and policy support. As society's awareness of the importance of physical activity has increased, physical activity participation has evolved from a simple competitive or recreational activity to a comprehensive way of promoting physical and mental health. As a result, scholars have increasingly focused on how physical activity participation affects individuals and groups across multiple dimensions. Among the motivations and influences on physical activity participation, individuals have a variety of motivations for physical activity participation, including health improvement, enjoyment, socialization needs, and athletic enhancement. For example, a study by Craike et al. [18] provided a comparative analysis of female adolescents' participation in physical activity in urban and rural areas and found that autonomy, sense of competence, and sense of belonging were the key factors influencing physical activity participation. Therefore, physical activity is not only about physical health but also involves multiple influences at the psychological, social, and cultural levels. As awareness of the benefits of physical activity has grown, participation in physical activity has been widely recognized as an important way to enhance one's quality of life.

Gentrification is a complex process of urban development that involves the transformation of residential, commercial, and public spaces, often accompanied by close cooperation between real estate developers and local governments, resulting in an economic and cultural upswing for the region. Gentrification architecture pursuit refers to a shift in emphasis in architecture and urban planning during gentrification, away from the original focus on functionality and utility to a greater emphasis on aesthetics and design styles that match the preferences of the new inhabitants [19]. This often includes the introduction of new architectural designs as well as urban beautification projects that increase property values. Gentrification of architecture also signals a change in consumer psychology. For example, Arkaraprasertkul [20] has demonstrated in his study the internal gentrification of a traditional community in Shanghai, where local residents and developers protect and emphasize the uniqueness of the architecture to increase the market value and social status of the area.

Gentrification not only changes the physical environment of the city but also reshapes the identity and social belonging of community members. In this process, the increase in sports facilities and the promotion of sports activities have become the key points of community reengineering. From the theory of identity construction, it is clear that sports activities are not only a means of physical health promotion but also a tool for community members' identity reshaping. In gentrification areas, newly introduced sports facilities (fitness centers, swimming pools, playgrounds, etc.) are often designed to conform to high-end and distinctive architectural styles, which not only satisfies the pursuit of high-quality life under the psychological condition of low security for groups with childhood left-behind experiences but also reflects the trend of an area's shift from a functional orientation to aesthetics and recreation orientation [21]. In addition, the social effects of sports activities may also have provided support for the gentrification architecture pursuit. For example, Meir [22] argues that sports activities can enhance community cohesion by organizing sports events and activities to strengthen the interaction and connection between residents and create a positive community atmosphere. Such an atmosphere is conducive to attracting more residents seeking a quality living environment, thus indirectly promoting the construction of residential and commercial facilities with higher-end demand and more unique designs. In conclusion, physical activity participation in gentrification is not just a part of improving the physical environment but also an important element of community culture and identity remodeling, which may attract people with childhood years of stay-at-home experience by improving the quality of life of residents, strengthening community ties, and enhancing the attractiveness and expressiveness of the area. Based on this, the following hypotheses are proposed in this paper:

H1. *There is a significant positive effect of physical activity participation on gentrification architecture pursuit for groups with childhood stay-at-home experiences.*

2.2. Physical Activity Well-Being, Physical Activity Participation, and Gentrification Architecture Pursuit

The word "happiness" is of Greek origin, which means a subjective feeling that arises when human beings acquire material needs in the material world. Academics generally define happiness as people's cognitive evaluation of their own life satisfaction [23]. Currently, most researchers generally agree with the concept of happiness proposed by Diener that individuals evaluate the overall quality of their lives according to a standard they set up for themselves, which can be used to describe the sum total of people's perceptions of their own state of life [24]. The modern definition of happiness is the feeling people have when their thirst is satisfied or partially satisfied, and this mental pleasure is happiness. Physical activity well-being is usually defined as the positive emotional experience and increased life satisfaction gained through physical activity. This sense of well-being stems from the enjoyment, health improvement, social interaction, and satisfaction of achieving personal goals brought about by the physical activity itself. Through physical activity, individuals not only enhance their physical strength and health but also experience a sense of achievement and belonging through group activities and competition, which leads to improved quality of life and well-being. For example, Barak et al. [25] have shown in their study that physical activity can enhance individual well-being by promoting health, enhancing social interactions, and providing a sense of accomplishment, etc. Wu [26] has also emphasized the importance of physical health, psychological satisfaction, and social interactions in physical activity to enhance individual well-being. This shows that participation in physical activity has a positive effect on physical activity well-being.

Physical activity well-being, as a positive affective state, may have important implications for the general public's pursuit of gentrification architecture. For example, regular participation in sports may improve people's psychological well-being, including reduced anxiety and depression and increased self-efficacy. Such psychological fulfillment and positive emotions make people more likely to pursue high-quality and aesthetically satisfying lifestyles, including living and working environments. For example, Frey et al. [27] showed in their study that physical activity well-being may promote wider community participation and social cohesion by increasing individual well-being and life satisfaction, which may have a positive impact on community development and building regeneration in gentrified areas. Kim et al. found that social interactions during physical activity can increase residents' sense of belonging and satisfaction with their neighborhood, which may reduce the community brought about by gentrification exclusion and feelings of fragmentation due to gentrification, thereby reducing the negative impacts of gentrified building development [28].

In identity construction theory, an individual's self-concept and identity are formed through social interactions and personal experiences, which in turn influence an individual's behavior and preferences. Thus, physical activity participation is often associated with positive identity traits such as health, vigor, and social status. This may be more consistent with the intrinsic needs of individuals with childhood years of stay-at-home experiences, who experience a positive change in self-perception as they build such positive identities through physical activity, which is usually accompanied by an increased sense of well-being. Physical activity well-being not only enhances individuals' identification with this positive identity but also motivates them to seek out elements consistent with this identity in other aspects of their lives (e.g., residential and work environments) as a way of reinforcing their social identity and self-worth [29]. Meanwhile, physical activity well-being, as an affective state, can significantly influence individuals' decision-making and behavioral patterns, and the well-being gained through physical activity can increase individuals' overall life satisfaction, driving them to seek higher quality and more attractive living environments. This sense of well-being through physical activity leads individuals to choose housing and other living spaces in favor of gentrified buildings that reflect their positive identities, such as homes with modern design, environmental friendliness, and high-end amenities. As Walseth found in his study, physical activity enhances well-being by increasing an individual's sense of self and social connectedness. This sense of well-being through physical activity can be seen as a motivator for wider community participation, including urban regeneration and gentrification building projects [30]. Based on this, the following hypotheses are proposed in this paper:

H2. *Physical activity well-being mediates the influence of physical activity participation on gentrification architecture pursuit in groups with childhood stay-at-home experiences.*

2.3. The Role of Metacognition between Physical Activity Well-Being, Physical Activity Participation and Gentrification Architecture Pursuit

Currently, academic scholars have different definitions of metacognition, with mainstream definitions focusing on disciplines such as pedagogy, neuroscience, and psychology. In pedagogy, for example, Thomas [31] argues that metacognition is an individual's knowledge, control, and awareness of his or her own thinking and learning processes, emphasizing the central role of metacognition in helping students construct scientific knowledge and understanding. In psychology, Norman et al.'s [32] study stated that metacognition encompasses an individual's knowledge, control, and monitoring of his or her own cognitive processes and emphasized the importance of metacognition as a cross-cutting concept. In the field of cognitive neuroscience, Fleur et al. [33] argued that metacognition includes the ability to be aware of one's cognitive processes (metacognitive knowledge) and to regulate them (metacognitive control). Today's research on metacognition focuses on four main areas: first, the measurement aspect of metacognition. For example, Fleming [34] discusses a variety of metacognition scales based on signal detection theory and receiver operating characteristic (ROC) analyses, which are able to more accurately measure how individuals assess their performance and determinism in a given task and can provide a more objective assessment of metacognition ability by avoiding response bias that is commonly found in traditional methods. Second, the developmental aspects of metacognition. For example, Kuhn [35] examined the developmental trajectory of metacognition from initial awareness in childhood to more sophisticated metacognitive abilities in adulthood. Stel et al. [36] found that metacognitive skills grow quantitatively and qualitatively over time and contribute to academic performance independent of intellectual ability. Third, there are applied aspects of metacognition. Metacognition plays an important role in how we integrate and interpret information from different senses. For example, Rhodes [37] discusses how metacognition skills can be enhanced in the classroom by improving students' monitoring and adjustment of their own learning process. He argues that good metacognition skills can significantly improve learning outcomes and academic achievement. Fourth, comparative metacognition aspects. This area of research explores metacognition abilities across species and how these abilities influence behavioral strategies. For example, Carruthers et al. [38] criticize the common interpretation of animal behavior as metacognition, arguing that behaviors such as "uncertainty monitoring" may be better explained by first-order risk estimation rather than true metacognition. They argue for a more rigorous attribution of metacognition to nonhuman animals. Based on this, this paper defines metacognition as an individual's ability to monitor and regulate his or her own cognitive processes, including awareness, assessment, and management of his or her knowledge, thinking, learning, and emotional states.

Identity construction theory emphasizes that an individual's social identity is formed through self-perception and expression in daily activities and social interactions [39]. In this scenario, sport becomes a key socialization field in which metacognition—the individual's awareness of his or her own cognitive processes—plays a crucial role. Metacognition enables individuals to gain a deep understanding of their emotions and behaviors in a variety of situations and, in turn, to effectively adjust these emotions and behaviors to the demands of the sport. This process of adjustment through metacognition not only enhances the individual's control over his or her own abilities but also enhances the individual's identification of his or her role through the successful experience and happiness of physical activity and promotes the formation of a positive social identity. For individuals who had the experience of being left behind in their childhood, this special upbringing made them hold a different perspective when evaluating the value of the living environment and buildings. Specifically, these individuals learn how to make and maintain social connections through interaction and cooperation in physical activity, not only for the sport itself but also for social and emotional fulfillment they may not have fully experienced in childhood.

The level of metacognition may have increased the importance of the home's ability to create a stable and cozy family atmosphere for individuals who had the experience of being left behind in their childhood years. For them, the concept of home goes far beyond symbolic structures, and a warm home is a source of emotional connection and security. Therefore, although gentrification buildings symbolize higher social status, for individuals with a stay-at-home background, the extrinsic value of such buildings does not satisfy their intrinsic need for family and emotional connection. They are more inclined to look for living environments that support and promote interaction and emotional communication among family members rather than simply pursuing expensive or status-symbolizing residential buildings. Based on this, the following hypotheses are proposed in this paper (the specific proposed model for this paper is shown in Figure 3):

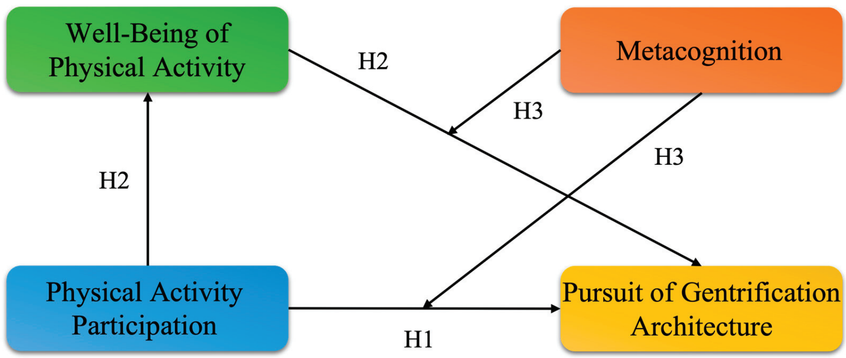

Figure 3. Proposed model diagram.

H3. *Metacognition plays a negative moderating role in the influence of physical activity participation and physical activity well-being on gentrification architecture pursuit in groups with childhood stay-at-home experiences.*

3. Study Design

3.1. Research Methodology

This paper adopts the method of convenience sampling to select the social masses in Xi'an City, Shaanxi Province, China, for testing; a total of 550 questionnaires were distributed, 519 questionnaires were retrieved, and 481 valid questionnaires were obtained after invalid questionnaires were excluded, with an effective recovery rate of 92.68%. Among them, there are 230 males and 251 females, which is a balanced ratio between males and females (Table 1); a total of 377 have left-behind experience, and 104 do not have left-behind experiences. (According to the definition of left-behind children, minors who are left behind in the place of domicile by both or one of their parents going out to work for more than 6 months and who are not able to live with both parents are classified as left-behind children and non-left-behind children as a criterion, which is the criterion of this paper). (This paper uses this criterion to divide the sample into two parts: those with left-behind experience and those without).

Table 1. Descriptive analysis of basic information of the sample.

Causality	Form	Quorum	Percentage
Sex	Male	230	47.8
	Female	251	52.2
Account type	Municipalities	183	38
	Countryside	298	62
Type of retention	No experience of being left behind	104	21.6
	Only the mother works outside the home	139	28.9
	Only the father works outside the home	103	21.4
	Both parents work outside the home	135	28.1
Age	18–25 years	206	42.8
	26–35 years	136	28.3
	36–45 years	99	20.6
	45 years and over	40	8.3
Incomes	Less than 5000 yuan	118	24.5
	5001–10,000 yuan	221	45.9
	10,001–15,000 yuan	103	21.4
	15,000 yuan or more	39	8.1

3.2. Measurement of Variables

In this paper, physical activity participation is measured using the SCL-6 and PARS-3 scales [40], which are established tools in Chinese physical education and psychology. These scales have been widely applied and tested in various studies, demonstrating good reliability and validity. Numerous Chinese academic studies use these scales as benchmarks, confirming their authority, credibility, and effectiveness. We extracted the core elements—intensity, duration, and frequency of physical activity—from these scales, integrating them with the characteristics of the research subjects to form a 3-item scale. An example item is, "How do you think about the intensity of your physical activity?". The Cronbach's alpha coefficient is 0.842, exceeding the 0.7 standard.

The measurement of physical activity well-being is based on Diener's [41] 1985 scale, combined with Koufaris's [42] research, incorporating the sports element. This results in a 4-item scale, such as "Having physical activities in life is in line with my ideal life". The Cronbach's alpha coefficient is 0.89, surpassing the 0.7 standard.

For measuring the pursuit of gentrification architecture, this paper integrates concepts from Sherman [43], Zukin [2], and Butler [44] to design a 3-item scale, including items like, "Do you believe that a building's exterior appearance and environmental quality correlate with social status and cultural tastes?" The Cronbach's alpha coefficient is 0.915, above the 0.7 standard.

Metacognition measurement is derived from the MAI scale by Schraw [45], excluding the emphasis on the learning process, resulting in a 5-item scale. An example item is, "When solving a problem, I will think about the validity of my own thinking process". The Cronbach's alpha coefficient is 0.845, which is greater than the 0.7 standard.

This paper uses a Likert 5-point scale, ranging from "strongly disagree" to "strongly agree", with higher scores indicating more pronounced characteristics of a variable. (See Appendix A. Questionnaire)

4. Findings

4.1. Common Method Bias Test

The use of self-reporting for data collection may lead to common methodological bias, and to avoid this possible bias, the present study controlled for it by using questionnaires that were organized separately and emphasizing anonymity. Meanwhile, principal component factor analysis of all items using Harman's one-way test showed that there were four factors with eigenvalues greater than one, and the factor with the highest explained variance was 38.058%, which is less than the critical criterion of 40%, which indicates that the data obtained do not suffer from the problem of common method bias in any significant way.

4.2. Mean, Standard Deviation, and Correlation Matrix for Each Variable

Table 2 shows the means and variances of physical activity participation levels, physical activity well-being, gentrification architecture pursuit, and metacognition of subjects with different types of childhood left-behind experiences and subjects without childhood left-behind experiences. Considering that the main purpose of this paper is to explore the relationship between physical activity participation, physical activity well-being, gentrified architectural pursuits, and metacognition in people with childhood left-behind experience, the data from people with childhood left-behind experience were chosen for all the analyses after this section. Table 3 shows the correlation matrix between the variables, and the results show that there is no significant correlation between the level of gentrification architecture pursuit and none of the demographic variables in the group with childhood left-behind experience, and there is a significant positive correlation between physical activity participation, physical activity well-being, and gentrification architecture pursuit, but there is a significant negative correlation between metacognition and all of the first three variables.

Table 2. Scores for each variable in each childhood type of retention scenario.

Whether or Not to Stay	Remaining Situation	N	PAP		WBPA		MC		PGA	
			M	SD	M	SD	M	SD	M	SD
No	No experience of being left behind	104	3.689	1.129	3.678	0.991	3.639	0.906	3.663	0.901
Yes	Childhood with only mother working outside the home	139	3.679	1.054	3.646	0.988	3.776	0.804	3.466	0.914
Yes	Childhood with only father working outside the home	103	3.618	1.113	3.522	1.063	3.515	0.956	3.635	0.911
Yes	Both parents worked as children	135	3.869	0.873	3.656	1.004	3.470	0.904	3.677	0.849

Table 3. Means, standard deviations, and correlation matrices for each variable for the group with experience of staying behind during childhood (N = 377).

	M	SD	Sex	Population	Residual	Age	Incomes	PAP	WBPA	PGA	MC
Sex	1.528	0.500	1								
population	1.615	0.487	0.071	1							
residual	2.989	0.854	0.032	−0.003	1						
Age	2.931	0.981	−0.056	−0.061	−0.026	1					
incomes	2.125	0.849	−0.087	−0.038	−0.035	0.1	1				
PAP	3.730	1.013	−0.023	0.025	0.08	0.068	0.002	1			
WBPA	3.615	1.014	−0.033	0.032	0.004	0.053	−0.027	0.506 **	1		
PGA	3.752	1.071	0.006	0.027	0.009	0.08	−0.006	0.472 **	0.545 **	1	
MC	3.595	0.892	0.084	−0.048	−0.147 **	0.02	0.014	−0.153 **	−0.192 **	−0.0342 **	1

Note: ** $p < 0.01$.

4.3. Moderated Mediation Model Test

In this paper, we follow the mediated effects analysis procedure proposed by Zhao et al. [46] and use Model 15 in the SPSS macro program PROCESS 4.0, developed by Hayes [47], to process the data and test the posterior and direct paths of the mediated model with moderation. We controlled for gender, household type, age of type left behind, and income as covariates. As shown in Tables 4 and 5, Bootstrap analysis showed that the mediating role of physical activity well-being and the moderating role of metacognition was established, and hypotheses H1, H2, and H3 in the pre-post of this paper were established.

Table 4. Moderated mediation effects model tests with moderation.

	WBPA				PGA				PGA			
		t	LLCI	ULCI	Coeff	t	LLCI	ULCI	Coeff	t	LLCI	ULCI
Sex	−0.047	−0.511	−0.227	0.133	0.058	0.645	−0.12	0.237	0.109	1.361	−0.049	0.267
Population	0.044	0.475	−0.14	0.228	0.018	0.19	−0.165	0.2	0.001	0.007	−0.161	0.162
Residual	−0.043	−0.809	−0.148	0.062	−0.017	−0.317	−0.121	0.087	−0.074	−1.571	−0.167	0.019
Age	0.022	0.475	−0.07	0.114	0.045	0.977	−0.046	0.136	0.051	1.246	−0.029	0.131
incomes	−0.039	−0.718	−0.145	0.067	0.003	0.064	−0.102	0.108	−0.01	−0.212	−0.103	0.083
PAP	0.506	**11.24** ***	0.418	0.595	0.278	**5.373** ***	0.176	0.379	0.244	**4.724** ***	0.142	0.345
WBPA					0.434	**8.427** ***	0.333	0.535	0.32	**6.209** ***	0.219	0.421
MC									−0.342	**−7.06** ***	−0.438	−0.247
Int_1									−0.185	**−3.132** **	−0.301	−0.069
Int_2									−0.166	**−2.721** **	−0.286	−0.046
R2	0.259				0.351				0.499			
F	21.584 ***				28.523 ***				36.395 ***			

Note: ** $p < 0.01$; *** $p < 0.001$.

Table 5. Mediation effects tests with Moderation.

Trails	Effect (Scientific Phenomenon)	Effect	SE	95% CI		Percentage of Total Effect
				LLCI	ULCI	
PAP-PGA	aggregate effect	0.498	0.049	0.402	0.593	
PAP-PGA	direct effect	0.278	0.052	0.176	0.379	
PAP-WBPA-PGA	indirect effect	0.22	0.037	0.149	0.297	44.2%
PAP-PGA	MC low	0.409	0.088	0.237	0.581	
	MC High	0.078	0.057	−0.033	0.19	
WBPA-PGA	MC low	0.468	0.087	0.297	0.638	
	MC High	0.172	0.061	0.052	0.292	
PAP-WBPA-PGA	MC low	0.237	0.053	0.146	0.351	
	MC High	0.087	0.043	0.002	0.171	
	Index	−0.084	0.036	−0.163	−0.02	

Specifically, in the mediation model with physical activity participation as the independent variable, physical activity well-being as the mediator variable, and gentrification architecture pursuit as the dependent variable, physical activity participation was able to significantly and positively predict gentrification architecture pursuit, with a significant direct effect ($p < 0.001$) and a significant total effect ($p < 0.001$). The confidence interval of physical activity well-being as a mediating variable did not contain 0, and the confidence interval of physical activity well-being as a mediating variable did not contain 0 after the introduction of the moderating variable metacognition, indicating that the mediating effect of physical activity well-being on physical activity participation and gentrification architecture pursuits was significant when only physical activity well-being was used as a mediating variable ($p < 0.001$). Meanwhile, when physical activity well-being was the mediating variable, and metacognition was the moderating variable, the mediating effect of physical activity well-being on physical activity participation in gentrification architecture pursuit was also significant ($p < 0.001$), with a relative effect value of 44.2%.

In addition, the interaction term between physical activity well-being and metacognition was a significant negative predictor of gentrification architecture pursuit ($p = 0.007 < 0.05$), and the interaction term of metacognition of physical activity participation was also a significant negative predictor of gentrification architecture pursuit ($p = 0.002 < 0.05$). This result suggests that metacognition plays a moderating role in the effect of physical activity well-being on gentrification architecture pursuit, moderating the second half of the path of the mediation model; at the same time, metacognition also plays a moderating role in the effect of physical activity participation on the direct path of gentrification architecture pursuit.

In order to further analyze the trend of the moderating effect of metacognition, metacognition was divided into two groups of high and low according to one standard deviation of positive and negative, and the simple slope test was used to examine the moderating effect of metacognition between physical activity well-being and gentrification architecture pursuit. As shown in Figure 4, when the level of metacognition was low, the positive predictive effect of physical activity well-being on gentrification architecture pursuit was higher in the group with childhood left-behind experience ($p < 0.001$); when the level of metacognition was high, the physical activity well-being of the group with childhood left-behind experience was the existence of a lower positive predictive effect on gentrification architecture pursuit ($p = 0.005 < 0.05$). That is, higher metacognition can attenuate the driving effect of physical activity well-being on gentrification architecture pursuit.

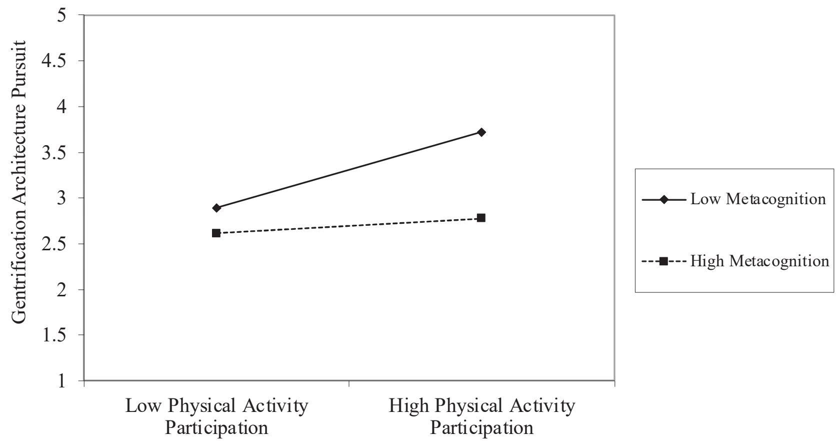

Figure 4. Diagram of negative moderating effects of metacognition.

Similarly, metacognition was divided into high and low groups by plus or minus one standard deviation, and a simple slope test was used to examine the moderating effect of metacognition between physical activity participation and gentrification architecture pursuit. As shown in Figure 5, when the level of metacognition is low, the positive predictive effect of physical activity participation of the group with childhood left-behind experience on gentrification architecture pursuit is stronger ($p < 0.001$); when the level of metacognition is high, the physical activity participation of the group with childhood left-behind experience, however, does not have a significant positive predictive effect on gentrification architecture pursuit ($p = 0.168 > 0.05$). That is, higher metacognition can attenuate the driving effect of physical activity participation and gentrification architecture pursuit.

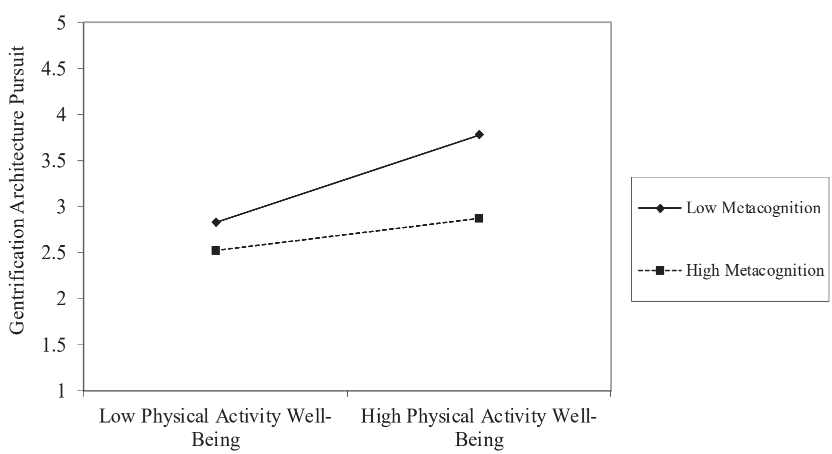

Figure 5. Negative moderating effects of metacognition.

5. Analysis and Discussion

This paper explores the relationship between childhood left-behind experiences and physical activity participation with gentrification architecture pursuit and its possible underlying mechanisms. The results show that the level of physical activity participation of individuals with childhood left-behind experiences positively predicts their gentrification architecture pursuits, i.e., the more actively involved in physical activity an individual affected by left-behind experiences is, the higher the degree of his/her gentrification architecture pursuits will be. In addition, this paper also found the mediating role of physical activity well-being, i.e., physical activity participation can have an indirect effect on gentrification architecture pursuit through physical activity well-being, which is manifested in the fact that the higher the frequency of physical activity participation of individuals affected by the left-behind experience in childhood, the stronger the well-being experienced by their participation in physical activity, and the higher the level of their pursuit of gentrification architecture. Further analysis revealed that metacognition plays a moderating role in the path of physical activity well-being in predicting consumers' gentrification architecture pursuits, i.e., when individuals with childhood left-behind experiences have higher levels of metacognition, their level of gentrification architecture pursuits (compared to lower levels of metacognition) is limited, even though their physical activity participation experiences more well-being. In addition, the metacognition ability of individuals with childhood left-behind experiences significantly and negatively predicts their gentrification architecture pursuit when the level of sport participation is low, i.e., the better the metacognition ability, the lower the level of gentrification architecture pursuit for individuals with left-behind experiences who have a lower level of sport participation.

The impact of the left-behind experience on individuals is not only in terms of participation in sports but also in terms of their subsequent development and consumer attitudes; Wen et al. [48] compared the psychological, behavioral, and educational outcomes of left-behind and non-left-behind children and found that the left-behind children were at a disadvantage in terms of health behaviors and school participation. It is clear that childhood is an important time in an individual's development and that the experience of being left behind has an impact on all aspects of their subsequent development. Belk et al. [49] showed that elementary school is a critical time for children to acquire most of the skills of consumer decoding, which involves recognizing the symbolic meanings of consumer goods, such as cars and houses. The lack of access to the Internet is a major factor in the development of children who have been left behind. Individuals who have been left behind are more likely to feel lonely due to the lack of communication with their parents, which may lead to a change in their consumption attitudes compared to those with parents, i.e., because of the absence of one or both parents during childhood, they may place more emphasis on the symbolic aspects of consumption (e.g., gentrification and architectural pursuits), and have a greater need to seek acceptance in the community.

5.1. The Direct Role of Physical Activity Participation and the Mediating Role of Physical Activity Well-Being

This paper finds that the level of physical activity participation of individuals with childhood left-behind experiences is an important predictor of individual gentrification architecture pursuit, which is more consistent with the findings of previous scholars' related studies [50]. More importantly, this paper also finds that the level of physical activity participation of individuals with childhood left-behind experience will enhance their gentrification architecture pursuit psychology through physical activity well-being. Physical activity participation is not only a form of entertainment but also an expression of cultural symbols and social identity. During childhood, left-behind individuals may lack family companionship and cozy family cultural inheritance, but through physical activity participation provides them with an ideal social platform to build close relationships with others, bringing physical and mental pleasure while also integrating into an emerging circle of people sought after by the mainstream culture of the society and establishing a new social identity. Physical activity participation is often promoted by the mass media as a positive image and is generally understood and recognized by the social crowd. This recognition and respect will inspire them to pursue a higher quality of life, including the pursuit of gentrification architecture [51].

Physical activity participation is not only a physical activity but also a kind of psychological exercise and healing. Individuals who lack family companionship in childhood can obtain a sense of security and warmth through sports activities, which can "replace" companionship. For example, the sense of achievement, cooperation, and body shaping gained from sports activities will significantly increase the individual's self-confidence and sense of well-being. Physical activity and well-being are not only a direct result of sports participation but also inspire individuals to aspire to a better quality of life [52]. According to the theory of identity construction, an individual's identity is gradually formed and constructed through social interactions and personal experiences; therefore, the sense of well-being gained through sports activities enhances an individual's satisfaction with life and the pursuit of a high quality of life, which in turn influences the pursuit of gentrification architecture pursuit. From another perspective, the enhancement of physical activity well-being reflects individuals' concern and pursuit of good living habits and physical and mental health. The gentrification building communities often provide better living environments and community facilities, such as high greening rates, excellent comprehensive quality of residents, and perfect sports supporting facilities, which are conducive to individuals' physical and mental health and quality of life.

Identity construction theory emphasizes that individuals construct their identities through the realization of self-worth and the pursuit of personal achievement [53]. Individuals with stay-at-home experiences may have experienced certain challenges and dilemmas growing up yet gained self-actualization and a sense of accomplishment through physical activity participation. High-end neighborhood properties are often seen as symbols of success and social status, and living in such an environment naturally enhances an individual's sense of identity and social status in the eyes of others [54]. Individuals with the experience of being left behind in childhood may have gained a certain sense of achievement through sports activities but still feel a certain degree of identity uncertainty and identity dilemma at the psychological level of social interaction. Gentrification architecture is not only a material enjoyment but also a symbol and pursuit of a better life. This pursuit not only comes from material fulfillment but is also a response to the deepest longing of the heart. Therefore, they are more inclined to demonstrate their success and status by pursuing properties in gentrified neighborhoods in order to gain social recognition and respect.

5.2. The Moderating Role of Metacognition

Interestingly, the results of the empirical analysis in this paper identified the conditional variable, metacognition, that can limit to some extent the impact of physical activity well-being on gentrification architecture pursuit in individuals with childhood stay-at-home experiences. Individuals with higher levels of metacognition may be better at goal setting, self-construction, and self-monitoring, more focused on internal growth and self-actualization, more likely to think and plan rationally for their own development, more focused on long-term goals and resource allocation, and more attentive to the trade-off between intrinsic and extrinsic satisfaction [55]. These abilities cultivate a higher degree of psychological resilience, enabling individuals to cope more effectively with the negative impacts of childhood experiences of being left behind, to break through the dilemmas brought about by childhood experiences of being left behind, and to seek opportunities for growth and development from them. If they seek active and healthy habits, such as cultivating interest in sports and increasing their level of physical activity participation, they will participate in physical activities more consciously, and individuals with a high level of metacognition may be more adept at monitoring their emotions and behaviors, and be able to cope with challenges by regulating their attention and emotions. This ability to self-regulate contributes to better enjoyment of the exercise process during physical activity, leading to increased physical activity well-being and a greater ability to enjoy the well-being brought about by the exercise proces.

Specifically, because individuals with high levels of metacognition focus on the rational allocation of their various resources, they weigh their options more carefully and cautiously consider where investing their resources will maximize their long-term personal interests and goals [56]. Therefore, even if they feel physically and mentally enriched by physical activity participation or have an increased sense of well-being brought about by physical activity, they are more likely to believe that instead of investing their resources in the pursuit of external material enjoyment such as high-end gentrified properties, they would be better off using their resources in other more important aspects, such as education, and thus pursue gentrification architecture pursuits to a relatively low degree. Because metacognition aids individuals to continuously overcome the effects of childhood left-behind experiences, gain more security and fulfillment, and enhance positive mindfulness and self-affirmation of life, they are more concerned with long-term personal development and goal attainment than short-term pleasure experiences [57]. Identity construction theory emphasizes that individuals with clear self-knowledge are more able to clearly understand the relationship between themselves and their social environment and more rationally deal with the social identity and identity brought by external material symbols [58]. Even though the experience of being left behind in childhood may have prompted individuals to face the challenges and responsibilities of adult life at an earlier age and experience identity troubles and struggles, even though the sense of achievement from physical activity participation and the sense of well-being from physical activity have increased, they are likely to pay more attention to their personal values and long-term goals, and will not pursue external material symbols such as high-end real estate excessively because they know better that it cannot truly satisfy their inner needs. Individuals with high levels of metacognition may be more inclined to internal self-worth and personal growth and less reliant on external material symbols, including gentrification architecture pursuits such as real estate.

6. Limitations and Future Research

This paper empirically explored the mechanism of the influence of individual sports participation levels of childhood left-behind experiences on their gentrification architecture pursuit, but there are still some shortcomings: first, this paper uses a convenience sampling method to find subjects to distribute and fill out the questionnaire, in which it must be considered that there may have been a very small number of subjects who do not fill out the questionnaire seriously due to subjective reasons, which resulted in the situation of bias; moreover, the sample in this paper was limited to the same region, and the social, economic, cultural, and environmental characteristics of a single geographic region may be so unique that they may not be replicated in other regions. Policies and institutions may vary greatly from region to region, and these differences can have a significant impact on the behaviors and attitudes of the subjects of this study. Therefore, a combination of different research methods can be used in future studies to broaden the scope of subjects and continuously improve the representativeness of the sample and the external validity of the study. Future studies can also increase the study area to enhance the reliability and validity of the findings by comparing and contrasting data from different regions. In addition, they can also provide detailed research instructions and methods, including sample selection criteria, data collection processes, and analysis methods. It is also beneficial to conduct a long follow-up study to observe the changes and trends of the variables in different geographic regions, to verify the continuity and stability of the study results, and ultimately to ensure the replicability of this study in other geographic settings.

Secondly, this paper only explored the influence of the experience of being left behind in childhood on individual gentrification architecture pursuit and does not differentiate the types of being left behind in detail, such as only the father working outside the home, only the mother working outside the home, and both parents working outside the home. In future research, we can construct a multicluster structural equation model according to the different types being left behind to analyze the specific links between individual variables further and find more valuable points from the comparison of the paths. Finally, gentrification architecture pursuit is affected by a variety of factors, and this study only explored the relationship between physical activity participation, physical activity well-being, metacognition, and gentrification architecture pursuit of individuals with childhood left-behind experiences, in addition to which there are other variables that have an impact on gentrification architecture pursuit, such as upward social comparison, mental toughness, and so on. Therefore, future research can consider more realities, combine them with richer literature, and examine and study the inherent mechanism of action and the relationship between variables from multiple perspectives and in multiple fields.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Questionnaire

Variant	Subject	Score
Physical activity participation	What are your daily hours of physical activity?	1. 10 min and below 2. 11–20 min 3. 21–30 min 4. 31–59 min 5. 60 min and above
	How intense do you consider your physical activity to be?	1. light 2. light intensity 3. medium intensity 4. medium-high intensity 5. high intensity
	How frequent is your physical activity participation?	1. less than once a month 2. 2–3 times a month 3. 1–2 times a week 4. 3–5 times a week 5. almost every day
Physical Activity Well-Being	Physical activity participation gives me a greater sense of purpose in life.	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	Sports are something I love and I tend to get into them	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	Having sports in my life matches my ideal life.	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	Physical activity participation relaxes me.	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
Gentrification Architecture Pursuit	Do you believe that the appearance of buildings and the quality of the environment correlate with social status and cultural tastes?	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	Do you think owning a gentleman's property will enhance your personal image?	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	Even if it's expensive, I'm still willing to buy gentrified real estate.	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
Metacognition	When solving problems, I think about the validity of my thought process	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	When I solve problems, I am able to be aware of my thought process	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	I am able to perceive myself correctly in my daily life	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	I'll be strict with myself to improve my focus and quality of life.	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree
	I will continue to self-reflect and self-adjust myself to have a good physical and mental condition	1. strongly disagree 2. somewhat disagree 3. generally 4. somewhat agree 5. strongly agree

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buildings

Article

The Spatial Patterns and Building Policies of Rural Settlements in the Context of Demolition: The Case of Xian'an, China

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Abstract: In China, the "land-restructuring" policy provides balanced land for urban settlements that is strictly limited in expansion. Therefore, reassessing and adjusting the layout of rural settlements is of great practical significance for promoting rural revitalization. In this paper, taking Xian'an district in Hubei Province as an example, we use the weighted rank-sum ratio comprehensive evaluation method and spatial association analysis method to analyze the development level and spatial pattern of settlements. The results show that: (1) The development level of settlements in Xian'an shows obvious spatial differences, with a spatial pattern of 'high in the core–low in the periphery' and 'high in the northwest–low in the southeast', which is the result of the combined effect of natural geographical conditions and socioeconomic conditions; (2) The comprehensive development level of settlements, evaluated based on four major indicators—population size, resource endowment, spatial characteristics, and material construction—reveals the presence of cluster effects, distance decay effects, administrative hierarchy effects, and "long board" effects; (3) Within village communities, settlements with significantly high levels and settlements with significantly low levels have a similar geographic distribution and mosaic spatial patterns. Lastly, based on the overall development level and spatial association patterns of settlements, this article presents possible options for governmental settlement governance from the standpoint of rural building management.

Keywords: building demolition policy; urbanization; spatial layout; Hubei; China

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1. Introduction

According to the results of China's seventh census, the country's urban resident population reached 901 million people in 2020, with China's urbanization rate reaching 63.89%. Yet, based on the population of registered households, China's urbanization rate is only about 45%. This gap exists because there are still over 200 million migratory workers and their families who work and live in cities but do not have urban household registration [1], most of whom live in informal housing such as collective dormitories or urban villages [2,3]. China's urbanization remains low in comparison to certain developed countries, such as Japan and the USA, and many researchers think that China's urbanization has considerable opportunities for expansion [4–6]. Therefore, the Chinese government is currently focused on fostering new urbanization and enhancing housing initiatives to address this issue [7,8].

China's current land use policy, which closely observes the 120 million hectares of the arable land red line [9,10], makes urban expansion planning extremely difficult. Despite this, expansion is still required in many Chinese cities. To remedy this, the federal government has implemented a land-restructuring policy known as "increasing versus decreasing balance" [11,12]. So, for every additional piece of urban land designated for construction, the rural settlement must be decreased proportionally. The objective is to promote urbanization while preserving China's food security. As a significant population of rural residents migrate to urban areas, they anticipate gaining greater access to education, health care, and other resources. There is abundant evidence that an increasing number of tiny villages in China are diminishing or perhaps dying as vast numbers of rural dwellings are abandoned [13–15]. According to scholars, the government's local urbanization policy has a crucial influence on this phenomenon [16,17].

In a report to the 19th National Congress of the Communist Party of China in 2017, Chinese authorities advocated a "rural revitalization" strategy and drafted a plan for it the following year [18,19]. This strategy intends to foster rural development by classification, which separates the countryside into four categories: agglomeration and augmentation, suburban integration, distinctive protection, and relocation and annexation. Communities in the first three categories would be uncontroversial, while those identified for removal and annexation could face fierce opposition, particularly from those annexed to neighboring settlements (Some news can provide evidence: https://www.163.com/dy/article/FGBVGMCC0512D03F.html (accessed on 10 September 2024); https://news.ifeng.com/c/7xgUIRxgf7g (accessed on 10 September 2024)). Despite objections, China's ambitious rural rejuvenation program cannot provide government funding for all settlements, and some people may need to move from their old rural towns to join other settlements or relocate to cities. Simultaneously, China's rural regeneration strategy must be linked with the new urbanization strategy to follow the path of intensive, efficient, urban–rural integration and harmonious and sustainable urbanization [8].

Hence, determining which communities should be abandoned or not has become a challenging task. The primary objective of this article is to determine the future development direction of settlements based on a rational assessment of these areas, while integrating the spatial characteristics of the assessment results. In particular, it aims to establish policies regarding the construction of new buildings. Earlier work on assessing the suitability of settlements using GIS and RS technology [20–22], with geospatial as the evaluation object, has produced some results [23]. Several earlier assessments were undertaken for administrative villages rather than settlements, and previous assessments overemphasized the natural condition attributes of administrative villages while paying little attention to transportation and facilities accessibility [24–26]. Earlier evaluations lacked consideration of the socioeconomic or material construction characteristics of settlements, as well as an emphasis on community involvement and government administrative expenditures [27,28]. In past local practices, the subjective evaluation by technical government officials took into account the current construction status of the settlement and the opinions of the residents to some extent, but the evaluation criteria were difficult to standardize and the results frequently sparked debate.

In response to the shortcomings of previous research, this paper presents our research materials and methodologies in the following sections, with a particular focus on how we established our own indicator system while referencing the metrics used in earlier studies [29–36]. In Section 3, we detail the assessment results and spatial characteristics of the settlements, conducting a correlational analysis between the scoring levels of the settlements and their spatial types. Sections 4 and 5 discuss our findings, proposing various relocation strategies and architectural policies for different types of settlements, and offering suitable policy recommendations for government initiatives aimed at rural revitalization.

2. Materials and Methods

2.1. Area of Study

Xian'an District, located in Hubei Province, China, is the center section of Xianning prefecture, whose authority covers the Xianning urban areas and its surrounding suburbs (Figure 1). At the city's outskirts, there are 10 townships and 1939 settlements. Its urban population was 480,879 inhabitants in 2020, while its rural population was 176,711 inhabitants. According to the sixth and seventh censuses, the majority of Hubei Province is losing population, with only the provincial capital Wuhan and surrounding districts having seen a population increase in the past decade (Figure 1). Between 2010 and 2020, the urban population of Xian'an increased by 6.65%, while the rural population increased by 2.87%. This urban–rural gap is thought to be the result of large rural-to-urban migration; however, the rural population loss in Xian'an is much larger than this gap, because, on the one hand, many villagers moved to cities for work, but their household registration remains in the countryside, resulting in a growing registered rural population but a declining actual rural population. Particularly in recent years, the number of births in China has declined significantly, and a vast number of rural schools has been abandoned [14], with educational resources steadily shifting to the county cities. Many villagers want their children to acquire a better basic education at the county's public schools and, under the applicable policy, are required to buy a house in the county, but the majority of them prefer to preserve their rural household registration. On the other hand, larger cities, such as Wuhan, take a portion of the population from Xian'an. The population of Xian'an is rising at a significantly slower rate than that of other cities.

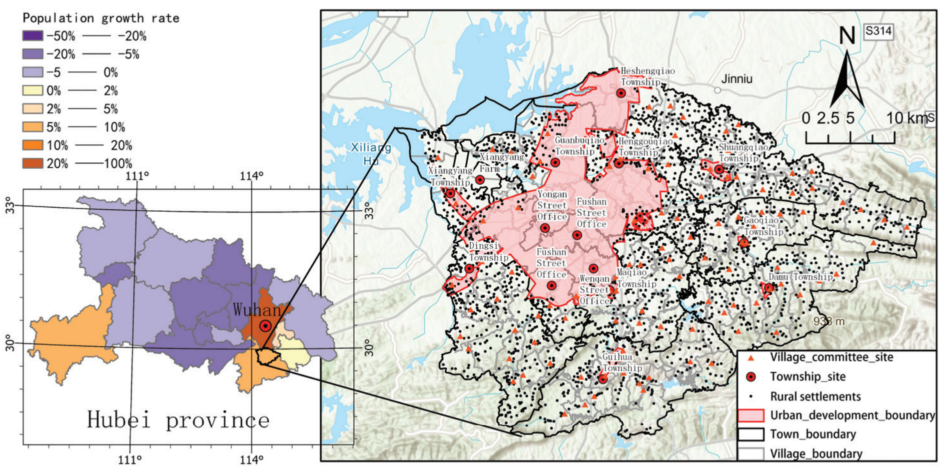

Figure 1. Location of the case study. Note: This map shows the spatial distribution of the settlements. In the main map, the red block is the government's boundary for urban development, which includes considerable farmland.

The first stage of urbanization is characterized by the siphoning of urban to the rural population, whereas the second stage is dominated by the siphoning of major cities to minor cities. Numerous studies have indicated that China has entered the second stage of urbanization based on the performance of various urban cities [37,38]. Xian'an has lost a significant proportion of the rural population in the last two decades, and several abandoned settlements have arisen. In terms of population growth rate, Xian'an District is very appealing to the rural regions under its control as well as neighboring cities in Hubei Province, and there is still a desire for urban expansion. As a result of China's land-restructuring policy, it was unavoidable that certain rural settlements in Xianan would be demolished.

2.2. Assessment Framework and Indicator System

2.2.1. Theoretical Structure Construction

The landscape form of rural settlements is the result of the combined effect of natural geographical conditions and socioeconomic development level [20], and the assessment of their residential suitability must consider the settlements' historical accumulation, development status, and future development potential. At the same time, it should be highlighted that this evaluation is also a scale relationship between the government and the villagers. The government wants to reduce administrative expenses and achieve land-restructuring goals, while villagers desire a higher quality of life. The key to the evaluation system and the establishment of construction regulations is how to balance the interests of both parties. Given that settlement development is a complicated process involving the interaction of various elements, it is required to investigate the influencing factors systematically and exhaustively from multiple viewpoints to assess the degree of settlement development in a targeted manner. This study investigates the factors that impact settlement development from four perspectives (Figure 2), taking into consideration relevant scientific studies. ① Population size: Population decrease is the expression of the abandonment process and its most direct cause [16], and the resident population, number of resident households, and average household size may be utilized as proxy variables for the settlement. ② Resource endowment: Contains the cultural history of the settlement's past and its current natural resources. Relevant evidence indicates that both historical culture and natural landscapes can significantly promote tourism development [39,40], thereby contributing to the reduction in rural poverty [41]. ③ Material construction: Verification of the existing physical infrastructure in the village, which includes several essential services such as potable tap water, an elementary school, and a medical clinic. These elements are critical for ensuring the sustainability of rural living [42,43]. ④ Spatial characteristics: Settlements should not be lonely entities. The location of the settlement almost affects the transportation cost of the settlement to gain access from the outside world, and the site environment is an important basis for settlement development. Certain objective objects are easy to count to assist these indicators in finding acceptable proxy variables; also, some government awards for villages are regarded as key reference indicators (Table 1). It is important to note that the assessment results serve as the foundation for identifying the spatial patterns of settlements. Only by recognizing these spatial patterns can more rational building policies be formulated. According to the theory of neighborhood effects [44], individuals who are geographically closer tend to interact more frequently, which confers advantages in community communication, volunteer services, and accessibility to facilities [45]. If the spatial pattern of settlements in a given area is characterized by the concentration of stronger entities, it indicates favorable development prospects, warranting the adoption of proactive expansionary building policies [46]. Conversely, if the pattern is one of weaker concentrations, the costs associated with the configuration of public service facilities in that area may be excessively high [47]. In such cases, stringent control over building policies should be implemented. This approach can enhance the efficiency of government investments in settlements and provide greater assistance to rural populations in their efforts to escape poverty [48].

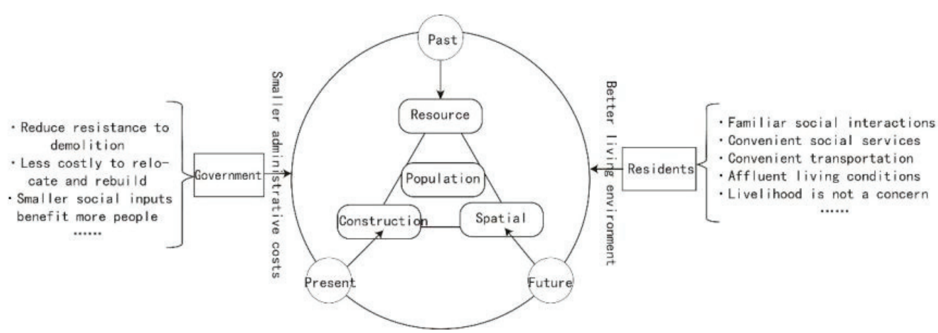

Figure 2. Theoretical structure of demolition-oriented settlement development level assessment.

Table 1. System of evaluation indicators.

Primary Indicators	Secondary Indicators	Tertiary Indicators	Code	Weights	Data Source	Tend
Population size (30%)		Number of households	X1	10%	III	+
		Permanent population	X2	10%	III	+
		Average number of households	X3	10%	I	+
Resource endowment (18%)	Natural resources	Forest land area per capita	X4	1%	I	+
		Garden area per capita	X5	1%	I	+
		Water resources per capita	X6	1%	I	+
		Arable land area per capita	X7	1%	I	+
		Construction land area per capita	X8	1%	I	+
		Ecological land area per capita	X9	1%	I	-
	Historical and cultural heritage	Traditional village	X10	3%	II	+
		Folk culture	X11	3%	II	+
		Historic monuments	X12	3%	II	+
		Other heritages	X13	1%	II	+
		Civilized countryside demonstration site	X14	2%	II	+
Spatial characteristics (20%)	Location	Distance to highway	X15	3%	I	-
		Distance to township	X16	4%	I	-
		Distance to village committee site	X17	3%	I	-
	Site environment	Average homestead area per household	X18	3%	I	-
		Distance to the nearest settlement	X19	2%	I	-
		Ground deformation	X20	3%	I	-
		Elevation	X21	2%	I	-
Material construction (32%)	Size of physical area	Built-up area	X22	10%	I	+
	Municipal infrastructure	Potable tap water	X23	2%	III	+
		Wastewater treatment system	X24	2%	III	+
		Communication network coverage	X25	2%	III	+
		Garbage collection system	X26	2%	III	+
	Public service facility	Village committee station	X27	2%	III	+
		Primary schools and kindergartens	X28	2%	III	+
		Medical clinic	X29	2%	III	+
		Cultural halls	X30	2%	III	+
		Sports plaza	X31	1%	III	+
		Beautiful countryside demonstration site	X32	5%	II	+

Note: I: GIS; II: Provided by the government; III: Field investigation team.

2.2.2. Selection of Evaluation Indicators

Whether or not a community should be demolished is intimately tied to its historical accumulation, present degree of development, and future potential, and we developed a multi-level indicator evaluation approach to assess these factors (Table 1). In this study, evaluation indices are allocated using a subjective assignment approach, and weights are derived using an expert judgment matrix once the hierarchical model has been constructed. We discovered that the weights estimated by various experts varied greatly, and so, we convened a meeting of specialists to examine them. We finalized the weights of each indication after examining the input of seven planning experts, three technical officials, and two leading officials, and the professional opinions are fully respected in this process.

2.3. Data Sources

We utilized both primary and secondary data for our research. The primary data were collected through a comprehensive census conducted by our research team at each settlement site. This extensive undertaking was supported by planning and design agencies, government management departments, and local village committees. The secondary data were sourced from government management departments and publicly available datasets online, detailed as follows: Geographic information data such as administrative divisions, settlement sites, and land use data were gathered from the local government land management departments and land use data were compiled in 2020 by the Third

National Land Survey. The DEM utilized digital elevation data with a 30 m resolution from GDEMV2, downloaded from the Chinese Academy of Sciences' Computer Network Information Center (http://www.gscloud.cn, accessed on 10 June 2024). The government's Culture and Tourism Administration provided the list of cultural heritage, while the government's Rural Rejuvenation Bureau provided the list of competition winners for the Beautiful Countryside Demonstration Site and the Civilized Countryside Demonstration Site. China has undertaken a total of six traditional village selection activities. Therefore, X10 is granted a score between 1 and 6 points; the earlier the title is earned, the higher the score; without the title, it is ascribed a value of 0. According to the level of government that granted the honor, X11–X14 and X32 are assigned as follows: the central government awards four points, the province government three points, the municipal government two points, and the district government one point. In addition, five experts organized a field study team to undertake in-depth site visits to 1937 communities located beyond the urban growth border. The village chief filled in X1 and X2, while the field research team filled in the remaining data after conducting field visits. X23–X31 must be determined by a site visit. If they exist and are routinely utilized, 1 point is awarded; otherwise, no points are awarded.

2.4. Methods

2.4.1. Weighted Rank-Sum Ratio

In this study, the WRSR (weighted rank-sum ratio) comprehensive evaluation method was utilized to conduct the evaluation. The basic idea of the WRSR is to rank the evaluation indicators and use the average of the ranks as the evaluation criterion, which is appropriate for the thorough assessment of indicators with multiple units of measurement. It continues as follows: ① Assemble the matrix: If there are n objects and m indicators, build the data matrix ($n \times m$); ② Transform data matrices into sorting matrices: In this study, a non-integer ranking approach was employed, overcoming the drawback of losing quantitative information on the original indicator values when employing conventional methods. ③ Calculating the rank-sum ratio with weighting using the equations provided below:

$$R_{ij} = 1 + (n-1)\frac{X_{ij} - mini\left(X_{1j}, X_{2j}, \cdots X_{nj}\right)}{max\left(X_{1j}, X_{2j}, \cdots X_{nj}\right) - mini\left(X_{1j}, X_{2j}, \cdots X_{nj}\right)} \tag{1}$$

$$R_{ij} = 1 + (n-1)\frac{max\left(X_{1j}, X_{2j}, \cdots X_{nj}\right) - X_{ij}}{max\left(X_{1j}, X_{2j}, \cdots X_{nj}\right) - mini\left(X_{1j}, X_{2j}, \cdots X_{nj}\right)} \tag{2}$$

$$WRSR_i = \frac{1}{n}\sum\nolimits_{j=1}^{p} W_j R_{ij} \tag{3}$$

Of the three equations above, (1) and (2) are used to calculate the value of the non-integer ranking (R_{ij}); the former is for positive indicators and the latter for negative indicators. $WRSR_i$ is then the final score for resident i, and W is the weight of the indicator. Owing to substantial regional differences, individual settlements vary significantly from other settlements in terms of some variables. The WRSR approach creates assessment indicators based on the ranking results of residential areas in statistical data, as opposed to directly employing statistical data, thus efficiently avoiding the circumstance in which certain statistical data are outliers [49]. This approach is beneficial because the data distribution is relatively concentrated and tends to follow a normal distribution, which facilitates a better observation of the spatial patterns of settlements in subsequent analyses. Its limitation lies in the potential loss of information, which may hinder the accurate calculation of the true distances between settlements.

2.4.2. Spatial Association Analysis

(1) Global spatial association. The global-based spatial association measures include Moran's I [50], Geary's C [51], and Getis-Ord's G and G* [52]. Assuming that the location

of the settlement is the result of a two-dimensional stochastic process, the global Moran's I measures the spatial distribution pattern of the settlement assessment score globally based on the location of the settlement and its WRSR value, determining whether the pattern is clustered, dispersed, or random [53]. Similar to the association coefficient in general statistics, Moran's I ranges from −1 to 1. A number larger than zero implies a positive spatial association, whereas a value equal to zero indicates there is no spatial association. The formula is as follows:

$$I = \frac{N}{\sum_i^N \sum_j^N W(i,j)} \frac{\sum_i^N \sum_j^N W(i,j)\left(X_i - \overline{X}\right)\left(X_j - \overline{X}\right)}{\sum_{i=1}^N \left(X_i - \overline{X}\right)_i^2} \tag{4}$$

In the above equation, N denotes the number of study subjects; X_i and X_j denote the observed values of positions i and j, respectively; and $W(i,j)$ is the spatial connectivity matrix between positions i and j. After calculating global Moran's I, the results are also subjected to statistical tests, generally using the z-test, as follows:

$$z(I) = \frac{I - E(I)}{\sqrt{var(I)}} \tag{5}$$

(2) Local spatial association. The local I of Moran is an extension of the global I of Moran. For an individual, the global is split into many regional units, and the local Moran's I coefficient for this individual is referred to as LISA (Local Indicators of Spatial Association) [54], a common indicator for the local spatial association. It can be used to detect various types of spatial outliers and local clusters [53]. For a certain spatial cell i:

$$I_i = \frac{N\left(X_i - \overline{X}\right)\sum_{j=1}^N W_{ij}\left(X_j - \overline{X}\right)}{\sum_i \left(X_i - \overline{X}\right)^2} \tag{6}$$

In the above equation, N, X_i, $\overline{X}$, W_{ij}, etc., have the same meaning as those in Equation (4), and its statistical test is similar to that of the global association. It is critical to select a statistical area for a settlement's local Moran's I, which is normally decided by the number of neighbors or the search radius. Then, by comparing the point to its neighbors, the co-type of settlement can be identified.

3. Results and Analysis

3.1. Evaluation of the Development Level

The aforesaid procedure was used for the evaluation. Firstly, the WRSR of each settlement can be determined, and the larger the WRSR, the higher the overall rating of the settlement. Then, the WRSR distribution was calculated, which included reporting the frequency of each group and calculating the cumulative frequency of each group; calculating the rank R and average rank R^- of each WRSR; calculating the downward cumulative frequency $R^-/n \times 100\%$; correcting the last term by $(1 - 1/4n \times 100\%)$; and determining the probability unit corresponding to the cumulative frequency. Then, the WRSR distribution values in the table were used as the independent variable and the Probit values as the dependent variable in the linear regression. The linear regression analysis reveals that the model's formula is "y = 0.154 + 0.043Probit"; the regression equation's significance test F value is 42,241.8; the significance probability value p is 0.000, which is lower than 0.01; and the coefficient of determination R^2 = 0.956, indicating that the requested regression equation is statistically significant, and the method's assessment results are scientific and reliable. Finally, the scores were sorted hierarchically, and they were classified into 1–5 star levels based on experience, equivalent to the five levels of very low, low, average, high, and very high (Table 2).

Table 2. Binning sort threshold table.

Level	Percentile Threshold	Probit	$\widehat{WRSR}$	Number
★	<3.593	<3.2	<0.2921	67
★★	3.593~	3.2~	0.2921~	462
★★★	27.425~	4.4~	0.344~	875
★★★★	72.575~	5.6~	0.3959~	465
★★★★★	96.407~	6.8~	0.4479~	70

3.1.1. Comprehensive Level Evaluation

According to the comprehensive level evaluation results, the development level of settlements in the study area ranged from 0.204 to 0.623, with considerable disparities in the overall development level, demonstrating hierarchical differentiation and unevenness. In particular, the number of settlements with a high development level of 4–5 stars is much higher in the northern and northwestern regions of Xian'an than in the southern and eastern regions. Because the northwestern portion of Xian'an is flat, the northern portion is hilly, and the southern and eastern portions are mountainous, 1–2 star settlements are primarily concentrated in the south and east. Moreover, the south and east parts are further away from the urban area and driven by the radiation of the urban area, which is smaller. There is a distance decay effect of the development level of settlements based on their spatial characteristics, and settlements with high development levels are closer to the urban development boundaries and important transportation routes (Figure 3). Due to the government's tendency to establish public service facilities in the village committee building, the development level of the settlement where the village committee is situated is much greater than the development level of other settlements.

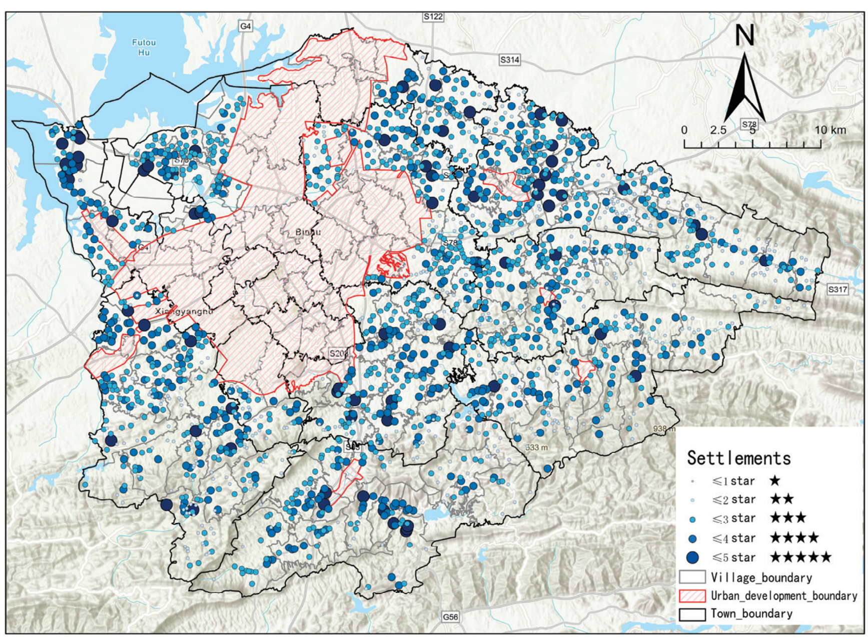

Figure 3. Levels of settlement development and potential. Note: The higher the score level, the larger the area of the corresponding points and the darker the color.

3.1.2. Multi-Dimensional Assessment

We calculated the standardized scores of WRSR values of different dimensions for each settlement using the index system's design, and then performed frequency distribution statistics and normal distribution curve fitting (Figure 4), before considering the administrative village as a statistical unit (Figure 5).

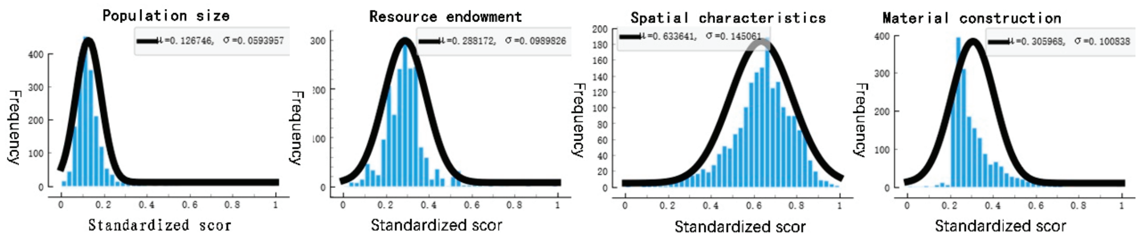

Figure 4. Frequency statistics of settlements score.

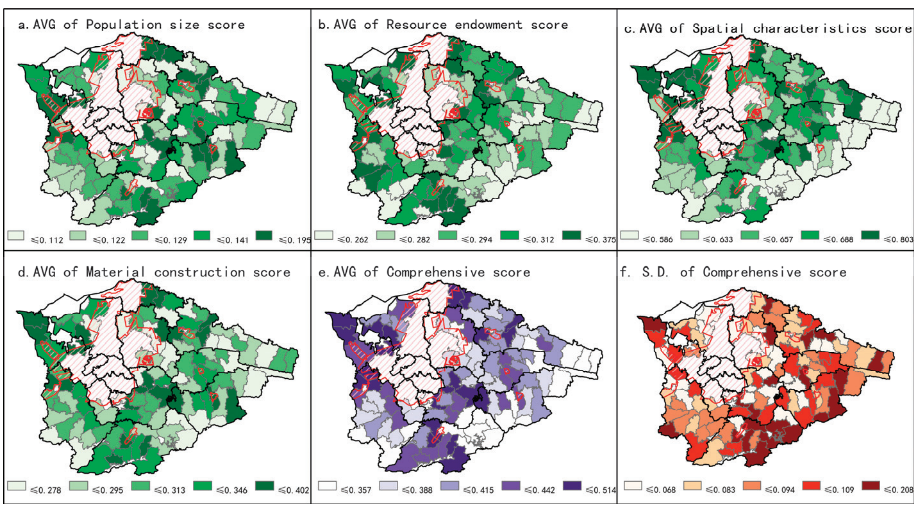

Figure 5. Settlements score statistics by villages. Note: AVG: The average scores of the settlements were calculated based on the administrative village boundaries. S.D.: The standard deviation of the score of the settlements are calculated with the administrative village boundary as the group.

(1) Population size dimension: The greater the population, the greater the community's vitality, with human resources being the primary guarantee for the existence and development of villages. Except for a few super-population size settlements, the population size of the village is largely equal in terms of development. In terms of space, communities with a high average population in the settlement are frequently clustered around the town.

(2) Resource endowment dimension: Resources are the foundation of a community's development. Many settlements have a high degree of resource endowment, and most settlements have a substantial difference in resource endowment, according to the distribution frequency of resource endowment scores. Spatially, resource-rich villages tend to be in the flat areas of Xian'an's west and north, and valleys in the south. Villages in Xian'an's west and north are richer in land and water resources. Furthermore, the plains have a long farming history, and particular settlements have richer material and cultural treasures. Individual communities in the south, on the other hand, are richer in biological resources while keeping better traditional cultural practices due to their relative isolation.

(3) Spatial characteristics dimension: The settlement's location and the site environment have a considerable impact on its potential for future residential land expansion. Apart from a few settlements with lower scores, the negative skewness and slope close to the normal kurtosis indicate that most settlements score at a more normal level in this dimension. The settlements with low scores in this dimension are located in the mountainous areas of Xian'an's east and south. Although the land usage is more intensive and the distance to the nearest communities is shorter, these villages have undulating terrain and are difficult to access.

(4) Material construction dimension: The amount of physical construction of communities is heavily influenced by the village's financial status and government assistance. In terms of the standard score for the physical construction of settlements, there is a significant difference between the number of settlements with a score of less than 0.2 and those with a score of 0.2 or above. The 32 settlements with a score of less than 0.2 were abandoned obviously during the village development activities, and the majority of them are located on the hillsides in the southern and southwestern parts of Xian'an. Villages with higher levels of construction are more likely to be regarded seriously by the government because they are located near towns or have more concentrated inhabitants.

In general, villages near towns have location advantages, while the population of the settlements is larger and the material construction level is higher; mountainous villages far from towns have obvious location disadvantages, and the population development level is lower; except for a few villages with resource advantages and a more concentrated population, most of the construction level is low; in terms of resources, the plains and mountains have an advantage. Some plain and mountainous places benefit from resource advantages, and some plain villages rely on land resources and material cultural relics to build tourism, with a high level of overall development. In contrast, some highland communities rely on ecological landscape resources and traditional cultural traditions to generate tourism, and the villages' overall development level is greater. In other words, some villages are able to leverage their strengths as a "long board", resulting in a comparatively high overall score. Settlements in Xianan's center region have a higher level of development than those in the suburbs. In terms of development, the periphery villages have greater internal differences than the core settlements.

3.2. Settlement Clustering and Spatial Association

The global Moran's I was calculated using the ArcGIS pro2.5 software. The global Moran's I score is 0.28, the z-score is 25.05, and the p-value is 0.00, showing that the settlement development level in Xian'an demonstrated a significant, positive, low degree of spatial association. It means that the settlement with the greater development level has a higher average development than the settlements around it, and vice-versa. Because of the occurrence of regional disparities in settlement development levels, this article employed local Moran's I for additional analysis. Using 5000 m as a search radius, the area of this search region is almost the same as that of a town, and we produced Figure 6 by comparing the development level of this settlement to the average development level of all settlements in the search area. Except for certain non-significant (NS) settlements in the middle gray area, the High–High clusters (HH) in the first quadrant indicate that the development level of the settlements surrounding this type of community is similarly high. The Low–High outliers (LH) in the second quadrant indicate that the settlement is underdeveloped, while its neighbors are much more developed. Low–Low clusters (LL) in the third quadrant and High–Low outliers (HL) in the fourth quadrant have the inverse meaning of HH and LH. Figure 7 is the result of mapping the co-types of these settlements.

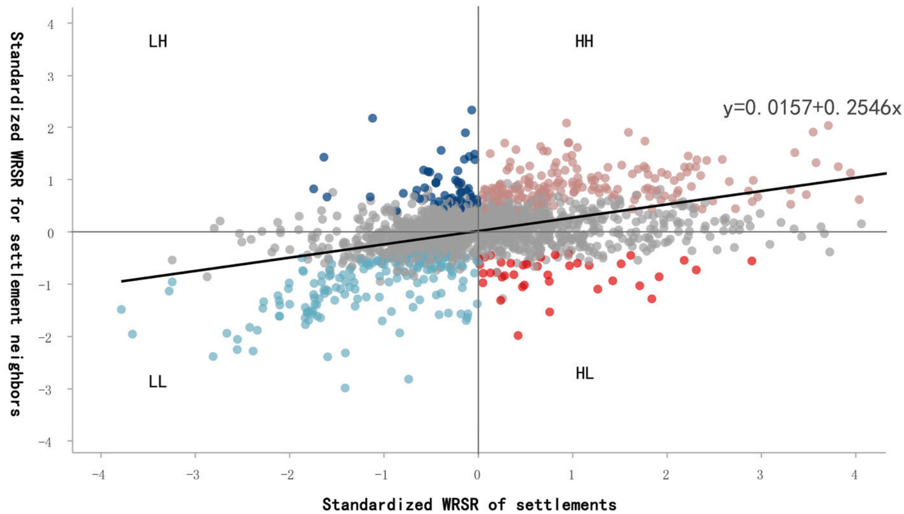

Figure 6. Scatter plot of LISA. Note: The coefficient of regression line represents the global spatial association index, it means that the scores of residential areas show a positive spatial association globally. The dots represent LISA's score; its significance is determined by its neighbors and it corresponds to Figure 7.

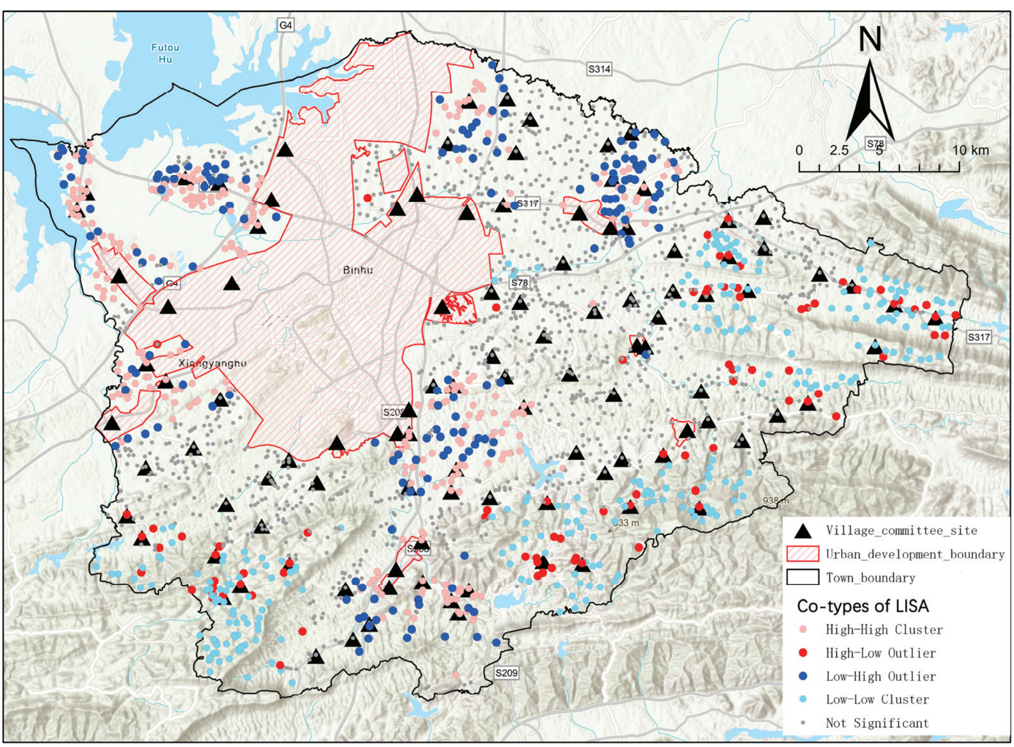

Figure 7. Spatial clustering and outliers of LISA (r = 5000 m).

According to the location of the settlements' co-types, the "HH" co-type is mainly located in the northern, northwestern, and central regions of Xian'an where it is flatter, as well as in canyon areas with better traffic in the south. The distribution pattern of the "LH" co-type is comparable, and they form a mosaic pattern in geographic space. The "HH" co-type is more crowded than the "LH" co-type and is located closer to towns and main transportation routes. The "LL" co-type and "HL" co-type have similar spatial association patterns, with the exception that the "HL" co-type and "LL" co-type are found in mountainous areas to the east and south of Xian'an. Meanwhile, the "HL" co-type is more concentrated, while the "LL" co-type is more dispersed, and the "LL" co-type is found on the outskirts of the "HL" co-type group.

3.3. Settlement Typology and Building Policy

We can propose different development strategies for settlements with different development levels using the association analysis of settlement development levels and co-types (Figure 8). In terms of building policies, this paper makes the following recommendations for various association patterns:

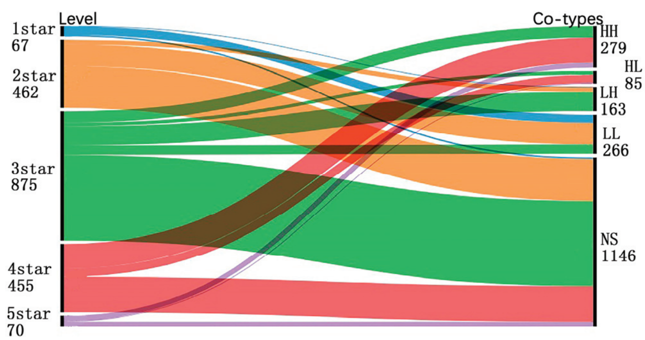

Figure 8. Association of evaluation levels with co-types.

For 4–5 star settlements, there are three spatial patterns, including "HH" (203), "HL" (61), and "NS" (271). The government should encourage "HH"-type settlements to actively absorb people of "LH"-type settlements (32) in neighboring 1–2 star settlements, and the government should encourage "HL"-type settlements to actively absorb residents of "LL"-type settlements (202) in nearby 1–2 star settlements. The "NS" kind of settlement follows a stable development plan, progressing while retaining the existing level of development.

For 3-star settlements, it exists in five spatial modes, including HH (76), HL (24), LL (64), LH (131), and NS (580). Based on the evaluation results of multidimensional indicators, the government should provide targeted aid to "HH" and "HL" settlements. For example, several villages in the southern mountainous areas with limited transportation facilities should make efforts to improve their transportation conditions and overall development level. The government should design some stimulation initiatives for the "LH" and "LL" settlements. For example, if the residents improve the shortcomings in the multidimensional indicators in a short period, their village construction and building expansion should be supported to improve the living environment and overall development of the village by stimulating the residents' endogenous motivation. As for the NS type of settlements, further observation should be made.

For 1–2 star settlements, it has three spatial patterns, including LL (202), LH (32), and NS (295). A severe restriction policy should be applied to the development of settlements at this level, and residents of LL- and LH-type settlements are advised to relocate to the 4–5 star HL- (61) and HH-type (203) settlements, respectively. Regarding villagers in NS-type settlements, the government might gradually and methodically direct them to the county and provide financial assistance to rural inhabitants who wish to acquire homes in the county.

4. Discussion

Rural–urban migration is a prevalent phenomenon in most emerging countries on the path to modernity. In China's urbanization process, the problems of hollowing out, aging, and fewer children in rural areas are more significant than in other developing countries [13,55], and the complete abandonment of some small settlements is also more typical in rural areas. According to Hudson, there are three stages of rural settlements, colonization, spread, and competition [56], and it is clear that many settlements in China are now at the third stage of development. Government financing for rural revitalization is limited, and low-development rural settlements are not competitive enough to avoid the risks of annexation. Therefore, the work conducted in this article is very meaningful, and we will discuss its progress and shortcomings next.

In assessing the livability of settlements, we referenced commonly used indicators from previous studies. For instance, in mountainous regions, geological hazards are a primary cause of residential abandonment [16], which is why topography was included in our indicator system. In addition to this, factors such as transportation [33], location, land quality, water resources, ecological environment [34], and public service facilities [31] were also taken into consideration. Several indicators that may have been overlooked by earlier authors are also provided. For example, whereas past assessments of rural settlements frequently focused solely on the current condition, this study takes into account more factors, including historical accumulation and the future development of settlements. Meanwhile, in the relationship between the government and the villagers, each other's concerns were accounted for. From the government's perspective, their previous evaluations concerning the villages have been respected and utilized; from the villagers' perspective, the interests of the villagers and their emotional attachment to the community have likewise been respected.

The developmental trajectory of rural settlements is likely to adhere to Zipf's Law, akin to urban scale distribution. Consequently, in this paper, the application of the weighted rank-sum ratio (WRSR) method during the evaluation process facilitates a closer approximation to a normal distribution in the scoring, which is advantageous for investigating the spatial patterns of settlement locations. In previous studies on the spatial patterns of rural settlements, it has often been difficult to incorporate scoring metrics into the analysis [20–25,57]. A likely reason for this challenge is the substantial developmental disparities among the settlements, which complicate the accurate identification of their spatial patterns. Of course, there are still ways to improve the indicator system in this study. On the population dimension, for example, we did not gather data on settlement population growth rates, which is unfair to those settlements that are still expanding in number despite their tiny population size. We only considered the distance between settlements and their nearest neighbors and ignored the map shape and community structure of settlements, both of which have a significant impact on villagers' social interactions, and we consider including indicators such as landscape pattern index and social network analysis [28] in future studies.

The assessment results indicate a significant disparity in the development levels of settlements, which exhibit a positively association in global spatial pattern. The settlements located near urban centers, towns, and major transportation routes demonstrate better development, consistent with previous research findings [21–25]. In contrast, we found that a small number of rural settlements located in mountainous areas, distant from urban centers, also achieved relatively high development scores. This can be attributed to two main factors: first, these areas possess rich cultural heritage and natural landscape resources that are conducive to tourism development; second, the limited availability of suitable land for construction in mountainous regions leads to a more concentrated development of buildings, thereby enhancing the overall development of these settlements. In addition, we identified local spatial patterns of settlements and integrated these spatial patterns with the levels of development of the settlements to propose our layout optimization method. Previous layout optimization approaches primarily relied on evaluation results as their basis [21,22,25,26] or considered the impact of cultivation radius on this foundation [24]. In contrast to these earlier methods, our proposed approach places greater emphasis on the future development of communities. The flexible demolition strategy we advocate can significantly reduce resistance to governmental efforts.

Under this paper's scenario, which is scheduled to be finished by 2035, at least 529 settlements (27% of the total) should be willingly abandoned, and we recommend that the government implement strategies and processes to assure sustainability. Our method meets the government's current expectations, reduces opposition to demolition, and encourages urbanization while minimizing disruptions in rural acquaintanceship. Our incentive program, based on villagers' attachment to their communities, aims to promote rural development and save government expenses. Some may regard the government's attempt to encourage villages to the urban area and move them close as a benefit of a strong government, while others may see it as antithetical to the spirit of liberalization. In particular, the plan benefits the local government and the preserved settlements, but the plan will have a vast impact on the few villagers who will need to be relocated [58], an impact that is not necessarily desired by the villagers. We would like to emphasize that our assessment and recommendations are purely for reference purposes, and in the process of dismantling and relocating, the government needs to consider and respect the views of the farmers.

5. Conclusions

Certain rural villages must be demolished to meet the goal of boosting land supply to cities and promoting rural revitalization. The weighted rank-sum ratio evaluation method was used in this paper to assess the settlement development level from multiple dimensions, with Xian'an District, Hubei Province, China, as an example. Moran's I coefficient was then used to analyze the spatial association characteristics of the settlement development level. The following are the main findings:

1. The livability levels of residential areas exhibit significant spatial heterogeneity. Residential areas located near cities, towns, and major roads generally demonstrate better development compared to those situated farther away. The overall spatial pattern follows a core–periphery model. Additionally, residential areas in flat regions tend to develop more favorably than those in mountainous areas, revealing marked regional disparities in spatial development.

2. In the spatial distribution of the study area, population size, resource endowment, spatial characteristics, and physical construction are related and separate, highlighting the importance of using a comprehensive approach to understanding settlement development. Settlements of flat topography and close to towns offer benefits in terms of population numbers and geographical features. The government frequently prioritizes material construction for settlements with population size advantages, while some villages in southern Xian'an depend on resource endowment advantages and concentrate their people in core settlements, with an increase in comprehensive development levels. In conclusion, villages with a flat terrain, proximity to towns, the location of village committees, and specific development expertise are likely to have greater levels of comprehensive development.

3. Through spatial association analysis, we found that there is a mosaic structure in the geography of "HH" and "LH", and "LL" and "HL" co-types of settlements. Settlements of the co-types "HH" and "LH" tend to congregate in the western, northern, and central plains, as well as the southern valleys, but settlements of spatial co-type "LL" in the eastern and southern mountains prefer to cluster with co-type "HL". Settlements of the "HL" spatial co-type tend to congregate in the eastern and southern mountainous areas. Finally, we made policy suggestions for the evacuation of co-type "LL" settlements based on the connection between spatial co-types and development levels.

Overall, the spatial disparity in the level of habitability of rural residential areas is a ubiquitous phenomenon. When formulating policies for the development of rural residential sites, governments can utilize the mosaic structure of high-level and low-level habitable sites to determine the future development typology of these residential areas.

The evaluation method proposed in this study provides a scientific and comprehensive framework for understanding and assessing settlement development in Xian'an, as well as a feasible and innovative building policy recommendation based on settlement development level and spatial association features. The findings of this study can be useful to local policymakers and planners in promoting rural revival and new urbanization under the land-restructuring policy of "increasing versus decreasing balance". In future work, efforts can be made to further refine plans, maps, and other spatial arrangements, while also promoting the application of this methodology in urban typology.

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Factors Driving Social Capital Participation in Urban Green Development: A Case Study on Green Renovation of Old Residential Communities Under Urban Renewal in China

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Abstract: Urban green development is crucial for citizen well-being and serves as a key pillar of sustainable development strategies. Collaborative governance mechanisms help address management, technical, and financial challenges in urban green development. The renovation of old residential communities within the context of urban renewal is becoming a focal point in the development of Chinese cities. To promote green development in the renovation of old residential communities in China, this study introduces the collaborative governance mechanism of government–social capital cooperation and identifies the factors influencing social capital participation in green development. A hybrid approach is proposed, combining grounded theory, IGAHP subjective weighting, CRITIC objective weighting, game theory, and ISM. This approach is applied to identify, evaluate, and analyze the factors driving social capital participation in the green renovation of old residential communities. The results indicate that government incentives and constraints, policy support, the costs and benefits of implementing green renovation, the development of green renovation technologies, and construction technical abilities significantly influence the decision-making of social capital. The findings provide theoretical support for decision-making by governments and social capital in participating in the green renovation of old residential communities and offer a methodological reference for analyzing social capital participation in other urban green development projects and for further policy formulation. Future research should focus on examining social capital involvement in other types of urban green development projects.

Keywords: social capital; green development; renovation of old residential communities; driving factor; collaborative governance

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1. Introduction

Amid profound adjustments in the global economic structure, new economic models such as green economy, circular economy, and low-carbon economy have gradually emerged. These models emphasize the simultaneous pursuit of economic growth, environmental protection, and resource conservation, aiming for coordinated development across economic, social, and environmental domains. The construction of green cities, which serve as crucial backdrops and vessels for daily life, has garnered global attention due to its impact on citizen well-being [1,2]. Consequently, evaluating urban ecosystems has become a focal point of research, with studies such as urban carbon stock assessments gaining prominence [3]. In recent years, governments around the world have introduced a series of policies, measures, and regulations to support green development, providing robust guarantees for the advancement of urban green initiatives [4,5]. These policies not only define the objectives and tasks of green development but also incentivize social capital investment in green industries and environmental projects through financial subsidies, tax incentives, and green finance mechanisms [6]. At the same time, enhanced environmental regulation and enforcement ensure the effective implementation of green development policies. However, due to variations in urbanization processes across different countries, certain urban development models have not received sufficient attention, yet they significantly impact urban ecosystems.

Why focus on the renovation of old residential communities (RORC) within the context of urban green development? Urban development is a continuous process of renewal and transformation. In the case of China, with the urbanization rate approaching 65%, the country has entered the mid-to-late stages of urbanization, where the quality of urban development has become a focal point [7]. Migration-induced urban shrinkage has led to a series of issues, including housing vacancies and a downturn in the real estate market. At this juncture, the Chinese government has proposed an "urban renewal" strategy as part of its broader urban development agenda [8]. While new construction projects are gradually decreasing, the renovation of existing projects has become the primary focus of construction activities. Moreover, the core component of China's current urban renewal strategy is RORC [9]. This renovation is emerging as a central task within China's construction sector and a key public welfare initiative that cities are actively pursuing [10]. During rapid urbanization over the past three decades, urban residential areas in China were often planned, constructed, and managed in a relatively unrefined manner, leaving behind numerous deficiencies. As the focus of construction shifts from expanding new developments to upgrading existing ones, critical questions arise: How can the renovation of old residential communities be made greener? How can the goals of urban green development be better achieved? Addressing these questions is essential in the current context.

Collaborative governance is key to advancing urban green development. Collaborative governance, which involves the participation of government, social capital, researchers, and citizens, is recognized as a crucial approach to promoting urban green development [11]. In the current context of renovating old residential communities in China, government fiscal funds have dominated the financial support for these projects [12]. However, social capital's participation has been limited due to the lack of clear investment return pathways. As RORC progresses, the sustainability of government financial support is increasingly in question, necessitating the exploration of new market-driven approaches. Social capital brings substantial financial resources, market expertise, and technological advantages to the table. Therefore, to ensure the green development of these renovation projects, it is essential to understand the complex mechanisms that influence social capital's participation in green renovation initiatives. This study aims to investigate these mechanisms.

In addition to the motivations outlined above, another primary objective of this study is to identify the most appropriate method for analyzing the problem. This research aims to assist both government bodies and social capital in making actionable decisions regarding RORC within the context of promoting urban green development. We posit that different scenarios may have varying impacts on social capital's participation in green renovations. Our preliminary research findings have provided initial evidence supporting this hypothesis [13]. Therefore, we have designed a hybrid approach that aids in exploring the complex mechanisms driving social capital's involvement in the green renovation of old residential communities. To the best of our knowledge, no existing literature has employed the hybrid approach proposed in this study, particularly within the field of urban green development research. The main contributions and innovations of this paper are as follows. Firstly, by focusing on green RORC within the context of urban renewal, this study introduces a new perspective that enriches the current research on urban green development. Secondly, considering that RORC is still a relatively new phenomenon in China, with its characteristics not yet fully explored, we have developed a comprehensive hybrid research framework. This framework integrates the principles of grounded theory, subjective and objective weighting methods based on IGAHP and CRITIC, game-theoretic weighted ranking, and ISM-based factor analysis. Finally, the study delves into the factors influencing social capital's participation in green renovation projects, offering theoretical support for government policymaking in urban green development and providing a reference for collaborative governance policies aimed at fostering urban sustainability.

The rest of this paper is organized as follows: Section 2 proceeds by presenting a literature review that discusses the current understanding of social capital participation in urban green development, particularly focusing on the green renovation of old residential communities within the context of urban renewal. In Section 3, the research methodology employed in this study is then outlined, detailing the hybrid approach that integrates grounded theory, subjective and objective weighting methods based on IGAHP and CRITIC, and game theory. This is followed by a comprehensive analysis of the influencing factors and their relationships, using interpretive structural modeling (ISM). In Section 4, the paper concludes with a discussion of the findings, highlighting the key drivers and barriers to social capital participation in green renovations, as well as recommendations for policymakers and practitioners. Finally, the conclusions, limitations, and potential further research are given in Section 5.

2. Literature Review

This study explores the connection between social capital participation and RORC in China within the broader context of urban green development, particularly from the perspectives of urban sustainability, community renewal, and encouraging social capital investment. This relationship was relatively overlooked in the existing literature.

Promoting green processes in urban development is a pressing issue that requires urgent attention. Existing studies have explored the spatial aspects of urban green development. Wang et al. [14] examined the spatiotemporal changes in urban environments across different stages of socioeconomic development, contributing to the theory of urban growth and the environment. Haaland et al. [15] conducted a review of green development in compact cities, suggesting measures such as improving green space quality to address the limitations of space for green development. Arshad et al. [16] argued that rapid and unplanned urban expansion has led to urban heat island effects, necessitating effective policies to improve living environments. Some researchers have also examined urban green development from the perspectives of government regulation and support. Vujičić et al. [17] studied the regulatory mechanisms of urban green development infrastructure, identifying obstacles and drivers that impact its development. The study emphasized that collaboration among stakeholders is essential for maximizing the benefits of green infrastructure. Yu et al. [18], using resource-based cities in China as a case study, evaluated the factors influencing green innovation, noting that government support plays a crucial role in fostering urban green development. Some researchers have also investigated the integration of green development with economic growth. Woon et al. [19] focused on urban green energy development, summarizing the challenges and recommendations across environmental, economic, and social dimensions—an important aspect of green city construction. Jiang et al. [20] explored the impact of the digital economy on urban green development, finding a positive relationship between the two. Ma et al. [21] studied the green transformation of urban clusters, addressing efficiency measurements, influencing factors, and implementation mechanisms to build a systematic theoretical framework for urban green transition. In addition, the rapid infrastructure development in some Asian regions has drawn attention to the urban heat island effect and its related environmental and social challenges, leading to a surge of interest in this area of research [22]. It is evident that the green and low-carbon transformation of cities has become a global consensus. However, in existing research on urban green development, the focus was predominantly on the green development of expanding cities, or incremental development, with relatively little attention given to the green development of existing urban infrastructure, or stock development.

As a crucial component of China's urban renewal strategy, the government is actively promoting the renovation of old residential communities. To improve the environment and living conditions in these communities, it is essential to make scientifically informed decisions regarding their renovation [23]. The relationship between the renovation of old residential communities and urban green development has gradually garnered attention. These communities, being a significant part of urban renewal, have a substantial impact on reducing carbon emissions in the urban building sector. For instance, Luo et al. [24] conducted a life-cycle assessment of the carbon emission impacts of renovating old residential communities, uncovering the carbon reduction potential of such projects. Similarly, Kertsmik et al. [25] discussed the effects of various renovation strategies on carbon emissions in heritage residential buildings, while Zhang et al. [26] advocated for maximizing climate and resource utilization to enhance resident comfort and drive decarbonization in these projects. Renovating old residential communities requires significant investments, making financing a critical area of related research. Galvin [27], using Germany as a case study, analyzed the costs associated with such renovations, finding that they require substantial financial input, with traditional returns unable to offset these costs. Liu et al. [28] argued that if the government can design systems to reduce coordination costs, the renovation of old residential communities can be sustainable. In recent years, researchers have begun to explore innovative financing models for these projects. For example, Han et al. [29] proposed the innovative "EPC + O + F" model to address financial bottlenecks in renovation projects. Additionally, some researchers have started considering the introduction of Public–Private Partnership (PPP) models into China's old residential community renovations, analyzing the factors that drive social capital participation [30]. Market-oriented financing models are likely to become key solutions to the funding challenges faced by these renovation projects [31]. While there is growing attention on green RORC and its financing, research on the involvement of social capital in these green renovations remains scarce.

The participation of social capital in construction projects is increasingly influenced and constrained by various internal and external factors. Social capital, in the context of PPP, refers to the entity providing advanced technology, management, and funding for construction projects [32]. From the perspective of the definition and characteristics of social capital, Liu et al. [33] discussed a range of factors affecting the escalation of social capital commitment. Government policies that support the involvement of social capital in PPP projects are also rooted in the fundamental nature of the collaboration between government and social capital [34]. For example, Filippini et al. [35] analyzed the determinants of investment decisions in energy-efficient renovations in Switzerland, emphasizing the supportive role of government policies. Kavishe et al. [36], focusing on the housing sector in Tanzania, identified professional skills, project management, and institutional frameworks as key factors influencing the implementation of PPP projects. The factors influencing social capital participation were continuously explored by researchers. Qin et al. [37], using coastal infrastructure projects as a case study, examined how the financial characteristics of social capital entities impact project outcomes, finding that factors like debt repayment capacity and equity structure can negatively affect participation. Solheim-Kile et al. [38] found that trust, reciprocity, and other relational factors significantly influence social capital participation and the quality of project collaboration. Hou et al. [39] proposed a novel dynamic subsidy mechanism that effectively enhances government incentives and the operational quality of social capital. Additionally, some researchers have highlighted risk factors as critical to social capital investment decisions. A well-balanced risk-sharing arrangement can increase the willingness of social capital to invest [40]. Wang et al. [41] demonstrated that social capital's focus on long-term versus short-term benefits is a key determinant of positive or negative decision-making behaviors, with "reasonable risk-sharing" and "partnerships" being effective means to promote positive decision choices. It is evident that the factors influencing social capital participation in PPP models are complex and diverse. Current research has produced a wealth of findings that provide valuable references and insights for the successful advancement of this study. In the process of urban renewal for aging residential communities, collaboration among multiple stakeholders—including governments, social capital, community residents, and professional organizations—is particularly critical. Existing studies have highlighted various aspects of stakeholder involvement. For instance, Teng et al. [42] evaluated and simulated key conflict-inducing factors based on stakeholder analysis, demonstrating that increasing income for both governments and residents significantly reduces the likelihood of conflict. Sun et al. [30] refined the application of the Public–Private Partnership (PPP) model in urban renewal projects by adopting the perspective of social capital. Meanwhile, Huo et al. [43] analyzed the distribution of benefits among stakeholders in urban renewal, providing a foundation for the sustainable advancement of such projects. However, research specifically addressing the factors influencing green renovation in aging residential communities remains limited. This study, while exploring social capital participation in the green renewal of older residential areas, aims to delve deeper into the progress of multi-stakeholder collaboration and its impact on social capital involvement. Nonetheless, challenges and obstacles exist in the collaboration process, such as unequal benefit distribution, communication barriers, and information asymmetry. These issues warrant further attention and resolution in future research.

In summary, the review of the existing literature provides important references for establishing a preliminary framework of the factors influencing social capital participation in urban green development projects, laying a solid theoretical foundation for future research. Additionally, it is worth noting that RORC is still a relatively new phenomenon in China, and the relevant literature may be incomplete, with respondents' understandings of the renovation process potentially showing some degree of bias.

3. Methodology

3.1. Research Philosophy

This study primarily examines the driving factors influencing social capital participation in the green renovation of old residential communities. In the foreseeable future, social capital is expected to play a central role in such renovation projects, making its willingness to engage in green construction a critical determinant of the overall success of these initiatives. Understanding the characteristics of social capital and how these characteristics shape their motivation to participate in renovation projects can provide valuable insights for the government in formulating strategies to promote the green development of old residential community renovation efforts.

However, the current literature on social capital participation in the green renovation of old residential communities remains limited and does not directly address the issues explored in this study. Additionally, relying solely on interviews with a subset of stakeholders risks introducing subjective biases. To address these gaps, this study adopts a scientific approach to investigate the research problem, ensuring a more rigorous and objective analysis beyond the subjective experiences of a limited group of participants.

3.2. Research Approach

To analyze the driving factors behind social capital participation in the green renovation of old residential communities, this study recognizes the limitations of existing literature in terms of relevance and sufficiency, as well as the inherent subjectivity of expert interviews. Therefore, a mixed-method approach combining qualitative and quantitative methodologies was adopted. Mixed-method research, as a branch of multi-method studies, integrates quantitative and qualitative data collection techniques with systematic empirical analysis procedures, making it particularly valuable for addressing complex practical issues.

Considering the nature of the research questions, the study's contextual background, and the anticipated research outcomes, this study ultimately selects a mixed-method approach, incorporating both qualitative and quantitative analyses, to provide a comprehensive understanding of the driving factors influencing social capital participation.

3.3. Research Strategy

Based on the objectives of this study, the following research strategy was adopted: First, drawing on the principles of grounded theory, we utilized a combination of literature review and interviews to gather information relevant to the research objectives, serving as the primary data sources. Subsequently, given the widespread application of subjective and objective weighting methods in existing research for factor identification and indicator system development [44,45], this study employed a mixed-method approach integrating these methodologies. Specifically, in the process of constructing the indicator system, the Improved Group Analytic Hierarchy Process (IGAHP) method was used for subjective weighting, while the Criteria Importance Through Intercriteria Correlation (CRITIC) method was employed for objective weighting. The combination of these methods, based on game theory, was used to select key indicators. Finally, the interpretive structural modeling (ISM) approach was chosen to represent the causal and hierarchical relationships among these key indicators.

We believe that through systematic data collection and analysis, the key role and influencing factors of social capital in the green renovation of old residential communities can be revealed. We collected data through literature reviews, interviews, and surveys. During the research process, a stratified random sampling method was employed to ensure the representativeness and diversity of the samples. The selected old residential communities were required to be representative and should have undergone renovation between 2021 and 2024.

3.4. Time Horizon

Given that old residential community renovation projects have only recently emerged in China, the government is still in the process of refining its conceptual framework, particularly for green renovation projects, which are far from widespread. Therefore, this study focuses on the planning and policy definitions for old residential community renovations in China during the five-year period from 2020 to 2024. This includes the policy orientation for social capital participation in such projects and the national-level policy guidance on urban green development under the "dual carbon" goals.

The case samples selected for analysis are old residential communities built before the year 2000. The interview participants consist of experts, technical professionals, and management personnel who were involved in theoretical research and practical work on old residential community renovation projects and urban green development between 2020 and 2024.

3.5. Data Collection and Data Analysis

This study aims to explore the factors influencing social capital participation in green RORC and to analyze the relationships among these factors. The evaluation of these influencing factors is conducted in three steps, as illustrated in Figure 1.

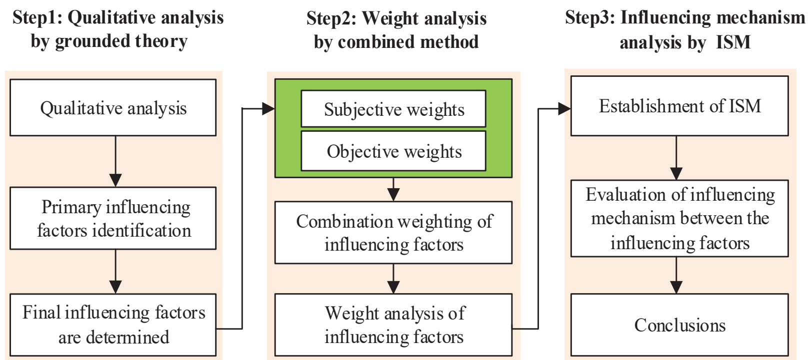

Figure 1. Research framework of hybrid approach.

3.5.1. Determination of Influencing Factors

The first step in the research framework proposed in this study is to identify the influencing factors. In this process, the study draws on the principles of grounded theory and employs literature reviews and expert interviews to identify the influencing factors. The process of identifying the preliminary influencing factors is illustrated in Figure 2.

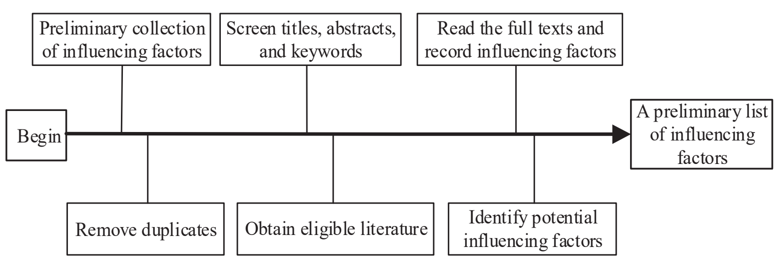

Figure 2. Identification of preliminary influencing factors.

3.5.2. Determination of Subjective Weights

The index weight vectors provided by the a-th and b-th experts for social capital participation in green RORC are denoted as $Y_a = (y_{a1}, y_{a2}, \ldots, y_{an})^T$ and $Y_b = (y_{b1}, y_{b2}, \ldots, y_{bn})^T$, respectively. Assuming that the degree of similarity between the decisions of the two experts is expressed by the Euclidean distance $d_{ab}(a, b = 1, 2, \ldots, T)$, the following formula is derived:

$$d_{ab} = d(Y_a, Y_b) = \sqrt{\sum_{i=1}^{n} (y_{ai} - y_{bi})^2} \tag{1}$$

where if $d_{aa} = 0$, $d_{ab} = d_{ba} \geq 0$, and the smaller the value of d_{ab}, the closer Y_a and Y_b are, indicating that the judgments of the two experts are more aligned. If and only if $d_{ab} = 0$, it shows that the judgments of the two experts are completely consistent.

Let the degree of similarity between the judgment of the i-th expert and the judgments of all other experts be expressed as d_i.

$$d_i = \sum_{j=1}^{m} d_{ij} \tag{2}$$

when if $d_i \geq 0$, a smaller d_i indicates that Y_i is closer to other weight vectors. When $d_i = 0$, and $d_{i1} = d_{i2} = \cdots = d_{im} = 0$, all feature vectors are equal, and the opinions of each expert are unified. At this point, the decision-making weight coefficient of the i-th expert is as follows:

$$\lambda_i = \begin{cases} 1/m, d_i = 0 \\ \frac{1/d_i}{\sum\limits_{j=1}^{m} (1/d_j)}, d_i \neq 0 \end{cases} \tag{3}$$

The final comprehensive weight of an index of social capital participating in green RORC is denoted as Y^*. Then, the following can be expressed:

$$Y^* = \sum_{i=1}^{m} \lambda_i \times Y_i = (y_1^*, y_2^*, \ldots, y_n^*) \tag{4}$$

3.5.3. Determination of Objective Weights

Assuming that the existing dataset includes m objects to be evaluated and n evaluation indicators, the original data matrix X is structured as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \mathrm{L} & x_{1n} \\ x_{21} & x_{22} & \mathrm{L} & x_{2n} \\ \mathrm{M} & \mathrm{M} & 0 & \mathrm{M} \\ x_{m1} & x_{m2} & \mathrm{L} & x_{mn} \end{bmatrix} \tag{5}$$

where x_{mn} represents the value of the n-th evaluation indicator for the m-th object.

Then, the data are standardized to eliminate the influence of dimensionality, allowing for analysis according to a uniform standard. For positive indicators, the data can be processed using Equation (6). For negative indicators, the data can be processed using Equation (7).

$$x'_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \tag{6}$$

$$x'_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \tag{7}$$

Then, the information carrying capacity should be calculated, which is represented by the standard deviation to indicate the contrast strength. The equation is as follows:

$$S_j = \sqrt{\frac{\sum_{i=1}^{m} (x_{ij} - \overline{x}_j)^2}{n-1}} \tag{8}$$

where $\overline{x}_j$ is the mean value of each index (column) data.

The equation for calculating conflict is as follows:

$$A_j = \sum_{i=1}^{n} (1 - r_{ij}) \tag{9}$$

where r_{ij} denotes the correlation coefficient between the i-th and j-th indicators.

The equation of information quantity is as follows:

$$C_j = S_j \times A_j \tag{10}$$

Finally, the equation for calculating the weight using the CRITIC method is as follows:

$$W_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{11}$$

3.5.4. Combinatorial Weighting Based on Game Theory

The previous steps have employed the IGAHP method and the CRITIC method to determine the subjective weights and objective weights, respectively. Let the basic weight vector be $v_p = \left\{ v_{p1}, v_{p2}, \ldots, v_{pn} \right\} (p = 1, 2, \ldots, n)$; n represents the number of indicators, p represents the number of methods for calculating weights, and p takes 2. Let the linear index weight combination be $\alpha = \left\{ \alpha_1, \alpha_2, \ldots, \alpha_p \right\}$, that is, any linear combination is as follows:

$$v = \sum_{p=1}^{n} \alpha_p \cdot v_p^T \tag{12}$$

where v represents the linear combination of weights, α_p is the weight coefficient, and ${v^T}_p$ is the transpose matrix of the basic weight vector set.

According to the aggregation theory of game theory, in order to minimize the sum of the deviation between v and v_p, the optimal combination weight coefficient should be sought. The equation is as follows:

$$\min \left\| \sum_{p=1}^{2} \alpha_p v_p^T - v_p \right\|_2, (p = 1, 2) \tag{13}$$

Equation (13) is transformed into a linear system of equations with the optimal first-order derivative conditions, resulting in the following:

$$\begin{bmatrix} v_1 v_1^T & v_1 v_2^T \\ v_2 v_1^T & v_2 v_2^T \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} = \begin{bmatrix} v_1 v_1^T \\ v_2 v_2^T \end{bmatrix} \tag{14}$$

Then, the optimized combination coefficients α_1 and α_2 are derived from Equation (14). These coefficients are subsequently normalized to yield the following:

$$\begin{cases} \alpha_1^* = \dfrac{\alpha_1}{\sum\limits_{p=1}^{2} \alpha_p} \\ \alpha_2^* = \dfrac{\alpha_2}{\sum\limits_{p=1}^{2} \alpha_p} \end{cases}, \tag{15}$$

The final combined weight is calculated as follows:

$$v^* = \alpha_1^* \cdot v_1^T + \alpha_2^* \cdot v_2^T, \tag{16}$$

3.5.5. Constructing the Interpretive Structural Model (ISM)

First, an ISM expert panel is established. Based on the defined problem and their years of accumulated experience, the expert panel engages in repeated discussions and research to identify the system elements and requirements. They then create a directed graph that illustrates the relationships between the system elements.

Next, the adjacency matrix and reachability matrix are determined. Based on the directed graph depicting the relationships between the system elements, the adjacency matrix A is established. The elements a_{ij} of matrix A are defined as follows:

$$a_{ij} = \begin{cases} 1 & S_i R S_j \quad R \text{ means that } S_i \text{ is related to } S_j \\ 0 & S_i \overline{R} S_j \overline{R} \text{ means that } S_i \text{ is not related to } S_j \end{cases} \tag{17}$$

where S is the set of directed graph nodes.

The unit matrix I is introduced into the adjacency matrix, and the reachability matrix M is obtained after multiple operations by Boolean algebra operation rules. The Boolean algebra operation process is as follows:

$$(A+I)^{K-1} \neq (A+I)^{K} = (A+I)^{K+1} = M, \tag{18}$$

Subsequently, hierarchical division is performed. The reachable set R is derived from the reachability matrix, the initial set Q, and the common set T, where $T = R \cap Q$. The reachable set represents all elements that can be accessed from node S_i; the antecedent set represents all elements that can reach node S_i. The intersection of the reachable set and the antecedent set represents the set of all elements that both reach and are reachable by node S_i. At this point, the elements within the set are identified as the top-level elements. By iteratively removing these top-level elements and reapplying the process, the subsequent levels are determined, ultimately resulting in the construction of a hierarchical directed graph.

Finally, interpretive structural modeling (ISM) is constructed.

3.6. Methodological Advantages and Limitations

This study primarily analyzes the factors influencing social capital participation in green RORC. Given that such renovations represent an emerging urban development model in China, with its specific connotations still being explored, there is a need to refine and improve traditional research methodologies. The advantages of the proposed hybrid approach in this study are as follows:

- Traditional Analytic Hierarchy Process (AHP) methods struggle to effectively capture expert opinions, particularly when there is significant disagreement among experts, leading to potential biases in evaluation results. The IGAHP method addresses these shortcomings by analyzing the variance in expert judgment weights and determining the decision-making weight coefficients among experts [46]. This approach mitigates the randomness of individual expert evaluations, reduces the uncertainty associated with subjective perceptions, and minimizes the impact of divergent opinions on the final evaluation. By balancing the commonality and individuality in expert decisions, IGAHP enhances the scientific rigor and rationality of subjective weightings. Ultimately, the aggregation of expert group decisions results in more reasonable indicator weights.
- The CRITIC method is a superior objective weighting technique compared to entropy weighting and standard deviation methods [47]. It calculates the objective weights of indicators by utilizing the standard deviation and correlation coefficients from statistical data, fully leveraging the data's objective properties to evaluate the research subject. Unlike methods that assume higher numerical values imply greater importance, CRITIC considers the correlation between indicators. For instance, a strong correlation between two indicators suggests a lower degree of conflict, while a weaker correlation indicates a higher degree of conflict. By accounting for both contrast intensity and inter-indicator correlation, CRITIC is particularly well suited

for calculating the objective weights of factors influencing social capital's involvement in green RORC.

- The study incorporates game theory principles and ISM to enhance the analytical process. The core idea of game theory in this context is to seek consistency in the weighting of evaluation indicators across different methods while minimizing the deviation between the composite weights of all evaluation indicators and the individual weights derived from each method [48]. ISM not only categorizes and stratifies the factors but also visually represents and explains the causal relationships between them, making the analysis more reliable and scientifically robust [49]. By integrating game theory and ISM, the study fully accounts for the practical experience and expertise of professionals, breaking down a complex system into multiple subsystems with various elements. This approach ultimately constructs a multi-level hierarchical model that clearly identifies the factors influencing social capital participation in the renovation of old residential communities.

Despite the careful design of the methodology in this study, several limitations still exist. For example, due to constraints on time, resources, and sample size, we may not have covered all relevant types of social capital and influencing factors. Furthermore, the subjectivity and uncertainty inherent in the data collection and analysis process may introduce some errors and biases in the research results. Therefore, future research should aim to expand the sample size and optimize data collection and analysis methods in order to enhance the accuracy and reliability of the findings.

4. Results and Discussion

4.1. Identifying Driving Factors for Social Capital Participation in Green RORC

The effectiveness of grounded theory in the selection of indicators was well documented in previous studies [50]. Green RORC in China represents an emerging type of construction project, with its specific characteristics and underlying principles still being refined. As such, the broader society has yet to fully recognize the unique aspects of these renovation projects, particularly those involving green initiatives. This study integrates the principles of grounded theory with a review of existing literature and expert interviews to identify relevant influencing factors.

Initially, relevant literature was reviewed through databases such as China National Knowledge Infrastructure (CNKI) and Web of Science (WOS) using keywords such as "old residential community renovation", "green renovation", "PPP", "social capital", "government regulation," and "influencing factors". A total of 448 relevant papers were identified. The process of extracting influencing factors from these papers was conducted in three steps. First, duplicate papers were removed, retaining only one representative study for analysis. Second, the outlines and abstracts of the remaining papers were reviewed to exclude those not aligned with the research objectives. Third, full-text readings were conducted, and the content that initially met the research criteria was recorded, organized, and summarized. This process resulted in the identification of 30 potential influencing factors, including competitiveness [51], government support [52], information disclosure [53], stakeholder needs [54], social responsibility [55], implementation costs [56], project benefits [57], technological levels [58], and financing capabilities [59]. Due to the lack of direct literature specifically addressing social capital participation in green RORC, this phase was primarily used to establish a preliminary list of potential influencing factors. This preliminary list of factors is presented in Table 1.

Table 1. Preliminary identified influencing factors.

No.	Influencing Factor	No.	Influencing Factor
1	Competitive ability promotion	16	Payback period
2	Government incentive and restraint mechanisms	17	Preferential tax policy
3	Information transparency	18	Completeness of policies and standards
4	Enterprise talent cultivation	19	The enterprise's own capabilities
5	Greenness of old residential community	20	The content of green renovation
6	Trust between partners	21	Improve the social visibility of enterprises
7	Uncertainty of the natural environment	22	Corporate social responsibility
8	Policy support	23	Research and development of green renovation technology
9	Patent rental fees	24	The cost of renovation
10	Government supervision	25	Benefits of renovation
11	Needs of participants	26	Project operation mode
12	Expected revenue	27	Project characteristics
13	Cost of publicity and education	28	The attitude of stakeholders
14	Environmental benefit	29	The stability of the economic environment
15	Social enterprise financing ability	30	Project characteristics

Subsequently, field research was conducted in old residential communities. Given that RORC in Liaoning Province was designated as a pilot project in China, the province's initiatives are considered representative. As the sample size reaches or exceeds 30, the properties of the normal distribution can be leveraged for inference of population parameters. Therefore, it is recommended to use at least 30 data points as the sample size. Thus, 30 old residential communities across 14 cities in Liaoning Province were selected for this study. Based on the findings from this field research, the initially identified influencing factors were refined. The revised list of influencing factors is presented in Table 2.

Table 2. Revised influencing factors.

NO.	Data Sources	Influencing Factors
1	The first field research survey	Competitive ability promotion, payback period, preferential tax policy, social capital responsibility consciousness, less profit space, expanding the market, research and development of green renovation technology, the competitive advantage is not obvious
2	The second field research survey	Laws and regulations, enrich the content of green renovation, reform enthusiasm, the government 's sense of responsibility, promotion of new technologies and methods, the quality of PPP projects, alleviate government financial pressure
3	The third field research survey	Improve the social visibility of enterprises, the degree of effort of social capital, the cost of implementing green renovation, benefits of implementing green renovation, the cost of implementing ordinary renovation, the income of ordinary transformation, sign a multi-party cooperation agreement, BOT mode is adopted, the renovation of the communities into a package

Finally, the influencing factor system was established. Considering that RORC in China is still relatively new, the content available in the literature may be incomplete, and the understanding of the renovation process by those surveyed may contain certain biases. Therefore, industry experts were invited to finalize the influencing factors. Five experts were consulted: two university professors specializing in urban green development, a government official involved in managing old residential community renovation projects, and two technical experts from a consulting firm. Through semi-structured interviews with these experts, their professional knowledge and practical experiences were leveraged to optimize the revised indicator system, ensuring that it is both scientifically sound and reasonable. This process laid a solid foundation for subsequent research. The final set of indicators is presented in Table 3.

Table 3. Finalized influencing factors.

NO.	Criterion Layer	Schematic Layer	NO.	Criterion Layer	Schematic Layer
1	Government institutional factors	Government incentive and restraint mechanisms	15	Cooperation mechanism factors	Trust between partners
2		Information sharing platform	16		Sign a multi-party cooperation agreement
3		Policy support	17	Technological factors	Enrich the content of green renovation
4		Government supervision	18		Research and development of green renovation technology
5		Preferential tax policy	19		construction technical ability
6		The renovation of the communities into a package	20	Demand factors	Environmental benefit
7	Economic factors	The cost of implementing green renovation	21		Residents' preference for greenness
8		Benefits of implementing green renovation	22		Needs of participants
9		The cost of ordinary renovation	23	Social capitals' own factors	Corporate social responsibility
10		The income of ordinary renovation	24		Reform enthusiasm
11		The government publicizes the cost of green renovation	25		Social capital financing ability
12		Patent rental fees	26		Improve the social visibility of enterprises
13		Payback period	27		The scale of social enterprises
14		Less profit space	28		Enhance the market competitiveness of enterprises

4.2. Determining the Indicator Weights

Following the establishment of the indicator system for factors influencing social capital participation in green RORC, the IGAHP-CRITIC method is employed to assign weights to the data. Subsequently, the game theory-based combinatorial weighting method is used to determine the final weights of the indicators. This process integrates both subjective and objective factors from the data, addressing the limitations of single weighting methods that may yield partial or incomplete results.

4.2.1. Determining Subjective Weights Using IGAHP Method

Given that the green renovation of old residential communities is still in its preliminary stages in China, and there are few mature and scalable practice cases to serve as references, this study adopts an expert evaluation approach based on a questionnaire survey. In selecting experts for evaluation, this study invited individuals from academia who specialize in old community renovation or green construction, policymakers involved in formulating policies for old community renovation and green construction, and project managers with practical experience in old community renovation or green construction within enterprises.

Five experts were invited to participate in the evaluation process, including two university professors, one government official, and two senior executives from enterprises. For 28 secondary indicators, each expert provided initial subjective weight values W_i using a scale of 1 to 9, as shown in Table 4.

Table 4. Subjective weight of secondary indicators.

NO.	Influencing Factors	Weight	NO.	Influencing Factors	Weight
1	Less profit space	0.1301	15	The government publicizes the cost of green renovation	0.0190
2	Policy support	0.1125	16	Residents' preference for greenness	0.0167
3	Research and development of green renovation technology	0.1043	17	Information sharing platform	0.0160
4	Benefits of implementing green renovation	0.0920	18	Payback period	0.0130
5	Government incentive and restraint mechanisms	0.0784	19	The scale of social enterprises	0.0127
6	The cost of implementing green renovation	0.0629	20	The renovation of the communities into a package	0.0097
7	Environmental benefit	0.0558	21	Sign a multi-party cooperation agreement	0.0095
8	Government supervision	0.0470	22	Patent rental fees	0.0092
9	The income of ordinary renovation	0.0423	23	Improve the social visibility of enterprises	0.0070
10	Trust between partners	0.0380	24	Needs of participants	0.0067
11	construction technical ability	0.0328	25	Social capital financing ability	0.0045
12	The cost of ordinary renovation	0.0283	26	Enhance the market competitiveness of enterprises	0.0030
13	Preferential tax policy	0.0250	27	Corporate social responsibility	0.0019
14	Enrich the content of green renovation	0.0207	28	Reform enthusiasm	0.0013

4.2.2. Determining Objective Weights Using CRITIC Method

A questionnaire survey was conducted to determine the objective weights. The survey participants included university faculty, government staff, consulting technicians, business managers, and residents of old residential communities. A total of 120 questionnaires were distributed, of which 98 were valid, resulting in an effective response rate of 81.67%. The questionnaire utilized a 5-point Likert scale for scoring, with the following criteria: "Very Strong" (5 points), "Relatively Strong" (4 points), "Neutral" (3 points), "Relatively Weak" (2 points), and "Very Weak" (1 point).

To ensure the reliability of the questionnaire data, it is essential to conduct validation tests on the collected data. Both the reliability analysis and validity analysis of the data meet the required standards. In this stage, the weight calculation results using the CRITIC method are obtained, as shown in Table 5.

Table 5. Objective weight of secondary indicators.

Influencing Factors	Variability of Indices	Conflict of Indicators	Information Content	Weight
Government incentive and restraint mechanisms	0.781	42.111	32.871	0.0838
Information sharing platform	0.778	13.648	10.617	0.0271
Policy support	0.699	21.757	15.207	0.0388
Government supervision	0.713	13.449	9.586	0.0245
Preferential tax policy	0.736	13.630	10.027	0.0256
The renovation of the communities into a package	0.679	20.557	13.962	0.0356
The cost of implementing green renovation	0.773	18.135	14.019	0.0358
Benefits of implementing green renovation	0.741	35.037	25.976	0.0663
The cost of ordinary renovation	0.799	13.861	11.082	0.0283
The income of ordinary renovation	0.760	13.901	10.562	0.0269
The government publicizes the cost of green renovation	0.684	13.645	9.329	0.0238
Patent rental fees	0.664	14.569	9.679	0.0247
Payback period	0.569	15.556	8.849	0.0226
Less profit space	0.707	13.467	9.525	0.0243
Trust between partners	0.700	14.102	9.875	0.0252
Sign a multi-party cooperation agreement	0.736	13.480	9.917	0.0253
Enrich the content of green renovation	0.729	13.940	10.163	0.0259
Research and development of green renovation technology	0.844	41.940	35.388	0.0903
Construction technical ability	0.715	41.721	29.819	0.0761
Environmental benefit	0.655	14.496	9.489	0.0242
Residents' preference for greenness	0.684	13.801	9.433	0.0241
Needs of participants	0.791	13.509	10.691	0.0273
Corporate social responsibility	0.766	17.810	13.650	0.0348
Reform enthusiasm	0.751	18.079	13.575	0.0346
Social capital financing ability	0.771	17.918	13.812	0.0352
Improve the social visibility of enterprises	0.730	17.907	13.064	0.0333
The scale of social enterprises	0.611	14.602	8.917	0.0227
Enhance the market competitiveness of enterprises	0.741	17.583	13.031	0.0332

4.2.3. Combining Weighting Based on Game Theory

Using the game theory-based combined weighting method, the comprehensive weights of the influencing factors were calculated. By substituting the above subjective and objective weights into Equations (11) through (15), the linear combination coefficients α_1^* and α_2^* were determined as 0.0432 and 0.0568, respectively. The final combined weights of the influencing factors for social capital participation in green RORC are presented in Table 6.

Table 6. Combination weight of secondary indicators.

NO.	Influencing Factors	IGAHP	CRITIC	Weight (%)
1	Government incentive and restraint mechanisms	0.0784	0.0838	8.14%
2	Information sharing platform	0.0160	0.0271	2.23%
3	Policy support	0.1125	0.0388	7.06%
4	Government supervision	0.0470	0.0245	3.42%
5	Preferential tax policy	0.0250	0.0256	2.53%
6	The renovation of the communities into a package	0.0097	0.0356	2.44%
7	The cost of implementing green renovation	0.0629	0.0358	6.75%
8	Benefits of implementing green renovation	0.0920	0.0663	7.74%
9	The cost of ordinary renovation	0.0283	0.0283	2.83%
10	The income of ordinary renovation	0.0423	0.0269	3.35%
11	The government publicizes the cost of green renovation	0.0190	0.0238	2.17%
12	Patent rental fees	0.0092	0.0247	1.80%
13	Payback period	0.0130	0.0226	1.84%
14	Less profit space	0.1301	0.0243	4.00%
15	Trust between partners	0.0380	0.0252	3.07%
16	Sign a multi-party cooperation agreement	0.0095	0.0253	1.85%
17	Enrich the content of green renovation	0.0207	0.0259	2.36%
18	Research and development of green renovation technology	0.1043	0.0903	9.63%
19	Construction technical ability	0.0328	0.0761	6.74%
20	Environmental benefit	0.0558	0.0242	3.78%
21	Residents’ preference for greenness	0.0167	0.0241	2.09%
22	Needs of participants	0.0070	0.0273	1.85%
23	corporate social responsibility	0.0019	0.0348	2.06%
24	Reform enthusiasm	0.0013	0.0346	2.02%
25	Social capital financing ability	0.0045	0.0352	2.19%
26	Improve the social visibility of enterprises	0.0070	0.0333	2.19%
27	The scale of social enterprises	0.0127	0.0227	1.84%
28	Enhance the market competitiveness of enterprises	0.0030	0.0332	2.01%

According to the calculation results of the combined weights, the highest weight factor is “Research and development of green renovation technology”, which is 9.63 %. The influencing factor with the lowest weight ratio is “Patent rental fees”, which is 1.80 %. Therefore, the greater the combined weight of the index, the more obvious the effect of the index on the target layer.

In this study, the indicators selected for the ISM analysis were screened based on composite weights. Given that an excessive number of indicators can increase the complexity and uncertainty of the analysis, the final set of indicators was chosen after a comprehensive consideration of their importance, representativeness, and data availability in reflecting the role of social capital in the green development process. Six indicators were selected from the 28 indicators in Table 7 as the key influencing factors for social capital to participate in green RORC, and 20% of the indicators reflect 99% of the original information. These six indicators are selected according to the size of the combined weight, which are the research and development of green renovation technology, the government incentive and restraint mechanisms, the benefits of implementing green renovation, policy support, the cost of implementing green renovation, and the construction technical ability. Although only six indicators were selected, these indicators encompass a substantial amount of information, effectively capturing the primary challenges and opportunities faced by social capital in the process of green renovation of old residential communities. They provide a comprehensive reflection of the key factors and their interrelationships in social capital’s involvement in green RORC thus enabling a thorough understanding of the critical elements influencing this process.

Table 7. The adjacency matrix.

	Q1	Q2	Q3	Q4	Q5	Q6
Q1	0	0	1	0	0	0
Q2	1	0	0	0	1	0
Q3	0	0	0	1	0	0
Q4	0	0	0	0	0	0
Q5	0	0	0	0	0	1
Q6	0	0	1	0	0	0

4.3. Hierarchical Structure of Key Influencing Factors

According to the six key influencing factors identified above, we can study the internal relationship between these factors and explore the internal motivation of driving social capital to participate in green RORC.

The six key influencing factors of the government incentive and restraint mechanisms, policy support, the cost of implementing green renovation, the benefits of implementing green renovation, the research and development of green renovation technology, and the construction technology ability are coded as Q1, Q2, Q3, Q4, Q5, and Q6. According to the opinions of the ISM expert group, the relationship between the key influencing factors of the whole system is obtained, as shown in Figure 3. According to Figure 3, the grid diagram of the relationship between the factors of the whole system can be obtained. The grid diagram is shown in Figure 4.

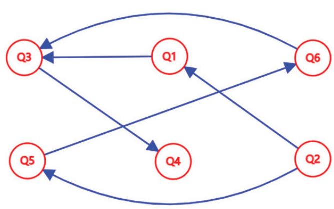

Figure 3. Relationships among key influencing factors.

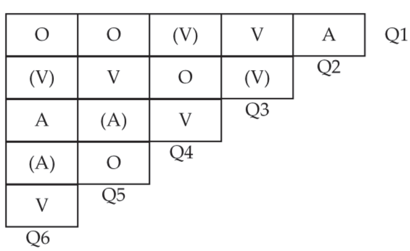

Figure 4. Network of relationships among influencing factors.

In Figure 4, "A" indicates that the column factor has an effect on the row factor, and "V" indicates that the row factor has an effect on the column factor. "O" indicates that the factors of ranks do not affect each other.

4.3.1. Establish Adjacency Matrix and Accessible Matrix

As seen in Figure 4, if one key influencing factor has an effect on another key influencing factor, mark it as "1"; however, if there is no connection between the key influencing factors (the connection between the influencing factors and themselves does not need to be judged), mark it as "0" and establish the adjacency matrix, as shown in Table 7.

The adjacency matrix indicates the direct relationship between the influencing factors. When the adjacency matrix is added to the unit matrix, the adjacency multiplication matrix can be obtained, as shown in Table 8.

Table 8. Adjacent multiplication matrix.

	Q1	Q2	Q3	Q4	Q5	Q6
Q1	1	0	1	0	0	0
Q2	1	1	0	0	1	0
Q3	0	0	1	1	0	0
Q4	0	0	0	1	0	0
Q5	0	0	0	0	1	1
Q6	0	0	1	0	0	1

According to the data in Table 8, the accessible matrix is obtained by using the SPSSPRO online data analysis platform. The accessible matrix shows that the transfer between influencing factors can bring indirect influence. The accessible matrix is shown in Table 9.

Table 9. The accessible matrix.

	Q1	Q2	Q3	Q4	Q5	Q6
Q1	1	0	1	1	0	0
Q2	1	1	1	0	1	1
Q3	0	0	1	1	0	0
Q4	0	0	0	1	0	0
Q5	0	0	1	0	1	1
Q6	0	0	1	1	0	1

4.3.2. Hierarchical Classification of Influencing Factors

The hierarchical classification of influencing factors is also the process of model decomposition. Based on the obtained reachability matrix, each influencing factor is classified into reachable sets and dominating sets, from which the intersection of the reachable and dominating sets is calculated. This allows for the extraction of the influencing factor set for hierarchical classification. The initial state of model decomposition is shown in Table 10, with the results of the first to fourth extractions listed in Tables 11–14, respectively. The hierarchical classification results are presented in Table 15.

Table 10. Initial state.

	Reachable Set	Reachable Set and Dominating Set
Q1	Q1, Q3, Q4	Q1
Q2	Q1, Q2, Q3, Q4, Q5, Q6	Q2
Q3	Q3, Q4	Q3
Q4	Q4	Q4
Q5	Q3, Q4, Q5, Q6	Q5
Q6	Q3, Q4, Q6	Q6

Table 11. Results after first extraction.

	Reachable Set	Reachable Set and Dominating Set
Q1	Q1, Q3	Q1
Q2	Q1, Q2, Q3, Q5, Q6	Q2
Q3	Q3	Q3
Q5	Q3, Q5, Q6	Q5
Q6	Q3, Q6	Q6

Table 12. Results after second extraction.

	Reachable Set	Reachable Set and Dominating Set
Q1	Q1	Q1
Q2	Q1, Q2, Q5, Q6	Q2
Q5	Q5, Q6	Q5
Q6	Q6	Q6

Table 13. Results after third extraction.

	Reachable Set	Reachable Set and Dominating Set
Q2	Q2, Q5	Q2
Q5	Q5	Q5

Table 14. Results after fourth extraction.

	Reachable Set	Reachable Set and Dominating Set
Q2	Q2	Q2

Table 15. Hierarchical decomposition.

Hierarchy	Factors
1	The benefits of implementing green renovation
2	The cost of implementing green renovation
3	The government incentive and restraint mechanisms, the construction technical ability
4	Research and development of green renovation technology
5	Policy support

4.3.3. Constructing Interpretative Structural Model

According to the division of Table 15, the influencing factors of the same layer are represented by boxes of the same level, different levels are divided by dashed lines, and the hierarchical relationship is represented by upward arrows. The specific key influencing factors explain the structural model, as shown in Figure 5.

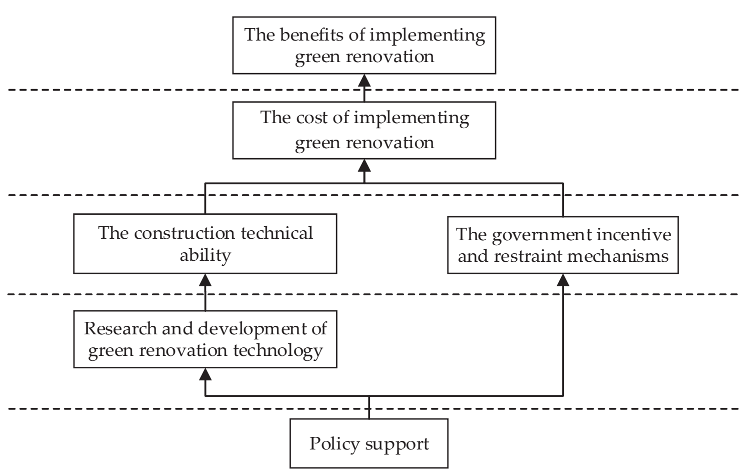

Figure 5. Interpretative structural model of key influencing factors.

4.4. Discussion

Unlike urban ecological renewal and redevelopment projects in the United States [60], which focus on telling the story of valuable communities, or those in Europe that integrate historical cultural heritage with the ecological environment [61], RORC in China is primarily focused on improving citizens' living conditions. Consequently, the factors influencing social capital participation in RORC under the urban green development goals differ not only from those in standard renovation projects but also from other types of urban green development initiatives. The findings of this study confirm this distinction.

1. Firstly, the urban environment serves as the foundation for residents' work and life, and its green development has garnered widespread global attention. Innovative solutions continue to emerge, such as the implementation of smart city initiatives to achieve low-carbon development [62]. Collaborative governance among multiple stakeholders is conducive to urban green development, with demand-driven initiatives and cost–benefit considerations being key to successful collaboration [63]. In particular, the coordinated governance between government and private capital can significantly reduce urban carbon emissions and promote sustainable urban development [64]. Davies et al. [65] investigated 30 companies of varying sizes and industries, analyzing their willingness to invest in urban green development projects. Key factors influencing their participation included project cost–benefit analysis, regulatory mechanisms, and corporate social responsibility. Meanwhile, He et al. [66], in their study on urban heat islands and sponge cities, emphasized that shared interests among stakeholders are critical in driving participation in green urban projects. They recommended considering technological, financial, institutional, and social aspects. For businesses, factors such as attitudes, subjective norms, and perceived behavioral control have a positive influence on their green development behaviors [67]. Most existing studies on factors influencing urban green development focus on production efficiency [68,69]. However, urban renewal projects, with their unclear return mechanisms, present more complex financing models under the green urban development framework. This study's findings also demonstrate that the factors social capital must consider in these projects are more intricate compared to traditional urban green development initiatives.
2. Secondly, existing research has already addressed the participation of private capital in traditional old residential community renovation projects. When making investment decisions, social capital involvement in such projects tends to focus more on factors like profitability and the financial strength of the enterprises themselves [30]. LIU et al. [70] explored the mechanisms behind corporate participation in old community renovations, concluding that participation attitude is the key factor influencing willingness to engage. However, their study was conducted from the perspective of internal capabilities and external conditions of the companies. While other studies on urban renewal projects have touched upon low-carbon urban development, the primary focus was on the models of social capital participation rather than on renovation projects for old residential communities, or the factors influencing such participation [71]. Collaborative governance is often regarded as an effective solution to the obstacles encountered during urban renewal processes, but cooperation among diverse stakeholders remains a key topic in current research [72]. Traditional urban renewal projects focus on collaboration among stakeholders, conflict resolution efficiency, and public participation, constrained by factors such as partnerships, location, and power dynamics [73]. Social capital typically views its involvement in these projects as an investment, with economic returns being the primary consideration, and governments have a variety of partners to choose from in such collaborations [74]. The

findings of this study however reveal that in the context of green urban development, social capital places more emphasis on factors such as government support policies for green development, green renovation technologies, environmental benefits, and corporate social responsibility. From the perspective of collaborative governance, this aligns with the profit-driven nature of social capital.

3. Thirdly, when analyzing the factors influencing social capital's involvement in green urban or old residential community renovation projects, existing studies have proposed various valuable research methods. For novel research topics where the concepts are still somewhat ambiguous, grounded theory is often employed to screen and analyze influencing factors [30,63]. The FUZZY-DEMATEL method, which can analyze the causal relationships between factors, is also frequently used in such analyses, especially when combined with grounded theory [30]. With the rapid development of artificial intelligence and big data, the methods for identifying influencing factors have also evolved. For instance, WANG et al. [64] used ChatGPT to identify valuable green urban development PPP projects. BU et al. [75] explored evolutionary stable equilibrium strategies and the factors influencing stakeholder decisions using evolutionary game theory. Case study methods are also widely applied, and analyzing existing data and conducting structured interviews are common approaches [65,76]. This study employs a mixed-methods approach, integrating grounded theory, IGAHP for subjective weighting, CRITIC for objective weighting, game theory, and the ISM method, leveraging the strengths of each methodology. The findings of this study demonstrate the effectiveness of the chosen research methods.

5. Conclusions, Recommendations, and Limitations

5.1. Conclusions

This study, using the example of green RORC within the context of urban renewal in China, explores the driving factors behind social capital participation in urban green development and promotes a healthy and sustainable real estate market. Through a comprehensive literature review, social practice surveys, and expert interviews, a multi-layered index system was established. By applying integrated weighting and interpretive structural modeling (ISM) methods, the interactions and hierarchical structure of the influencing factors were thoroughly analyzed, ultimately revealing the mechanisms through which social capital functions in this field. The main conclusions of this study are as follows:

First, the study finds that the research and development of green renovation technology, the government incentive and restraint mechanisms, the benefits of implementing green renovation, policy support, the cost of implementing green renovation, and the construction technical ability have significant impacts on social capital participation in green RORC. Among these, government policy support and incentives play a critical role in motivating social capital involvement. Moreover, the benefits of implementing green renovation and the level of development in green renovation technologies directly affect the feasibility and attractiveness of such projects.

Second, the study reveals a certain level of correlation and hierarchy between different factors. For instance, policy support can facilitate the development and application of green renovation technologies thereby enhancing both the economic and environmental benefits of the projects. On the other hand, the construction technical ability is influenced by multiple factors, such as the policy environment, market conditions, and the enterprises' own strengths. These interrelated factors together form the complex mechanism driving social capital's participation in green renovations.

Third, through empirical analysis and case studies, the effectiveness of the proposed research framework and methods was validated. The findings demonstrate that a comprehensive application of multiple research methods can more holistically uncover the influencing factors and their relationships in social capital participation in green renovations of old residential communities. This provides a scientific basis and valuable reference for relevant policy formulation and practical implementation.

This study explores the involvement of social capital in urban green transformation from the perspective of the renovation of old residential communities, leading to several valuable conclusions. In future research, the findings of this study should be continuously validated and refined based on the specific implementation of old residential community renovations. Additionally, further research should actively explore the participation of social capital in other urban green development projects.

5.2. Recommendations

Based on the research findings discussed earlier, we propose the following recommendations to enhance the involvement and overall effectiveness of social capital in the green renovation of old residential communities:

- Improve government incentive and constraint mechanisms: The government can implement more incentive measures, such as tax reductions and subsidies, to encourage social capital investment in the green renovation of old residential communities. Additionally, corresponding constraint mechanisms should be established to ensure the quality and sustainability of the projects.
- Enhance technical and managerial support: Governments or relevant institutions can provide advanced technical and managerial support to improve the efficiency and effectiveness of social capital involvement in green renovation projects of old residential communities.
- Establish risk assessments and sharing mechanisms: When guiding social capital participation in the green renovation of old residential communities, the government should emphasize the importance of developing risk assessments and sharing mechanisms to reduce the perceived risks of social capital investments thereby increasing their willingness to participate.
- Promote community involvement and feedback mechanisms: Communities should actively participate and establish feedback mechanisms to better meet residents' needs and expectations thereby enhancing the social acceptance and overall benefits of the projects.

5.3. Limitations and Research Prospects

5.3.1. Limitations

Despite the achievements of this study, several limitations remain. First, this research primarily focuses on the factors influencing social capital participation in green RORC but does not delve into the specifics of project implementation or the evaluation of outcomes. Second, the study sample is limited in scope, which may not fully represent all regions and types of green renovation projects for old residential areas. Therefore, future research should expand the sample size and increase the depth of analysis. Furthermore, as green RORC in China is still in an exploratory phase within the country's urban green development, stakeholders' understandings of the process is limited. With the continuous introduction of new policies and increasing public awareness, the findings of this study may need to be further refined.

5.3.2. Research Prospects

Despite these limitations, we believe that this study has explored a compelling topic within the urban green development literature, addressing an area that was not fully explored. To address the identified limitations, the following recommendations are proposed for potential future research: First, a more in-depth examination of the specific implementation processes and evaluation methods for green renovation projects could provide a more comprehensive understanding of the role and contribution of social capital. Second, expanding the scope of the study to include other countries and different types of urban renewal projects would help to better reveal the factors influencing social capital participation and the relationships among them. Additionally, integrating new technologies and methods, such as big data analysis and artificial intelligence, could enhance the accuracy and efficiency of the research. These efforts could further encourage active social capital participation in urban green development and foster a healthy, sustainable real estate market.

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