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Edited by
Michelangelo Savino

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Guest Editor

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About the Editor

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Article

Equity Study on Urban Park Accessibility Based on Improved 2SFCA Method in Zhengzhou, China

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Abstract: The distribution of urban parks is closely related to the opportunities of daily use by residents as well as the performance of the park system. The question as to whether parks are distributed equitably within cities is therefore becoming the focus of attention. However, only a few studies have explored a comprehensive and systematic procedure for urban park accessibility analysis and equity evaluation. In this study, by applying an improved two-step floating catchment area (2SFCA) method and K-means cluster analysis, based on the application of multi-source data, we provide insights into an equity study on park accessibility at the neighborhood scale and urban ring scale in the central urban area of Zhengzhou. These results suggest that the spatial access to parks in Zhengzhou is generally unevenly distributed among neighborhoods, and both the mean and standard deviation of accessibility show an increase from the center to the periphery. The cluster analysis reveals a set of four types of neighborhoods, including a high-supply medium-demand medium-accessibility type (HMM), a low-supply medium-demand low-accessibility type (LML), a high-supply low-demand high-accessibility type (HLH), and a medium-supply high-demand low-accessibility type (MHL), each with different characteristics and causes. The spatial distribution of the accessibility types exhibits both similarities and differences between the urban rings. The findings of this study could serve as a tool for identifying areas in which parks are underserved and the ways in which they differ from other areas, which can guide urban planning to address specific inequities.

Keywords: public green space; urban park catchment area; improved supply and demand; park quality; urban neighborhoods; Baidu Maps API

1. Introduction

In addressing the social differentiation and spatial segregation in the process of urbanization, spatial equity during the process of urban regeneration among cities around the world has been receiving increasing attention [1–10]. Especially in China, most cities have experienced extremely rapid urbanization in recent decades. Urban social space is characterized by heterogeneity and complexity [11,12], and presents a series of conflicts, in particular, serious residential segregation problems and inequitable availability of public resources. With growing concerns about this issue, promoting social equity and justice has become crucial for Chinese governments in formulating urban development policies.

Parks are an important part of urban landscapes, providing environmental, social, and economic benefits to urban areas [13–16]. In addition, they are widely recognized to play a vital role in enhancing the quality of urban life by providing significant public health and sustainability benefits to urban communities [14,17–19]. The distribution of urban parks is closely related to the daily access opportunities of residents, as well as the performance of park systems [20]. The question as to whether parks, as essential public facilities and services, are equitably distributed in the urban space has therefore always been a focus of attention.

Plenty of studies have examined the equity of urban parks by measuring accessibility [10,21–24], which considers spatial distribution of supply and demand as well as the impact of individual mobility. However, the general geographic approach usually uses park size and proximity to represent the supply of parks, ignoring general preference for different kinds of parks [19,23,25]. Only a few studies have incorporated park quality indicators including features and conditions in the assessment of park services [10,24,26]. Additionally, most of the literature on equity has emphasized the identification of distributional disparity and underserved areas within the study area, while failing to examine the causes behind the spatial differences. To advance comprehensive and systematic equity research and targeted strategy development, it is necessary to investigate spatial patterns of supply, demand, and accessibility.

Our study aims to perform a comprehensive analysis of spatial accessibility of parks at multiple scales based on an improved 2SFCA method, combined with multi-source big data and site survey data, while incorporating K-means cluster analysis for a systematic evaluation of park equity in the central urban area of Zhengzhou. This paper is structured as follows. Section 2 reviews the existing literature on equity and accessibility measures in order to develop our theoretical framework. Section 3 describes the study area, and the data source and processing. Section 4 explains the improved 2SFCA method and K-means cluster analysis adopted for equity evaluation. Section 5 presents the analysis and results of spatial accessibility and equity. Section 6 summarizes the main contributions and discusses the limitations. Finally, we conclude and outline practical implications in Section 7.

2. Literature Review

2.1. Accessibility Measurements

Spatial accessibility has gradually become one of the key conceptual approaches to examining urban patterns and processes, especially public resource allocation [22,27–30]. The concept of spatial accessibility was first proposed by Hansen [31] and defined as "the potential of opportunities for interaction". Basically, accessibility measures mainly involve the interaction of four spatial and non-spatial components: the spatial distribution of potential destinations, the ease and time of reaching each destination, the type and force of attractiveness of services, as well as individual needs and preferences for services [32,33]. For public facilities and services such as parks and green spaces, hospitals, and schools, the concept of accessibility is of great significance in terms of spatial equity. By effectively correlating the locations of public facilities with population groups, accessibility can intuitively reflect individuals' use opportunities with respect to public facilities. Therefore, accessibility is an important metric for measuring equity [34–36]. Various models and methods have been developed to evaluate access to public facilities and services, which can generally be divided into three main types:

1. **Buffer analysis method** [37] and **network-constrained service area method** [38], using a predefined distance/time as the search radius to identify the population covered by a particular public facility or to calculate the number/size of public facilities accessible to a specific location. They implicitly assume that public facilities are equally enjoyed within the covering range, which is not true. In addition, it has difficulty determining the threshold distance/time, especially when distinguishing between different types of public facilities. Furthermore, these accessibility measures lack consideration of residents' demand.
2. **The nearest distance method** and **the minimum cost method** [20,25] assume that residents always choose the closest or most convenient public facilities to visit. However, accessibility is not necessarily better, the shorter the distance is from a given area to public facilities. Since residents have other considerations besides proximity, such as a likely preference for parks of better quality and with larger spaces that may nevertheless be further away, the supply factors of public facilities are not properly considered in accessibility measurements.

3. **Gravity-based model** [26,28,39] and **two-step floating catchment area method** [24,40,41] measure the spatial accessibility by the sum of the possibility of multiple facility choices at each demand location. They incorporate the effects of the size/attraction and spatial friction, but this needs to be estimated based on empirical access behavior. The larger the sum of the potentials, the better the accessibility. Compared with the other two types of methods, such models take into account both supply and demand sides, and thus can more comprehensively reflect residents' access to public facilities.

As a special case of the gravity-based model [42], a two-step floating catchment area method improved by Luo and Wang [40] has become one of the most commonly employed and developed methods. Subsequently, through a series of explorations in the aspects of spatial scale, search radius, distance decay, supply and demand estimation, travel modes, user groups, etc., the rationality of this accessibility measurement is gradually enhanced [24,29,30,35,43].

2.2. Measuring Access to Parks

While extensive research on park accessibility suggests inequitable access in cities around the world, significant gaps remain in how park access is defined. There are many studies that highlight only one aspect of park accessibility or a single park attribute, such as examining travel distance/time cost to the nearest park, and the number of parks covered or the total park area available within a certain travel range. The validity of the findings is limited, since such approaches disregard what kind of parks are available to the residents of the surrounding areas. In addition to access cost and size, park quality is also a key parameter, including recreational opportunities, landscape features, maintenance etc., that has a large impact on park visits and use [10,18,26,44]. Additionally, park category needs to be considered, as it determines different values of per capita park area from a design perspective, and thus affects actual park accessibility. Developing an integrated approach to model park access, incorporating park proximity, size, category, and quality, has important implications for objectively evaluating urban park accessibility.

The difficulty of current accessibility research lies in obtaining high-precision demand data. Estimates of population demand from existing accessibility studies in China rely primarily on census data. However, the census data are aggregated on a relatively rough scale, such as at the district and sub-district level, which is difficult to match with the actual layout scale of urban parks, thus affecting the accurate assessment of accessibility differences and identification of underserved areas in cities. Therefore, population data of small-scale units (e.g., communities and neighborhoods) are needed to more effectively reveal the details of variations in park accessibility.

Travel cost is one of the key factors in measuring park accessibility [8,45]. Traditionally, it is mainly measured by travel distance based on the road network analysis through GIS. However, this approach ignores actual traffic conditions and thus may lead to deviations from reality. To address this limitation, the Application Programming Interface (API) of open map service was introduced to provide real-time navigation data on travel time. On the one hand, focusing on travel time rather than travel distance is more in line with social reality. In this way, on the other hand, travel cost measurement between origin and destination points can reflect factors that affect actual travel time and speed, such as traffic congestions, speed limits, turn restrictions, and other conditions [34,46,47]. Given more accurate and convenient measurement compared to traditional methods, it has gradually been applied to collect travel cost data in recent park accessibility studies [11,19,48].

2.3. Research Purpose and Contributions

To fill the conceptual and methodological limitations of the above reviews, we focus on three specific questions in this study: (1) How to effectively measure the accessibility of urban parks? (2) What are the characteristics of accessibility distribution both at the neighborhood scale and the urban ring scale? (3) What is the accessibility pattern across the city and how do accessibility types differ? First, this study applies an improved 2SFCA method to measure park accessibility, combining park quality with size and category to comprehensively describe park supply, and considering selection probability of residents among multiple available parks. Additionally, residents' demand is refined by population estimation for neighborhood-scale units. In addition, the measurement of travel cost is improved by applying real-time navigation data. Second, park accessibility is analyzed spatially and statistically both at the neighborhood scale and urban ring scale, so that the characteristics of accessibility distribution can be examined. Lastly, by using K-means cluster analysis, we reveal the accessibility patterns as well as causes behind the spatial accessibility differences. Accordingly, targeted improvement decisions can be made. The findings of this study could serve as a tool for identifying areas of urban park shortage and how they differ from other areas, which can guide urban planning and landscape design to address specific inequities. The research framework is shown in Figure 1.

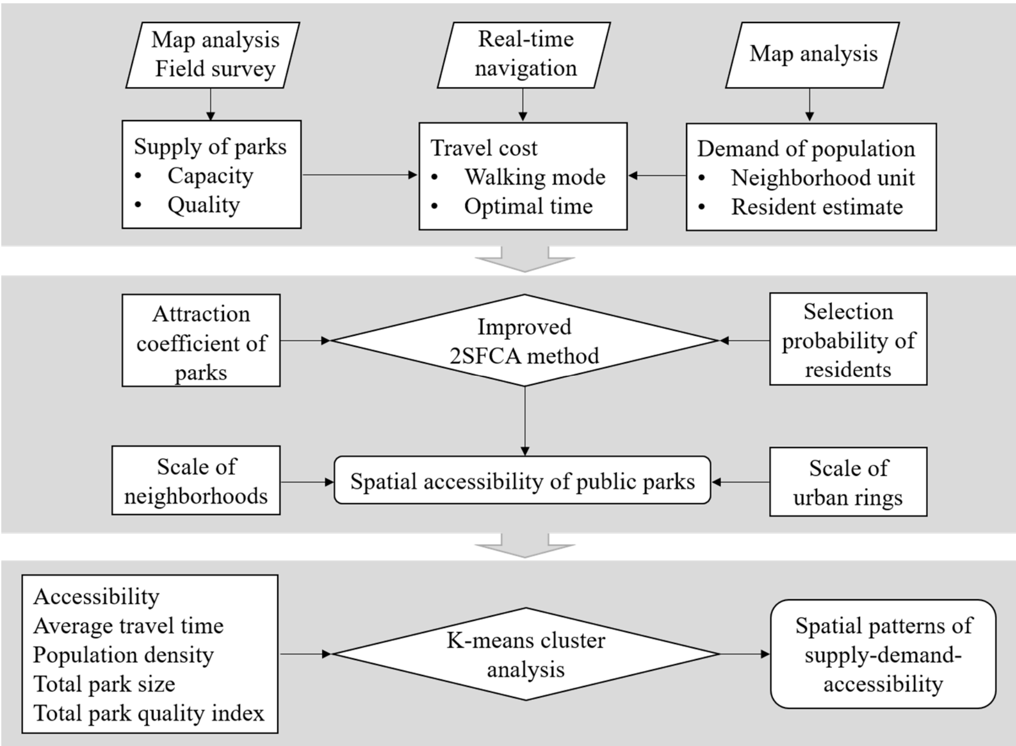


Figure 1. Research framework for accessibility analysis and equity evaluation of urban parks.

3. Study Area and Data Preparation

3.1. Study Area

Zhengzhou is the capital of Henan Province in central China, located on the North China Plain and the south bank of the Yellow River. In 2016, the city was designated as a "National Central City" and became a new first-tier city in China. During the rapid urbanization process in recent decades, the central urban area of Zhengzhou has gradually expanded from the center to the periphery in the form of concentric rings. By the end of 2019, there were five rings, defined by four main urban ring roads (Figure 2), with an area of about 1010.3 km^2 and a population of 5.22 million (Zhengzhou Municipal Bureau of Statistics). Compared with the outer rings, the inner two rings have higher population density, building density and urban functions. In 2019, Zhengzhou's per capita park area reached 14.5 m^2 (Zhengzhou Municipal Bureau of Statistics), which was at a relatively high level compared with Shanghai's per capita park area of 8.4 m^2 (Shanghai Municipal Bureau of Statistics). Zhengzhou was approved as one of the National Ecological Garden Cities in 2020. However, previous studies have shown that park allocation varies widely in our study area [48–50].

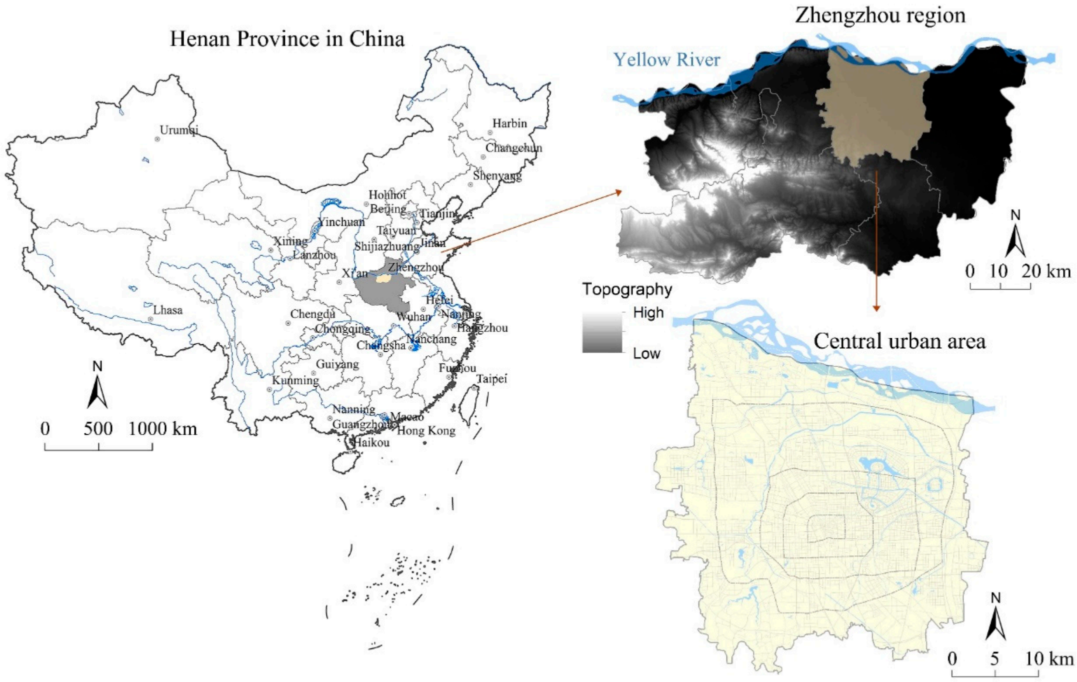


Figure 2. Geography, topography and the five rings of development in Zhengzhou, Henan Province.

3.2. Data Source and Processing

3.2.1. Data on Supply of Parks

Regarding supply, the attributes of parks, including size, category and quality were applied to comprehensively consider the supply effect of parks. We extracted the AOI (Area of Interest) of parks through a widely used map platform in China, Amap (https://ditu.amap.com/ (accessed on 9 October 2022)). A total of 163 urban public parks in the central urban area of Zhengzhou were included, ranging from 1 ha to 374 ha in size. As specified in the Standard for Classification of Urban Green Space (CJJ/T85-2017), there were 41 urban parks, 31 theme parks, 19 community parks, and 72 linear parks (Figure 3). Urban parks and theme parks are designed to attract citizens from the entire city. Community parks and linear parks are mainly built to meet the demand of the surrounding residential areas. Given that actual entrances can affect the scope of services provided by parks, multiple entrances to each park were used as supply points rather than geographic centroids [20,37,51]. Through Google Earth image recognition combined with on-site investigations, a total of 864 entrances of these parks were identified. To measure park quality, we assessed the facilities and amenities within each park, and also the presence or absence of water bodies, based on fieldwork and Google Earth imagery. The ratio of tree coverage was derived from high-spatial-resolution GF-2 satellite imagery (2017), classified and calculated in ArcGIS 10.8.

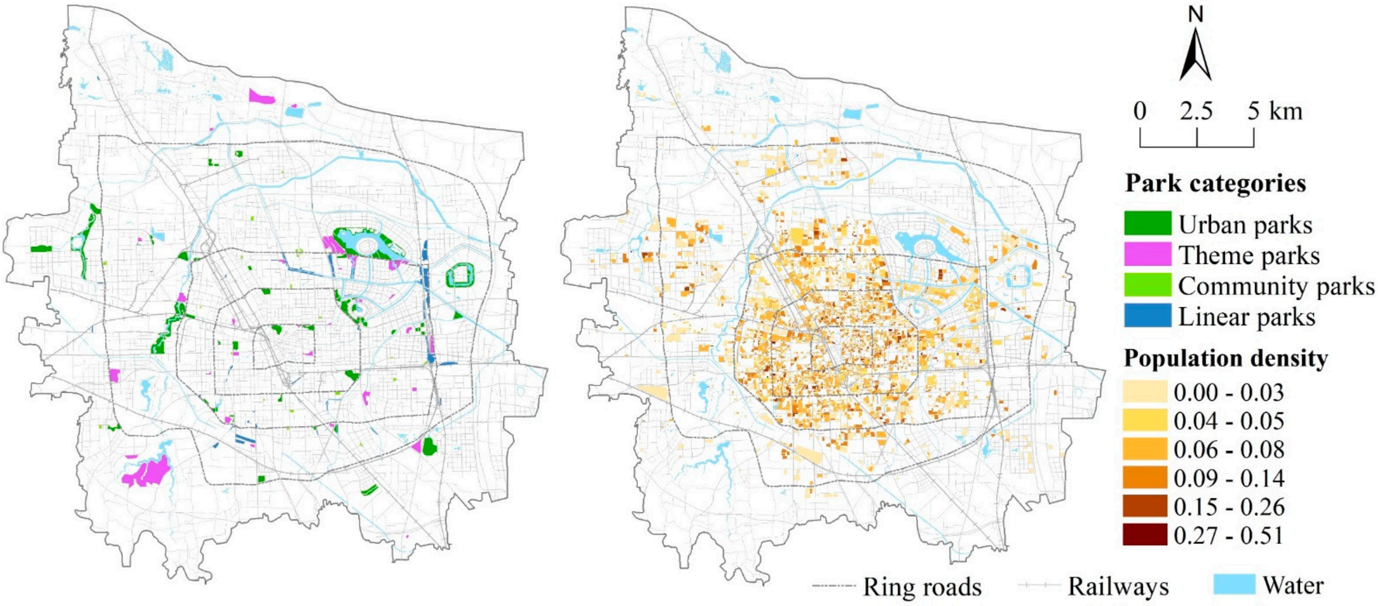


Figure 3. Spatial distribution of parks and population density in the central urban area of Zhengzhou.

3.2.2. Data on Demand of Population

For demand, the centroid of each neighborhood was used to reflect the demand location of potential visitor population of parks. The neighborhood population was calculated and aggregated at residential building level. The AOI data of neighborhoods and residential buildings were obtained through Baidu Maps, one of the most popular Chinese map platforms (https://map.baidu.com/ (accessed on 9 October 2022)). In the central urban area of Zhengzhou, a total of 4180 neighborhoods and 49,397 residential buildings were identified after data screening and cleaning. The residential building data includes the footprint area and the number of floors. According to the 2019 Zhengzhou Statistical Yearbook, the per capita living area is 31 m^2. Thus, the number of residents in each neighborhood were estimated as follows. The calculated total population of each district has been verified to be roughly in line with the 2019 demographic data.

$$P = \sum_{l=1}^{n} \frac{S_l N_l}{R} \tag{1}$$

where P denotes the potential population of the neighborhood; S_l is the footprint area of each residential building l in the neighborhood; N_l is the number of floors corresponding to each residential building l; R is the per capita living area; and n is the number of residential buildings in the neighborhood.

3.2.3. Data on Travel Cost

The travel time was obtained using the API service of Baidu Maps based on the actual travel situation between two geographic locations within the study area. Taking the entrances of 163 parks as destination points and the centroids of 4180 neighborhoods as origin points, we collected the optimal time cost of several travel paths from each neighborhood to the different entrances to each park in walking mode. Figure 4 presents an example visualization where path 1 takes the shortest time from the neighborhood to the park, and thus 9 min is filtered into the database. Walking is the main mode for urban residents to reach the parks on a daily basis. The travel time threshold, t_0, was designated as 30 min, since this represents the maximum time that can be widely accepted for routine park visits [11,24]. While real-time traffic conditions can affect the travel time by public transport and driving even on the same travel route, the actual time cost is less affected when walking on sidewalks. Therefore, the variation in acquisition time due to the large amount of data made little difference for our results.

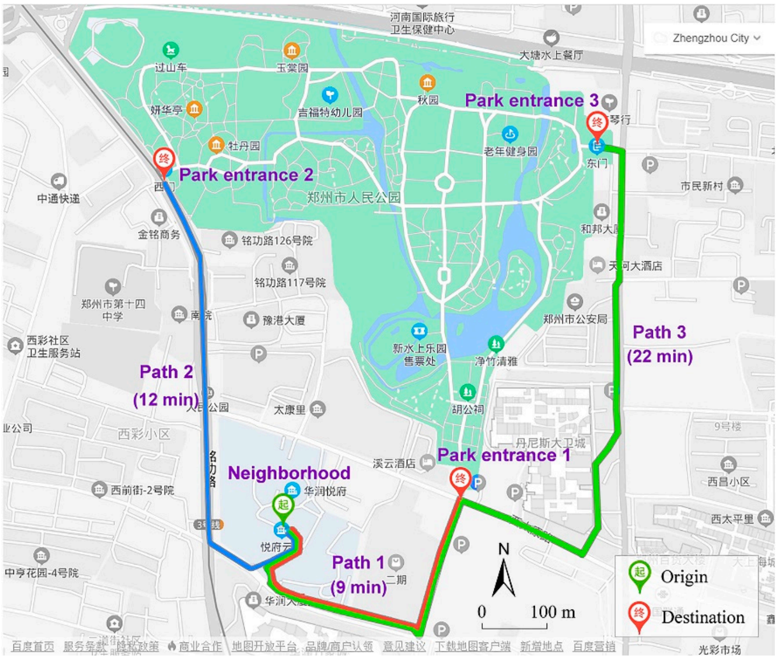


Figure 4. Example of travel path and time cost visualization in walking mode of Baidu Maps Navigation.

4. Methodology

4.1. Improved 2SFCA Method

The classic two-step floating catchment area (2SFCA) model takes into account both supply and demand factors. It has been extensively applied to evaluate access to public facilities and services, thus providing an important foundation for our study. In terms of supply, urban parks of higher quality levels and greater service capacity are positively correlated with higher rates of park access and use. Therefore, several studies have introduced park quality and park capacity to assess park supply [18,24].

For park quality, we described residents' destination parks on the basis of facilities and amenities, water features, and tree canopy. According to previous studies [44,52,53], these are the major characteristics of park quality that influence park visits. Facilities and amenities were assessed regarding the presence and condition of three aspects, specified in "Code for the design of public parks (GB51192-2016)": recreational amenities, service amenities, and management facilities. During on-site investigations, all selected parks were classified into five grades, from 0 to 1, representing the amenities provided as from excellent to bad facilities (Table 1). Water features and tree canopy were scored separately, based on the presence of water bodies and the ratio of tree coverage. Additionally, the weights of the three variables were calculated using the AHP (Analytical Hierarchy Process) method. The park quality index is the sum of three weighted variable values for each park, expressed as follows.

$$Q_j = \sum_{i=1}^{n} W_i V_i \tag{2}$$

where Q_j denotes the quality index of park j; W_i is weight of variable i; V_i is the value of variable i corresponding to park j; and n is the number of variables.

Table 1. Variables of the park quality index.

Variables	Description	Score	Weights
Facilities and amenities	Recreational amenities; Service amenities; Management facilities	Excellent as 1; Good as 0.75; Fair as 0.5; Poor as 0.25; Bad as 0	0.8421
Water features	Presence of water bodies	Yes as 1; No as 0	0.1053
Tree canopy	The ratio of tree coverage	≥50% as 1; <50% as 0.5	0.0526

Regarding park capacity, this is affected by park category in addition to park size. Park capacity was expressed as the ratio of park size to per capita park area. According to "Code for the design of public parks (GB 51192-2016)", the per capita park area varies by park category, with urban parks and linear parks set to 60 m^2, and theme parks and community parks set to 30 m^2. We applied the attraction coefficient S_j to substitute park size by combining park quality and park capacity to comprehensively reflect the supply effect of parks. This enhanced model is expressed as follows.

$$S_j = \frac{A}{A_m} Q_j \tag{3}$$

where S_j denotes the attraction coefficient of park *j*; *A* is the park size of park *j*; A_m is the per capita park area corresponding to the category of park *j*; and Q_j is the quality index of park *j*.

The Gaussian decay function [54] was developed to solve spatial friction problems. It can reflect the law that the relationship between supply and demand weakens with the increase in spatial distance. In addition, it is widely used in spatial accessibility measurement of parks, expressed as follows.

$$G(t_{ij}) = \begin{cases} \frac{e^{-(1/2)\times(t_{ij}/t_0)^2} - e^{-(1/2)}}{1-e^{-(1/2)}} & (t_{ij} \leq t_0) \\ 0 & (t_{ij} > t_0) \end{cases} \tag{4}$$

Given the competition among multiple available parks, recent improved models have only considered the impact of travel impedance on both demand of population and supply of parks [51,55].However, in addition to travel cost, differences in supply effects among multiple available parks can also affect residents' selection probability. Residents may prefer to visit parks with not only shorter travel time, but also greater appeal. To address this issue, Luo [56] drew on a Huff model to improve the selection weights by introducing park capacity together with travel impedance, without considering park quality. Xing [24] developed the selection probability involving park attractiveness, travel cost, and travel impedance, while the impact of distance decay was doubled into account. We refined the selection probability $Prob_{kj}$ of residents in a neighborhood among multiple available parks to improve the weighted estimation of potential demand and supply, as shown below.

$$Prob_{kj} = \frac{S_j G(t_{ij})}{\sum_{k\in\{t_{kj}\leq t_0\}} S_j G(t_{ij})} \tag{5}$$

Therefore, in the first step, through travel impedance coefficient $G(t_{ij})$ and selection probability coefficient $Prob_{kj}$, the population of neighborhoods within the travel time threshold of each park was adjusted, and then summed to represent each park's potential visitors. The supply demand ratio R_j for each park is defined as follows.

$$R_j = \frac{S_j}{\sum_{k \in \{t_{kj} \le t_0\}} Prob_{kj} P_k G(t_{ij})} \quad (6)$$

In the second step, the supply demand ratio corresponding to the parks within the travel time threshold of each neighborhood was calculated and weighted by travel impedance coefficient $G(t_{ij})$ and selection probability coefficient $Prob_{kj}$. These weighted supply demand ratios were then summed to obtain park accessibility A_i for each neighborhood, as shown below.

$$A_i = \sum_{j \in \{t \le t_0\}} Prob_{kj} R_j G(t_{ij}) \quad (7)$$

In Formulas (4)–(7), above, $Prob_{kj}$ denotes the selection probability of population at k visiting park j; S_j is the attractiveness of park j; t_{kj} is the travel time from k to j; t_0 represents the travel time threshold; $G(t_{ij})$ is the travel impedance coefficient; R_j denotes the supply/demand ratio of park j; P_k is the population of neighborhood k; and A_i denotes the park accessibility in neighborhood i.

The improved model is expected to provide an overall evaluation of park accessibility by comprehensively considering the supply of public parks (including park size, category and quality), the demand of neighborhood residents, travel costs, and residents' selection probability.

4.2. K-Means Cluster Analysis

Based on neighborhood-scale spatial accessibility, a cluster analysis was performed to identify various accessibility types and regions and explore spatial similarities and differences in park accessibility. In various cluster analysis methods, K-means is extensively applied because of its simplicity and efficiency. We adopted it to cluster the major factors with respect to supply, demand, and accessibility, including accessibility, average travel time, population density, total park size, and total park quality index (Table 2). By trying different clustering schemes for three to eight categories, respectively, in SPSS 27, the appropriate number of clusters was determined. Then, the results were imported into ArcGIS 10.8 for spatial visualization. The clusters can reflect accessibility patterns as well as explain the causes behind spatial accessibility differences.

Table 2. Factors involved in clustering.

Factors	Description
Accessibility	Accessibility value calculated for each neighborhood by improved 2SFCA method
Average travel time	Average travel time to parks within a 30-min walk of each neighborhood
Population density	The ratio of the population of each neighborhood to the corresponding neighborhood area
Total park size	Total area of parks within a 30-min walk of each neighborhood
Total park quality index	Total quality index of parks within a 30-min walk of each neighborhood

5. Results

5.1. Spatial Accessibility based on Improved 2SFCA Method

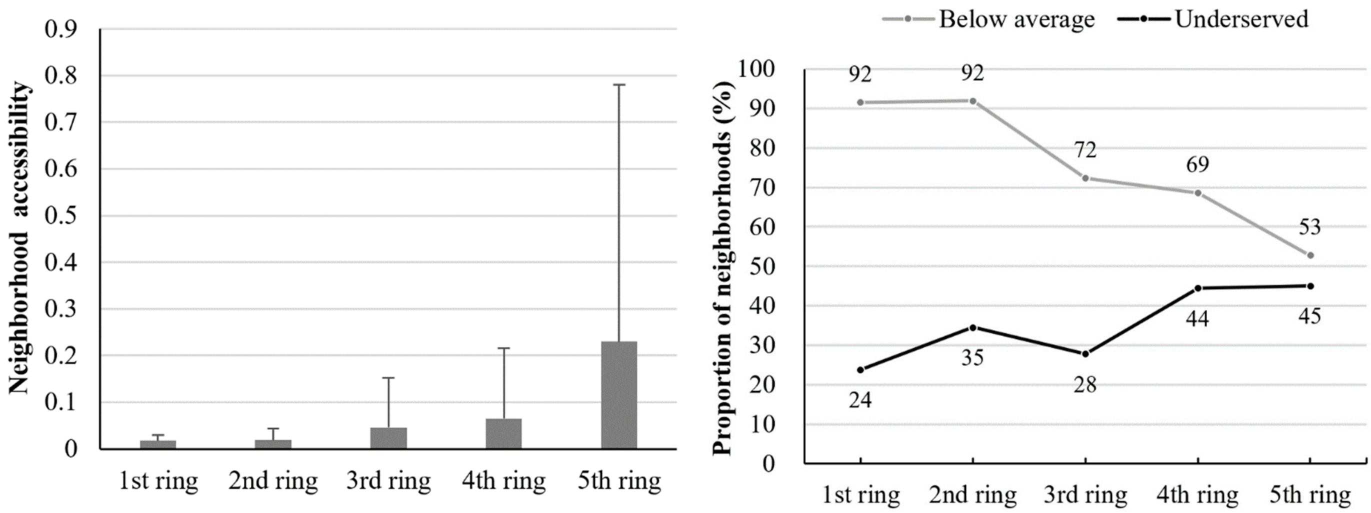
Statistical analysis indicated significant differences in accessibility distribution among neighborhoods (Table 3), with a mean of 0.038 and a standard deviation of 0.119. A total of 82.18% of the neighborhoods have lower accessibility than the city average. Additionally, the proportion of underserved neighborhoods (<0.01) is significantly high, with a value of about 32.78%.

Table 3. Statistical analysis of neighborhood accessibility.

	Mean	Standard Deviation	Below-Average Neighborhoods	Underserved Neighborhoods
Accessibility	0.038	0.119	82.18%	32.78%

The underserved neighborhoods are defined as those with an accessibility value below 0.01.

The graphs (Figure 5) show that the park accessibility of each ring is obviously different, and thus it is a demonstration of unfairness. From the city center to the city fringe, both the average accessibility and the standard deviation of neighborhoods increases. The inner rings have lower average accessibility due to dense population and relatively insufficient parks. The outer rings have a higher standard deviation of accessibility, which is related to the imbalanced distribution of parks. In terms of neighborhoods with below-average accessibility, the inner rings have a significantly higher share than the outer rings, while the outer rings have an apparently higher percentage of underserved neighborhoods than the inner rings, which is also consistent with the change in standard deviation.



(**a**) (**b**)

Figure 5. Statistical analysis across urban rings: (**a**) neighborhood accessibility; (**b**) proportion of below-average and underserved neighborhoods. Error bars indicate standard deviation.

According to the classification of the geometric interval method, the accessibility value of the overall neighborhoods was grouped into six grades (Figure 6). Overall, the map highlight that park accessibility is not equally distributed across the city. The areas with high accessibility are relatively agglomerated around large lakes and major rivers due to a few large waterfront parks such as Xiliu Lake Park and Dongfeng Canal Park. Several neighborhoods with extremely low accessibility are primarily distributed in the southwest of the first ring, the south and east of the second ring, the west of the third ring, and the north of the fourth ring, where parks are generally lacking and far from large and high-quality parks. Additionally, there is an apparent linear extension trend of low accessibility from northwest to southeast within the third ring road affected by the main railway line. Since areas along the railway line has been dominated by industrial and warehouse land in the historical development of the city, there are few urban parks planned around. As the population increased during urbanization, residential land expanded along the railway line, yet away from parks.

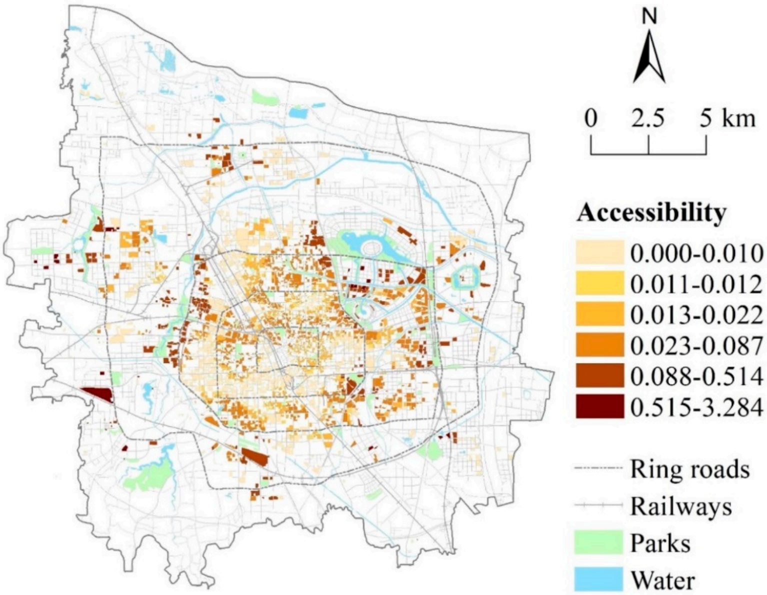


Figure 6. Spatial distribution of park accessibility value.

5.2. Equity Evaluation Based on K-Means Cluster Analysis

K-means cluster analysis was performed on 4030 neighborhoods after deducting neighborhoods with no data and extremely high accessibility. We identified the optimal clusters of four accessibility types based on five major factors (accessibility, average travel time, population density, total park size, and total park quality index). Table 4 shows the final cluster centers. By comparing the mean values of each factor of the clusters, typical attributes of each accessibility type and the way these types differ from each other were revealed. Each cluster was named separately for factor characteristics (high, medium, or low) in terms of supply, demand, and accessibility.

Table 4. Final cluster centers.

	HMM	LML	HLH	MHL
Neighborhood (numbers)	997	2494	228	311
Population ratio (%)	20%	56%	11%	13%
Accessibility	−0.00866	−0.25272	3.0144	−0.15549
Average travel time	−0.1629	0.11978	−0.41835	−0.13161
Population density	−0.20521	−0.18257	−0.34133	2.3722
Total park size	0.39058	−0.42391	3.03554	−0.07804
Total park quality index	1.19771	−0.46355	−0.15096	−0.01162

Except for the number of neighborhoods and population ratios, the above data were transformed to standard normal distribution by means of Z-score normalization.

The distinguished accessibility regions were mapped in Figure 7, revealing accessibility patterns across the city. The high-supply medium-demand medium-accessibility type (HMM) is mainly distributed within the third ring, comprising 997 neighborhoods and 20% of the population. The total park quality index of these neighborhoods is the highest due to their proximity to urban parks and theme parks in good conditions. However, the supply of total park size is relatively not high, so the accessibility level is moderate. The low-supply medium-demand low-accessibility type (LML) is primarily located within the fourth ring. This cluster has the majority of neighborhoods (2494) and population (56%) of all the clusters. However, both total park size and total park quality index in cluster LML are the lowest, and the average travel time is the longest. Consequently, these neighborhoods have the lowest accessibility among the four categories. The high-supply low-demand high-accessibility type (HLH) is mostly situated around city lakes both in the eastern and western areas of the city. This is the smallest group, with only 228 neighborhoods and

11% of the population. It has the lowest population density but the highest total park size. Furthermore, the average travel time is the shortest, so the accessibility is the highest of all the clusters. Due to proximity to large waterfront parks, these neighborhoods have become livable places on the periphery of the central urban area. The medium-supply high-demand low-accessibility type (MHL) is spread across the city, with 311 neighborhoods and 13% of the population. These neighborhoods have the highest population density. In contrast, the supply of total park size and quality is relatively insufficient, thus the corresponding level of accessibility is low.

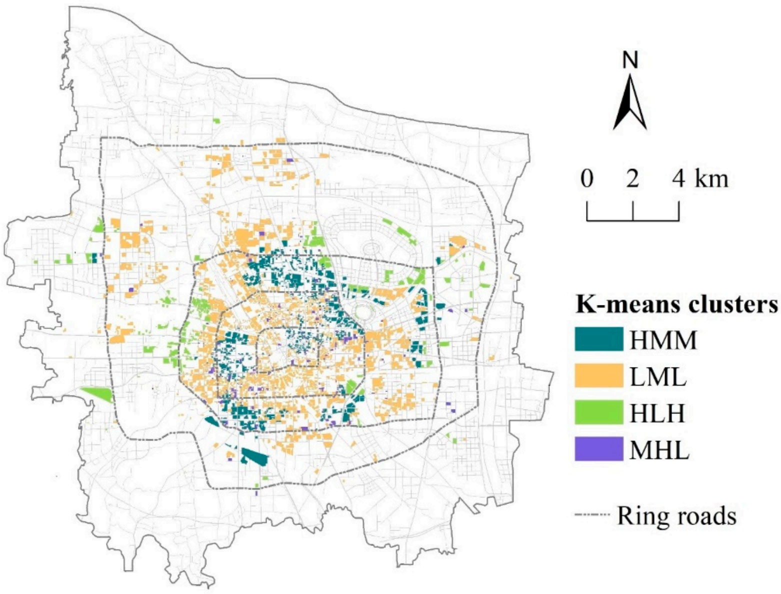


Figure 7. Neighborhood clusters in terms of supply, demand, and accessibility (based on accessibility, average travel time, population density, total park size, and total park quality index).

The graph (Figure 8) shows that the spatial distribution of accessibility types has both similarities and differences between urban rings. The low-supply medium-demand low-accessibility type (LML) is the most widely distributed, with more than half of the neighborhoods in each ring. This indicates that the low accessibility of neighborhoods within each ring is mainly affected by park supply shortages. The second-highest proportion of neighborhoods is high-supply medium-demand medium-accessibility type (HMM) in the inner rings, and high-supply low-demand high-accessibility type (HLH) in the outer rings. This suggests that for neighborhoods with a high supply of parks, the outer rings have higher accessibility due to a lower demand than in the inner rings. In addition, the proportion of neighborhoods in the medium-supply high-demand low-accessibility type (MHL) showed an overall decreasing trend from the city center to the city fringe. This shows that, compared to the outer rings, the inner rings have more low-accessibility neighborhoods because of the high demand.

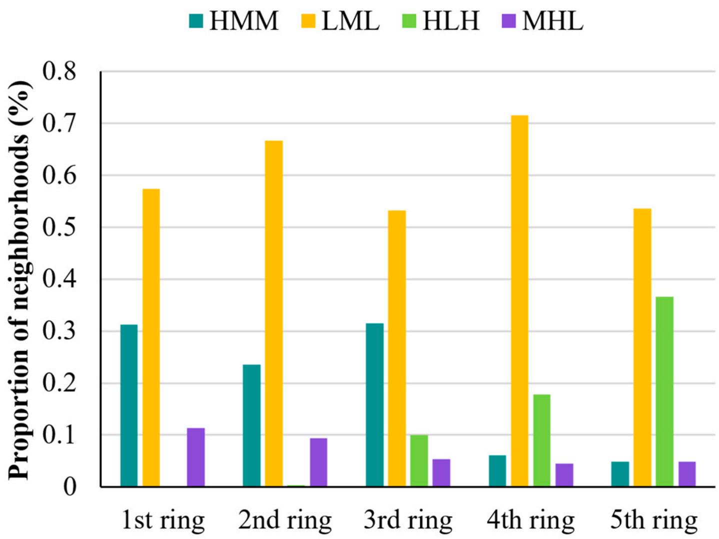


Figure 8. Statistical analysis across urban rings of the proportion of four accessibility types of neighborhoods.

6. Discussion

The output of this study is primarily threefold. One is the improved modeling of urban park accessibility combined with the application of multi-source big data and site survey data, the second is to explore a comprehensive and systematic procedure for urban park accessibility analysis and equity evaluation and the third is the empirical findings and solutions for decision making at multiple urban scales in Zhengzhou.

We used a supply–demand improved 2SFCA method to evaluate spatial accessibility and equity, particularly introducing the attraction coefficient of parks and selection probability of residents, which has been statistically validated against empirical results based on traditional 2SFCA methods [24]. Specifically, for our study, the attraction coefficient of parks combined the park size, category and quality based on efficient big data and on-site investigation data. Selection probability of residents among multiple available parks was quantified by combining the park attractiveness and travel impedance. This was applied as selection weights to both steps of the model to fit possible supply and demand relationship. In terms of the demand, the population of the neighborhood-scale unit was estimated based on residential building attributes (including footprint area and floors) derived from map service platform, rather than rough administrative unit demographics. Additionally, we used travel time instead of travel distance to measure travel cost based on real-time navigation data, which can more accurately reflect the actual travel situation of residents and is relatively more convenient than traditional data collection. Overall, the accuracy of the park accessibility measurement has been improved in terms of both the model and data. Then, the spatial patterns, differences, and causes of park accessibility were further examined by K-means cluster analysis. By clustering the results of five main factors (accessibility, average travel time, population density, total park size, and total park quality index), we got integrated spatial patterns of supply, demand, and accessibility for neighborhoods and thus revealed how these regions differ from each other. This study illustrates the feasibility and limitations of the research framework for park accessibility and equity evaluation in the central urban area of Zhengzhou, which can be flexibly applied to other cities with the use of appropriate data following the approach.

The results reveal, both spatially and statistically, that the access to parks in Zhengzhou is generally unevenly distributed among neighborhoods and between urban rings. Additionally, the cluster analysis identified four types of neighborhoods as well as causes behind the spatial accessibility differences. Specific to different types of regions, the following solutions may help reduce spatial disparity in urban park accessibility. First, parks should be increased or expanded for underserved neighborhoods. Regarding neighborhoods in crowded built environments, surrounding underused and neglected land can be efficiently used to increase pocket parks while reducing travel time [57]. Second, for densely populated neighborhoods, limited opening of nearby high-quality green enclosures or the application of dual-use parks on certain types of open spaces (such as schoolyards and rooftops) can well balance the supply and demand of parks [58]. Third, as the quality of a park can significantly impact visitor numbers [17,26,59], unpopular parks should be improved by involving community members in the park development process with regard to renovation and management [57], including increasing the diversity of facilities and amenities, enhancing the appeal of landscape features, and paying attention to maintenance. Fourth, in areas with higher travel time, road connectivity between parks and surrounding neighborhoods can be improved by increasing sidewalk density and adding entrances to large parks. Specifically, better connections over the railway axes could facilitate improved park accessibility. Finally, residential area planning should be integrated with urban park allocation to manage land use patterns around parks from the perspective of urban planning, so that parks can fully serve the nearby residents.

This research has several limitations that may be addressed in the future. First, it uses a unified indicator system to characterize park attractiveness to the whole population, regardless of the visitor preferences of different groups in terms of park quality and type. With the help of a detailed social survey, a pre-analysis of residents' park usage behavior and opinions of various groups can better reflect their subjective needs for parks. Second, numerous studies have shown that the distribution of urban parks tends to differ between different social groups [10,17,54,60]. Therefore, combined with detailed demographic data, comparative studies of park accessibility across age or income groups can be conducted to reveal underserved groups and then develop proper strategies to achieve social equity in parks. Third, transit to parks by other modes, including public transport and personal cars, was not considered, while several related studies have confirmed different results [11,50,55]. Additionally, with the exception of walking in the walkable concept, access to parks on bicycles, skates, etc., may be appreciated, but was rarely discussed, which can be incorporated into studies to match the specific situation of park visits in different cities. Finally, based on survey data or urban big data, such as mobile phone data and social media data, of residents' actual park visits, the match between calculated accessibility and actual access can be measured to further verify the accuracy of our accessibility evaluation.

7. Conclusions

In this study, an attempt was made to establish a comprehensive and systematic procedure for urban park accessibility analysis and equity evaluation by applying a supply-demand improved 2SFCA model and K-means cluster analysis, based on multi-source data. Accordingly, we conducted a case study at the neighborhood scale and urban ring scale in the central urban area of Zhengzhou. The results show that access to parks is not equitable among neighborhoods across the city. In addition, the mean and standard deviation of accessibility both show an increasing trend from the center to the periphery. All the neighborhoods are broadly clustered into four accessibility types, each with different characteristics and causes. The spatial distribution of accessibility types has both similarities and differences between urban rings. An equity study on park accessibility could guide decision makers and urban planners to target underserved neighborhoods and formulate effective policies and strategies aimed at urban park equity.

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Are Cave Houses a Sustainable Real Estate Alternative?

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Abstract: The high level of energy consumption of buildings has outlined the need for more sustainable and environmentally friendly constructions, which has led to cave houses now being more highly valued. This study looks to study whether sustainable constructions, such as cave houses, have an economic impact with regard to other construction types in the real estate market in Granada. Moreover, this study looks to determine whether energy rating is a relevant characteristic for the price of cave houses and whether the price determinants vary according to whether the house in question is a cave house or a single-family one. To develop this study, a final sample of 61,573 properties was used. A regression model estimated by ordinary least squares was performed. This study shows that cave houses are being marketed at higher prices than single-family houses. It was noted that energy rating is not an important characteristic for estimating the price of a cave house. Finally, in this type of housing, refrigeration equipment is not one of the determining characteristics for the price.

Keywords: cave houses; hedonic regression model; house sale prices; price determinants; energy rating

1. Introduction

In the history of architecture, caves were man's first refuge or house, and, despite now being in disuse, they were once one of the most widespread construction types in the world. Housing, since its beginnings, has been evolving and adapting throughout the centuries according to the human and social needs of the time; structures were made with local materials and techniques and were adapted to the local climate. Both the industrial revolution and the huge demographic explosion caused excessive urban development [1], which resulted in the current worldwide problem of high energy consumption in buildings, being above both the transport and industry sectors [2]. This consumption is mainly due to the demand for electricity needed for a heating, ventilation, and air-conditioning (HVAC) system and the use of household appliances [3].

The main result of this has been the implementation of politics that favor the improvement of energy efficiency in the European Union (EU) [4–7], which have been integrated into a series of decrees in Spain [8,9]. As a result, there is a need to look for more sustainable and environmentally friendly construction solutions.

Cave houses are considered to be a sustainable housing typology as they are built using a construction type that utilizes the thermal inertia of the land. As a result, the interior temperature of the house scarcely changes throughout the different seasons of the year, which allows for thermal comfort to be ensured in the interior of the house without the need for additional energy inputs (air-conditioning or heating) [10,11]. Cave houses are also considered sustainable because of the combination of social, economic, and cultural factors [12–14].

There are different studies on cave houses (Figure 1a) that address different lines of research, such as: (1) the importance of preserving and maintaining architectural heritage [15,16]; (2) the importance of assessing the application of bioclimatic strategies used for cave houses in present-day constructions [17]; (3) the importance of analyzing thermal comfort or whether the ventilation in cave houses is adequate; [10,18–25]; and (4) the psychological and physiological problems associated with this type of construction [26,27].

(**a**)

(**b**)

Figure 1. (**a**) Cave house in the Baza area. (**b**) Single-family houses in Guadix town. Source: own elaboration.

Moreover, several studies have been carried out in which it has been noted that the buyers of single-family houses (Figure 1b) are willing to pay more if a house is more efficient [28–42]. A broader overview regarding housing prices and energy ratings can be found in the work by [43,44].

Cave houses are excavated in the rock itself, normally with vaulted forms for a better transmission of the upper loads, and may or may not have attached constructions. They are made up of one or more cavities where the usual activities and living and sleeping are carried out. The walls and vaulted ceilings are finished with a lime coating and the most rustic pavements are made with the ground itself or with a layer of cement. As a consequence of the current housing needs, these constructions have been adapted and improved, increasing the number of interior spaces and improving the qualities and facilities.

The single-family houses are characterized by having a structure based on load-bearing walls or reinforced concrete structures. They are usually distributed in a living–dining room, kitchen, bathroom and bedrooms. The most common materials used are ceramic bricks covered with plaster for the vertical partitions; the floors are usually made of natural or artificial stone, ceramic tiles or wood; and the ceilings can be made of plaster or plasterboard.

Vernacular architecture is one of the most widespread types of architecture in Spain and is specifically used for housing. Authors such as [45–48] have confirmed that society has changed its attitude towards cave houses and considers this type of construction to be sustainable. However, has this change in attitude been reflected in the asking price of this type of construction? As far as the authors are aware, there have been no studies that analyze the prices of cave houses. The lack of results in the literature has resulted in new research questions. Firstly, as cave houses are considered sustainable, does this mean that they are marketed at higher prices than single-family houses? Secondly, is energy rating a relevant characteristic for cave houses? Thirdly, if the interior of a cave house is maintained at a constant temperature throughout the year, would an HVAC system be a price-determining feature?

The main objective of this study was to determine the economic impact that cave houses have with regard to single-family houses in the real estate market in the province of Granada (Spain). The secondary objective of this study was to understand whether energy rating and HVAC systems are relevant characteristics when determining the price of a cave house.

The first hypothesis that was put forward for the study (H_1) was that cave houses are being marketed at higher prices than single-family houses. The second hypothesis that was proposed (H_2) was that energy ratings for cave houses are a relevant characteristic. The third hypothesis generated (H_3) was that the availability of an HVAC system is not a determining characteristic for the price of cave houses. However, it is for single-family houses.

The estimates made from the regression model showed that cave houses are marketed at higher prices than single-family houses. It was also observed that energy ratings and the availability of air-conditioning are not determining characteristics for the price of cave houses.

This document is organized as follows: the first section includes the introduction, objectives and hypotheses. The second section denotes the materials and the methods used, outlining the sources that were employed and the database generated. The third section details the results. The fourth section denotes the discussion, and finally, Section 5 explains the conclusions obtained.

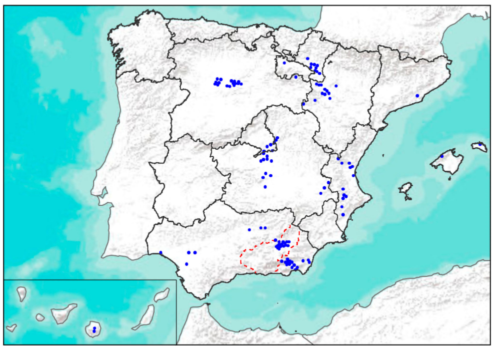
2. Materials and Methods

To understand what characteristics determine the asking price of a house, an ordinary least squares (OLS) hedonic regression model was performed. This type of analysis began to be used with the "New Consumer Theory" developed by Lancaster [49]. Later, Ridker and Henning [50] used the regression model in the housing market for the first time. Authors such as Zietz et al. [51] noted that a hedonic regression analysis is typically used to identify the marginal effect that a set of characteristics has on housing prices. In terms of heterogeneous goods such as housing, the hedonic methodology allows for the effect of each characteristic on the price to be estimated [52]. Currently, this is one of the most used methodologies for determining the economic premium generated by different characteristics.

2.1. Population and Sample

The database consisted of cave houses and single-family houses offered for sale in the province of Granada (Andalusia). This province is located in the south of Spain and has 10 regions or *comarcas* [1] (Figure 2a).

(**a**)



(**b**)

Figure 2. (**a**) Map of the Granada province with the delimitation of the *comarcas* and municipalities (own elaboration); (**b**) Towns with cave dwellings in Spain, own elaboration based on [12] (p. 3, Figure 2).

The interest and selection criteria for this territory were due to the fact that cave houses are a traditional construction in Spain. The province of Granada and the province of Almería have the highest concentration of cave houses and have developed them the most in the country [45,53] (Figure 2b).

The representativeness of the sample was verified using the equation for large or infinite populations when the exact size of the component units is unknown [54]. Using a confidence level of 95% ($z_{\alpha/2} = 1.96$), a probability level of $p = 0.50$ and a sample size of $N = 61{,}573$, a maximum error of 0.39% (0.0039) was estimated, which guaranteed a high statistical precision of the sample.

The main information sources were two real estate portals. The first was *idealista*, which was used between June 2017 and March 2018, and the second was *habitaclia*, which was used between June 2019 and January 2021. During these time periods, information on the houses offered was collected, and data about the characteristics of the houses were extracted. A geographic information system (GIS) was then used to provide the location and neighborhood information from other sources of information. Data from the population and housing census tract by the National Institute of Statistics were used [55]. Each house was assigned information about the type of occupation (vacant, main residence and second residence) as well as the socio-demographic characteristics of the population (dependency, aging, foreign population and level of education).

The research had several limitations. Firstly, a limitation was the lack of information from official sources about the real transaction prices and housing characteristics. Another limitation was the possible errors in the information or the omission of information on the prices and/or characteristics of the houses that were offered on the two real estate portals.

With regard to the first limitation, authors such as [56–59] suggest that real estate asking prices are an adequate substitute for transaction prices. Moreover, there are studies that analyze the effect of the housing characteristics on the price, using listing price information from real estate portals due to the lack of information from other official sources [35,39,60–64].

In terms of the second limitation, the data was preprocessed so that properties with missing data could be identified and discarded. As a result, 3030 properties were discarded. To identify the atypical values in the quantitative variables, a limit of three standard deviations was established for the set of values [65,66]. As a result, 595 properties were discarded. The final sample consisted of 61,573 properties.

2.2. Data

To identify the most important variables in the estimate of the single-family house prices, a literature review was carried out, which is shown in Table 1.

Table 1. Variables used by other authors for the determination of single-family house prices.

Category	Characteristics	References
House characteristics	*House surface area*	[51,67–74]
	Number of bedrooms	[70,71,75,76]
	Number of bathrooms or toilets	[69–72,76,77]
	Availability of air conditioning	[51,69,70]
	Availability of heating	[69,76–79]
	Availability of fireplace	[71,72,76,77,80]
	Availability of built-in closets	[81,82]
	Availability of furniture	-
	Newly built housing	[83–85]
	House typology	[71,74,75,86,87]
	Parking	[70,76,77,80]
	Garden	[51,67,68]
	Swimming pool	[51,69,74,77,80,84]
	Energy rating	[34,38,41,75,86,88]
Location characteristics	*Location within the territory or the city*	[67,68,74–77,86]
Neighborhood characteristics	*Age of the population*	[37,89,90]
	Number of foreigners	[87,89,91]
	Level of studies	[79,87,92]
	Type of house occupancy	[71,72,79]

Based on the information received, 40 variables were obtained, as summarized in Table 2. The variables were ordered according to three categories. House characteristics (A); Location characteristics (B); and Neighborhood characteristics (C). The unit with which each variable was measured, a brief description of the variable and the descriptive statistics are indicated.

Table 2. Set of variables that make up the study, with their units, description and descriptive statistics.

Category	Variable	Unit	Variable Description	Continuous Variables				Dummies Variables		
				Mean	*SD*	Min.	Max.	Coding.	Freq.	%
	Ln_Price	numerical	Dependent variable. The natural log of the property price offered by the seller (in EUR).	12.105	0.668	9.2	14.8			
House characteristics (A)	*Area_m2*	numerical	Built area of the house (sqm), gross square meters of the house.	214.854	111.884	20.0	1746.0			
	Bedrooms	numerical	Number of bedrooms in the house.	3.806	1.375	1.0	29.0			
	Bathrooms	numerical	Number of bathrooms.	2.348	1.023	0.0	11.0			
	Toilets	numerical	Number of toilets.	0.193	0.456	0.0	10.0			
	Air_cond	dummy	Availability of air conditioning (=1).					(1) With	21,005	34.1
	Heating	dummy	Availability of heating (=1).					(1) With	24,170	39.3
	Fireplace	dummy	Availability of fireplace (=1).					(1) With	2080	3.4
	Closet	dummy	Availability of built-in closets (=1).					(1) With	5458	8.9
	Furnished_house	dummy	Availability of furniture (=1).					(1) With	3768	6.1
	New_construction	dummy	Newly built housing that can be: a project, under construction, or less than 3 years old (=1).					(1) With	343	0.6
	Cave_house	dummy	Indicates whether the property has this typology (=1).					(1) With	440	0.7
	Parking	dummy	Availability of garage slot (=1).					(1) With	37,618	61.1
	Garden	dummy	Availability of garden (=1).					(1) With	6219	10.1
	Pool	dummy	Availability of swimming pool (=1).					(1) With	22,482	36.5
	Letter_A	dummy	Indicates if the dwelling has an energy rating: letters A, B, C, D, E, F or G, or has no energy rating label.					(1) With	285	0.5
	Letter_B	dummy						(1) With	166	0.3
	Letter_C	dummy						(1) With	279	0.5
	Letter_D	dummy						(1) With	1021	1.7
	Letter_E	dummy						(1) With	2923	4.7
	Letter_F	dummy						(1) With	684	1.1
	Letter_G	dummy						(1) With	1066	1.7
	Not_EPC	dummy						(1) With	55,149	89.6
Location characteristics (B)	*Alhama*	dummy	Identifier of the *comarca*: *Alhama*, *Alpujarra Granadina*, *Baza*, *Costa Granadina*, *Guadix*, *Huéscar*, *Loja*, *Los Montes*, *Valle de Lecrín* and *Vega de Granada*.					(1) With	520	0.8
	Alpujarra_Granadina	dummy						(1) With	886	1.4
	Baza	dummy						(1) With	651	1.1
	Costa_Granadina	dummy						(1) With	5137	8.3
	Guadix	dummy						(1) With	603	1.0
	Huescar	dummy						(1) With	230	0.4
	Loja	dummy						(1) With	1073	1.7
	Los_Montes	dummy						(1) With	462	0.7
	Valle_Lecrin	dummy						(1) With	2240	3.6
	Vega_Granada (Ref.)	dummy						(1) With	49,771	80.8
Neighborhood characteristics (C)	*Dependency_ratio*	numerical	Dependency ratio (sum of the population aged >64 and <16/population aged 16–64).	0.474	0.133	0.0	1.8			
	Elderly_index	numerical	Aging index (population aged >64/population aged 0–15).	0.836	0.863	0.0	11.5			
	Foreigners_pct	numerical	Percentage of foreign population.	6.152	7.183	0.0	52.6			
	No_studies_pct	numerical	Percentage of population without education.	8.449	6.620	0.0	44.8			
	University_pct	numerical	Percentage of the population with university studies.	18.780	10.822	0.0	58.5			
	Secondary_pct	numerical	Percentage of vacant dwellings and secondary.	12.537	14.273	0.0	81.9			
	Vacant_pct	numerical		18.058	9.711	0.0	75.7			

Figure 3 shows the location of the cave houses (Figure 3a) and single-family houses (Figure 3b) analyzed within the territory. Regarding the distribution of prices, it can be noted that in the center of Granada and on the coast, unit prices (€/m^2) are higher than in the rest of the regions of the province (Figure 3c,d). At the same time, it can also be noted that there is a higher percentage of cave houses with high ratings (letters A, B and C) with respect to the sample of single-family houses (Figure 3e,f).

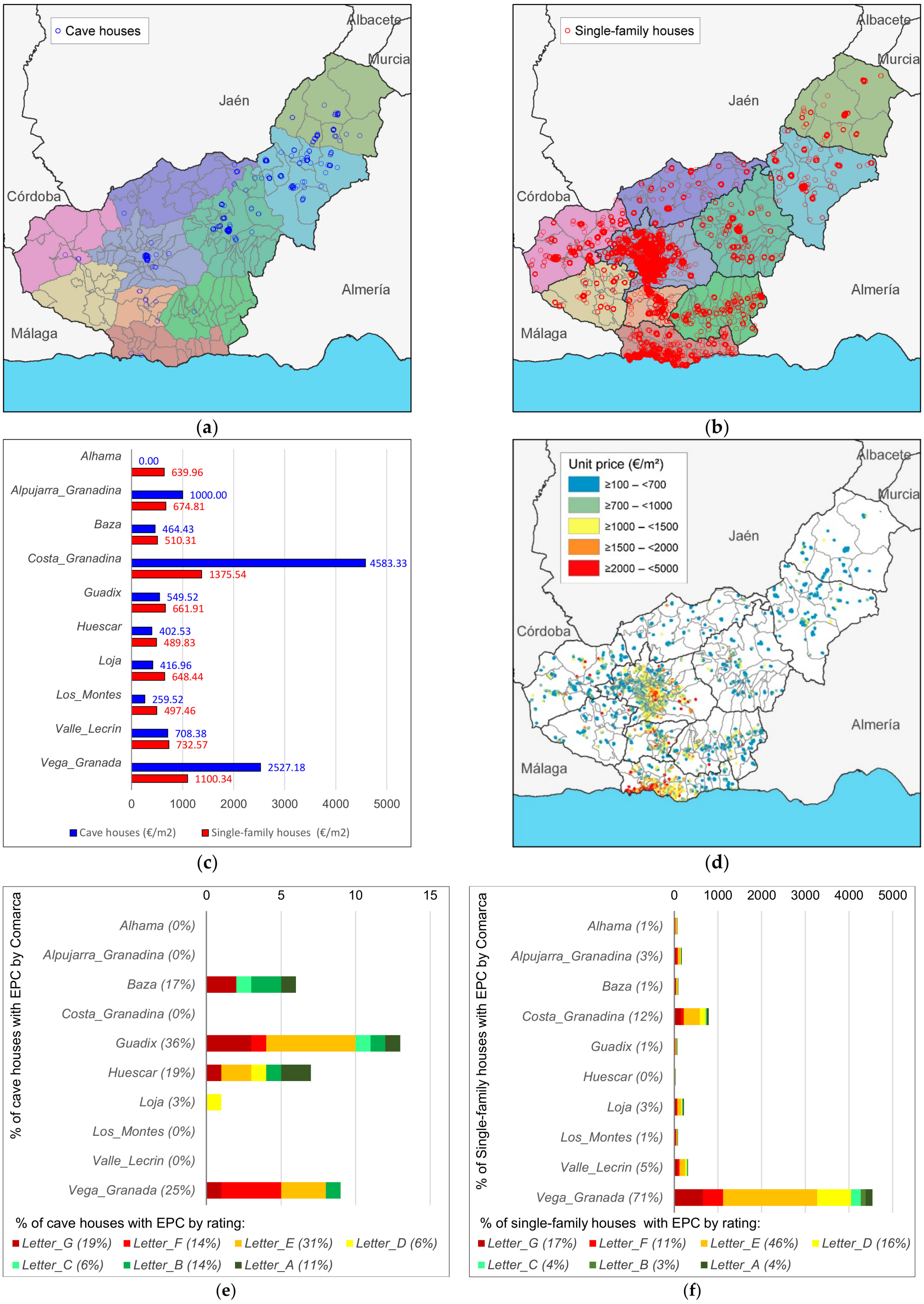


Figure 3. (**a**) Spatial distribution of cave houses; (**b**) Spatial distribution of single-family houses; (**c**) Bar chart with unit prices according to house typology and *comarca*; (**d**) Kernel density map with unit prices of the complete sample of houses (euros/m^2); (**e**) Chart of the energy rating distribution of cave houses by *comarca*; (**f**) Chart of the energy rating distribution of single-family houses by *comarca*.

2.3. Methodology

The regression model was estimated by ordinary least squares (OLS) with a semi-logarithmic functional form, as this facilitated the interpretation of the coefficients as average percentage premiums. Moreover, this reduced problems of heteroscedasticity and improved the goodness of fit of the data [58,93]. The model used had the following expression:

$$ln(P_i) = \alpha + \sum_{j=1}^{n} \beta_j X_{ij} + \sum_{k=1}^{m} \gamma_k D_{ik} + \varepsilon_i \quad (1)$$

where:

$ln\ (P_i)$ is the natural logarithm of the advertised asking price for the house "*i*";
α is the fixed component, it does not depend on the market;
β_j is the parameter to estimate related to the characteristic "*j*";
X_{ij} is the continuous variable that collects the characteristic "*j*" of the observation "*i*";
Y_k is the parameter to estimate related to the characteristic "*k*";
D_{ik} is the dummy variable that collects the characteristic "*k*" of the observation "*i*";
ε_i is the error term in the observation "*i*".

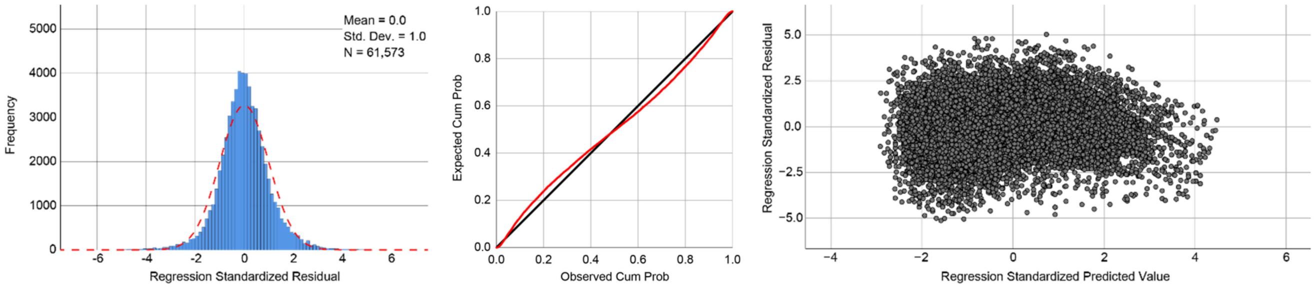
The model was estimated three times. The first estimate was for the complete set of observations. The other two estimates corresponded to the subsamples according to whether the houses were cave houses or single-family houses. This was in such a way that the results obtained made it possible to compare the determining characteristics for each group. The SPSS for Windows version 26 IBM Corp. statistical package [94] was used to perform this analysis, using the listwise deletion method.

3. Results

Regression Analysis

To determine whether the estimates reach the adequate level of quality, the following checks were carried out: the normality of the population; ensuring that there are no specification problems in the estimates (no multicollinearity, heteroscedasticity or autocorrelation); the statistical significance of the estimates; and, finally, whether the proportion of variance estimated is high (R^2).

The normality of the population was tested through the use of a histogram (Figure 4a) and a normality plot of the residuals (Figure 4b), which showed that the sample is a normal distribution. Multicollinearity was verified by using the VIF statistic (variance inflation factor). Many authors suggest that collinearity problems exist if any VIF is greater than 10 [95,96]. In the three estimates carried out, the majority of the VIF values are found to be between 1 and 3.5, which leads to the conclusion that there are no problems due to multicollinearity. Heteroscedasticity is analyzed with a scatter plot of the residuals (Figure 4c), and no serious problems of heteroscedasticity are found, showing a random distribution of the residuals. The existence of autocorrelation is checked with the Durbin–Watson statistic, obtaining the closest values to two in all the estimates, suggesting the absence of autocorrelation in the residuals [97,98]. The significance of each estimate is measured with the Snedecor's F test and is statistically significant. The coefficient of determination (adjusted R^2) of the estimates is shown in Table 3. and an explanatory power of 69% is obtained for estimates 1 and 3 and 81% for estimate 2. In summary, it can be said that the estimates reach a sufficient level of robustness and statistical significance to make them acceptable for inference.



(**a**) (**b**) (c)

Figure 4. Graphs of the estimate 1: (**a**) Histogram and normal curve of the standardized residual error; (**b**) Normal P-P plot of regression standardized residual; (**c**) Scatter plot of the predicted values and standardized errors.

Table 3. OLS model results for the different estimates depending on the selected sample (Estimate 1: full sample; Estimate 2: cave houses and Estimate 3: single-family houses).

Category	Variable	Estimate 1: Full Sample	Estimate 2: Cave Houses	Estimate 3: Single-Family Houses
	Intercept	10.536 *** (0.011)	10.633 *** (0.304)	10.539 *** (0.011)
House characteristics (A)	*Area_m2*	0.002 *** (0.000)	0.001 *** (0.000)	0.002 *** (0.000)
	Bedrooms	0.026 *** (0.001)	0.038 ** (0.014)	0.025 *** (0.001)
	Bathrooms	0.157 *** (0.002)	0.238 *** (0.025)	0.154 *** (0.002)
	Toilets	0.108 *** (0.004)	0.092 (0.065)	0.108 *** (0.004)
	Air_cond	0.053 *** (0.003)	–0.012 (0.067)	0.054 *** (0.003)
	Heating	0.114 *** (0.004)	0.472 *** (0.079)	0.113 *** (0.004)
	Fireplace	–0.004 (0.009)	0.134 * (0.067)	–0.006 (0.009)
	Closet	0.067 *** (0.006)	0.139 (0.084)	0.066 *** (0.006)
	Furnished_house	0.071 *** (0.006)	0.299 *** (0.086)	0.068 *** (0.006)
	New_construction	0.069 *** (0.020)	–	0.069 *** (0.020)
	Cave_house	0.053 ** (0.019)	–	–
	Parking	0.081 *** (0.003)	0.157 * (0.062)	0.083 *** (0.003)
	Garden	0.097 *** (0.006)	0.101 (0.086)	0.098 *** (0.006)
	Pool	0.198 *** (0.004)	0.149 (0.101)	0.200 *** (0.004)
	Letter_A	0.090 *** (0.023)	0.311 (0.275)	0.086 *** (0.023)
	Letter_B	0.139 *** (0.030)	0.179 (0.259)	0.142 *** (0.030)
	Letter_C	0.006 (0.024)	0.379 (0.364)	0.005 (0.023)
	Letter_D	0.052 *** (0.014)	–	0.052 *** (0.014)
	Letter_E	Ref.	Ref.	Ref.
	Letter_F	–0.011 (0.016)	–0.096 (0.263)	–0.014 (0.016)
	Letter_G	–0.073 *** (0.013)	0.359 (0.233)	–0.076 *** (0.013)
	Not_EPC	0.047 *** (0.007)	0.085 (0.147)	0.047 *** (0.007)
Location characteristics (B)	*Alhama*	–0.315 *** (0.017)	–	–0.316 *** (0.017)
	Alpujarra_Granadina	–0.337 *** (0.014)	–	–0.336 *** (0.014)
	Baza	–0.472 *** (0.016)	–0.646 *** (0.167)	–0.444 *** (0.017)
	Costa_Granadina	0.211 *** (0.007)	–	0.213 *** (0.007)
	Guadix	–0.262 *** (0.016)	–0.464 ** (0.164)	–0.233 *** (0.017)
	Huescar	–0.545 *** (0.026)	–0.779 *** (0.183)	–0.484 *** (0.028)
	Loja	–0.179 *** (0.013)	–	–0.179 *** (0.013)
	Los_Montes	–0.394 *** (0.019)	–	–0.383 *** (0.019)
	Valle_Lecrin	–0.174 *** (0.009)	–	–0.174 *** (0.009)
	Vega_Granada	Ref.	Ref.	Ref.

Table 3. *Cont.*

Category	Variable	Estimate 1: Full Sample	Estimate 2: Cave Houses	Estimate 3: Single-Family Houses
Neighborhood characteristics (C)	*Dependency_ratio*	0.146 *** (0.013)	0.075 (0.243)	0.151 *** (0.013)
	Elderly_index	0.041 *** (0.002)	–0.111 ** (0.038)	0.042 *** (0.002)
	Foreigners_pct	0.007 *** (0.000)	0.020 *** (0.005)	0.006 *** (0.000)
	No_studies_pct	–0.003 *** (0.000)	0.001 (0.006)	–0.003 *** (0.000)
	University_pct	0.018 *** (0.000)	0.014 * (0.006)	0.018 *** (0.000)
	Secondary_pct	–0.001 *** (0.000)	–0.001 (0.003)	–0.001 *** (0.000)
	Vacant_pct	–0.0004 * (0.0002)	0.0002 (0.0027)	–0.0004 * (0.0002)
	N	61,573	413	61,133
	R^2	0.686	0.822	0.685
	adj. R^2	0.685	0.809	0.685
	Std. Error	0.375	0.460	0.373
	F (*sig.*)	3625.41 (0.000)	63.23 (0.000)	3586.14 (0.000)
	Durbin-Watson	1.806	1.859	1.803

Notes: dependent variable *Ln_price*; signification: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; Standard errors in parentheses.

The results of the different estimates of the regression model are shown in Table 3. The results obtained for estimate 1 of the model are described, as they correspond to the complete sample. With respect to the housing characteristics, the model estimates that increasing one square meter of floor space leads to a price increase of 0.2%, while the inclusion of an additional bedroom, bathroom or toilet leads to an increase of 2.6%, 15.7% and 10.8%, respectively. The average price impact of a house including extras such as air-conditioning, heating, built-in closets or being sold furnished was estimated by the model as having an increase of 5.3%, 11.4%, 6.7% and 7.1%, respectively. A house being a new construction (less than 3 years) leads to an increase in the price of 6.9%. The values obtained in the estimate of the parameters related to other characteristics, such as a house having a garage, garden or pool, lead to an average price increase of 8.1%, 9.7% and 19.8%, respectively. If the house is a cave house, the average asking price is 5.3% higher than that of a single-family house.

With regard to energy rating, houses with an E letter rating are taken as a reference. The results show that houses with a high letter rating (letters A and B) have higher economic premiums than other houses with worse ratings or those that do not advertise them (with some of these coefficients being non-significant).

Regarding location, the estimated impact for the price of the houses located in the Costa Granadina *comarca* is an increase of 21.1% in relation to the reference region, which is the Vega de Granada *comarca*. For the other *comarcas*, the model estimates a decrease in the asking prices offered, reaching reductions of between 17.4% and 54.5% with respect to the Vega de Granada *comarca*.

In terms of the neighborhood characteristics, a 1% increase in the dependency ratio and aging ratio leads to a price increase of 0.15% and 0.04%. Regarding the percentage of foreigners or people with university-level studies, the model estimated that an increase of 1% in these variables leads to a price increase of 0.7% and 1.8%, respectively. On the contrary, an increase in the percentage of uneducated people leads to a reduction of 0.3%.

Regarding the type of housing occupancy, the model shows price reductions of 0.1% and 0.04% respectively, in areas with a higher percentage of secondary residences or vacant houses.

In the estimates of the subsamples (estimates 2 and 3), some differences are observed (Figure 5 and Table 3). In the estimate of subsample 2 (cave houses), with regard to the characteristics of the house, only surface area, number of bedrooms and bathrooms, availability of heating, fireplace, furniture in the house and parking have positive and significant premiums. Other variables are not significant, such as the number of toilets, the availability of air-conditioning, built-in closets, a garden and a swimming pool. With regard to the energy rating, all the variables are non-significant, which may highlight that this characteristic is not relevant in this market segment. In terms of location, there are four *comarcas* that do not have a sufficient number of observations and are consequently discarded from the estimate. Using the Vega de Granada *comarca* as a reference, the houses situated in Baza, Guadix and Huéscar have an average price reduction of between 46.4% and 77.9%. In terms of the neighborhood characteristics, only the variables regarding the aging index, foreigners and those with university studies are significant. Finally, the occupation-type variables are not significant.

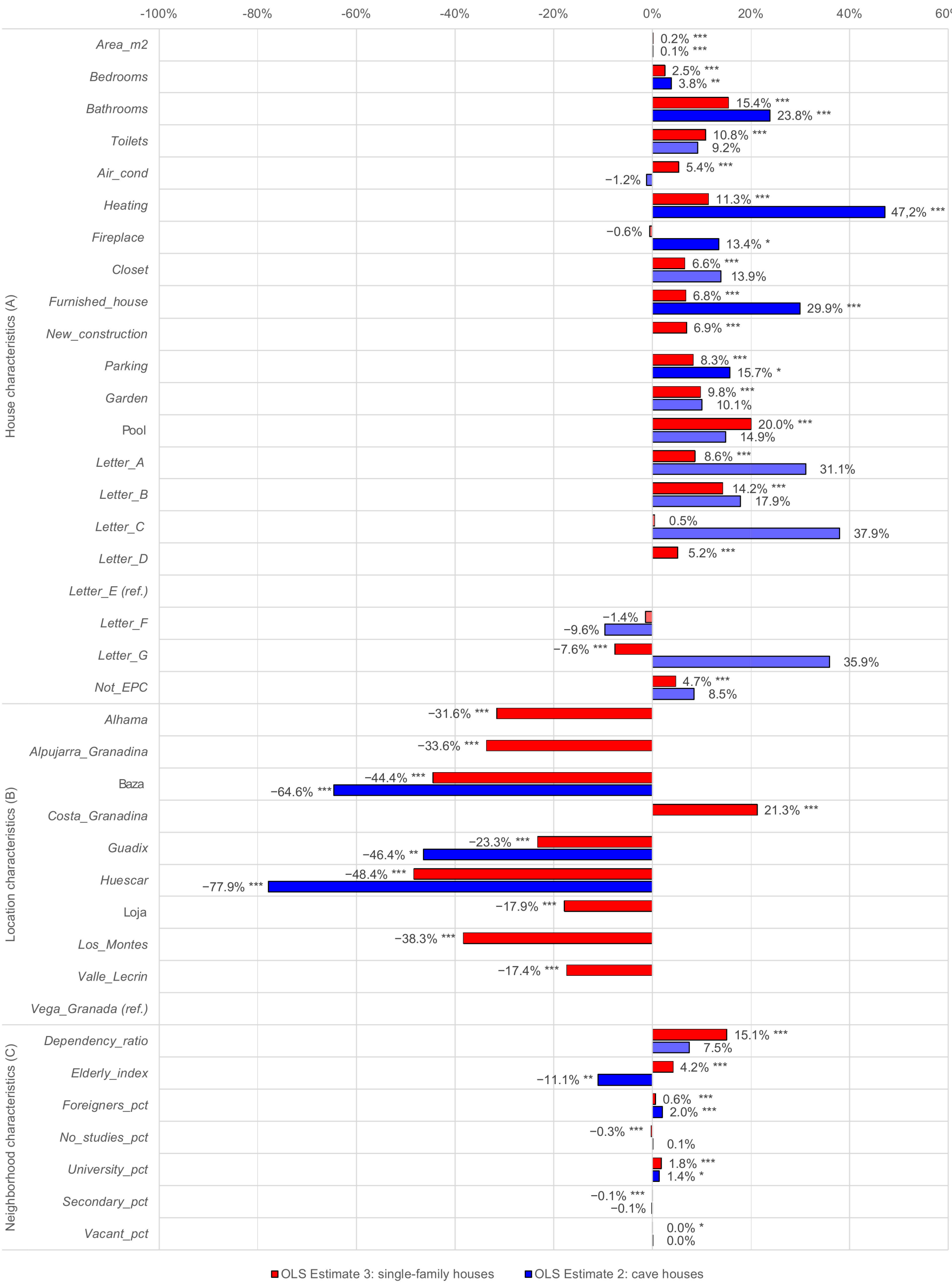


Figure 5. Bar chart with the regression coefficients (in %) of estimate 2 (sample of cave houses) and estimate 3 (sample of single-family houses). Notes: dependent variable *Ln_price*; signification: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

4. Discussion

Regarding the first objective, the aim is to determine the economic impact of cave houses, as opposed to single-family houses, and, as such, the first hypothesis—H1—is proposed. Estimate 1 confirms this hypothesis since cave houses are marketed 5.3% more expensive than single-family houses. This may be due to several factors. It is possible that this is due to a greater interest in exploiting these houses for short-term rental, as can be seen in platforms such as Booking or Airbnb, with a high supply of these homes and tourist resorts in prominent areas such as Huéscar, Guadix, Baza or Granada. This tourist interest was already highlighted by Urdiales [45] in 2003, being a movement initiated in the 1990s and mainly led by foreign promoters. Another main factor may be a consequence of foreign buyers who want to establish their residence in Spain. As can be seen in estimate 2, the incidence of the percentage of foreigners in the price of cave houses is higher than in estimate 3 for single-family houses. This suggests that there is a positive relationship between the price of cave housing, the existence of cave house offers and the presence of a higher foreign population.

In addition to the above factors, there are other aspects that have enhanced the value of this type of housing:

- Firstly, it may be due to the effort made for many years by different public entities that have been able to promote the tourist value of cave houses through different projects and financing initiatives such as the Rural Development Leader programs I, II, and +, the Proder Operational Programs I and II for the Development and Economic Diversification of Rural Areas [99,100], and the Eurocuevas Project, launched by the provincial council of Granada, which has received financial aid from the European Union under the European Regional Development Fund—ERDF—and has had the following results: (a) the creation of an international association of caves [101]; (b) the creation of an interpretation center in the cave houses of Benamaurel [102]; (c) the start of the first phase of creating an inventory of cave houses in the province, which involves a series of provincial plans that improve the urban environment of cave houses [103–105]; and (d) the drafting of a manual for intervention in cave houses, with the aim of providing municipal technicians with tools to be able to carry out renovation work or new construction [106]. Moreover, Andalusia is one of the first autonomous communities to regulate the cave house typology through the Law for the Promotion of Territorial Sustainability in Andalusia [107].
- Secondly, there are construction technicians who are trying to promote the renovation of cave houses by producing documents that outline the necessary process to render them legal and the considerations that must be adopted in order to adapt this type of construction to the national regulations, that is, the Technical Building Code, which regulates the basic requirements [47,108].
- Thirdly, the promotion and distribution of this type of construction through the design of a cave house with the "ideas competition" promoted by the project "La Herradura" of Huéscar with the participation of the international research group "Aedificatio" from the University of Alicante, the City Council of Huéscar, and the Rural Development Group of the Altiplano de Granada, with the support of Forum UNESCO—University and Heritage [109].

Through the second objective, we propose to identify whether the energy rating is a relevant characteristic of cave houses, and, as such, the second hypothesis—H2—is proposed. Estimate 2 rejects this hypothesis. Regarding energy rating, a very small percentage of the sample provides information about the energy rating; around 8% of cave houses and 11% of single-family houses. The result about energy ratings for the cave house sample suggests that this characteristic is not relevant for the estimation of house prices. These results could be due to the fact that sellers and buyers know the thermal advantages of cave houses, which is why the letter of the energy rating is not taken into consideration in this typology. Therefore, it would be interesting to gather data in different sociocultural and economic contexts on the population of Granada to analyze the perception they have about the energy rating of cave houses and identify whether they are aware of the energy-saving potential of this typology against other houses. In contrast, in single-family houses, values in energy rating premiums are estimated in accordance with the literature, since houses with high—letters A and B—ratings obtain positive premiums of 8.6% and 14.2%, respectively. Houses with a low rating—letter G—receive a negative premium of 7.6%.

Regarding the HVAC systems, the third hypothesis—H3—is proposed. Estimates 2 and 3 (Table 3 and Figure 5) confirm that the availability of air-conditioning is not a determining characteristic at the time of buying a cave house. However, the availability of heating or a fireplace is a determining characteristic. The reason for these results may be because cave houses, as opposed to other typologies such as single-family houses, have a ground enclosure that has high thermal inertia and reduces heat gains in the summer, meaning it would not be necessary for these houses to have air-conditioning. However, the availability of air-conditioning is in fact a determining characteristic in terms of the price of single-family houses (with an economic premium of 5.4%). At the same time, cave houses reduce heat loss in winter due to the conduction of the enclosure (high density of the soil). This is in such a way that those cave houses that have heating have an economic premium that is four times that of single-family houses that are in similar condition (11.3% compared to 47.2%). Similarly, in cave houses, the availability of a chimney is positively valued (13.4%) since, as suggested by many authors [15,24,110], it is one of the characteristics of caves in Granada, while in single-family houses, this is not a determining characteristic.

With regard to neighborhood characteristics, cave houses increase in price three times more than single-family houses if they are located in areas with a higher percentage of foreigners. This price difference between typologies may be due, in the first place, to cave houses not being accepted by the local population for either socioeconomic or cultural reasons [45,110,111]. Secondly, as noted by Mejías del Río [48], at the end of 1990, an economic sector orientated toward foreigners was developed and was dedicated to the renovation and sale of cave houses.

In contrast, in areas where there is a high population of elderly people, the price premium of cave houses is four times lower than that of single-family houses. This difference in premiums may be due to these areas being depopulated, unequipped, and unattractive [112]. Lastly, the percentage of people with university studies has the same impact on cave houses as it does on single-family houses.

5. Conclusions

This study looks to study whether sustainable constructions, such as cave houses, have an economic impact with regard to other construction types in the real estate market in Granada. In addition, it is determined whether the energy rating and air conditioning systems are relevant characteristics in determining the price of cave houses. As far as the authors are aware, there have been no studies that analyze the prices of cave houses.

To carry out the research, a regression model estimated by ordinary least squares is used, using a sample of 61,573 properties offered for sale, both single-family houses and cave houses. Real estate prices have been collected in two time periods between 2017 and 2021 from two Spanish real estate portals.

In conclusion, society is changing its perception of cave houses and is beginning to consider them to be a sustainable construction typology that allows for significant energy savings (between 23% and 35%) compared to other typologies, according to the results obtained by Kumar, et al. [113]. The consequence of this is that currently cave houses are being marketed at higher prices than single-family houses and the energy rating or the availability of air-conditioning are not determining characteristics of the price.

This study, as previously mentioned, has some limitations due to the lack of information from official resources regarding the transaction prices and the characteristics of the houses. The results are obtained from the people offering houses and refer to a specific place (province of Granada) and cannot be extrapolated to other places.

At the same time, the results are encouraging for the government as it can be considered that the economic aid and the projects carried out are having a significant impact on society, given that the energy crisis is having serious repercussions on energy costs.

This study presents many lines for future research. The first is the opportunity to analyze the perception of the population of Granada in terms of the economic and sustainable advantages of cave houses. The second is the opportunity to analyze the costs of renovating cave houses and complying with construction standards. The third is the opportunity to analyze the prices of cave houses within the tourist sector and the sharing economy.

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Conflicts of Interest: The authors declare no conflict of interest.

Notes

1 A *comarca* is a division of territory comprising several municipalities, forming an intermediate level of administrative subdivision between the municipalities and the provinces.

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Review

Challenges, Experience, and Prospects of Urban Renewal in High-Density Cities: A Review for Hong Kong

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Abstract: Redevelopment in Hong Kong must be accelerated in response to urban decay and land shortages. However, due to a lack of incentives and effective policy tools under Hong Kong's floor area ratio regulations, there has been limited public–private partnerships in the urban renewal process, reducing both the public welfare and the efficiency of land use. We review the evolution of Hong Kong's density schemes for addressing urban redevelopment issues to identify the most important barriers to private sector involvement. We also summarise the international experience and identify viable policies, compare cases in Hong Kong with successful transfer of development rights (TDRs) examples, point out TDRs' shortcomings, and propose targeted policy optimisation strategies. On a practical level, this study has implications for the creation of targeted density policies to address Hong Kong's ageing infrastructure and facilitate the urban transformation of Hong Kong and similar high-density cities so that they can continue to support sustainable urban growth.

Keywords: floor area ratio regulation; urban renewal; transfer of development rights; density relaxation; Hong Kong

1. Introduction

Urban renewal is a significant issue in many nations. In recent years, urban decay, characterised by ageing buildings and a shortage of land for future urban growth, has increased the demand for urban renewal in Hong Kong. In response, the Hong Kong government has issued case-by-case approvals of land premium payment exemptions (through the Urban Renewal Authority) and density relaxations (through the Development Bureau under the Outline Zoning Plan and Building (Planning) Regulations). Nevertheless, a variety of factors are causing sluggish redevelopment momentum. The most prominent of these factors is the contradiction between developers' desire for the high returns associated with high-density development and the reality that only low-density development is possible. Due to the nature of redevelopment in large urban environments, project sites are typically located in historic city centres with high land prices and high population densities, imposing on developers the additional burden of negotiating the transfer of property rights with multiple residents. Additionally, some of Hong Kong's building blocks have plot ratios that are either equal to or higher than the maximum level permitted by existing laws and norms, further constricting developers' profit margins and decreasing the economic potential of their rehabilitation projects. Furthermore, the demands for additional public open spaces and the preservation of sites in Hong Kong's redevelopment areas require developers to design low-density projects, at the expense of profits.

From an economic perspective, Hong Kong's floor area ratio (FAR) regulations reduce private developers' profit incentives to participate in redevelopment projects, while direct fiscal subsidies increase the government's financial burden, and further increase the cost of redevelopment. From a social perspective, some people are dissatisfied with Hong Kong's FAR regulations for urban renewal projects, as they believe they create obstacles to the implementation of redevelopment projects. From an environmental perspective, private developers have insufficient incentives to engage in environmental protection during the redevelopment process. FAR regulation has three main types, including on-site FAR bonus, land-use variance, and transfer of development rights (TDR). The policy tool of TDR proposed by the Secretary for Planning and Lands to solve these public–private problems has only been applied in cases involving heritage preservation projects and lacks practical applications in the general field of urban redevelopment.

This study identifies the obstacles to public–private redevelopment in Hong Kong's urban renewal process and discusses the optimal incentive policy based on a factual review of urban renewal experiences in Hong Kong and internationally. We focus on the following three research questions: (1) What is the core obstacle to Hong Kong's urban renewal process and what are the potential solutions to density issues under various FAR regulations? (2) Which density scheme has been the most successful internationally? (3) How can a targeted incentive policy be guaranteed to improve Hong Kong's current shortcomings?

To answer these research questions, we focus on changes to Hong Kong's FAR regulations over time and describe the latent political, legislative, and practical challenges that threaten to impede the resolution of urban redevelopment issues. We find that the private sector's unwillingness to participate in high-density projects is Hong Kong's most important urban renewal challenge.

To solve this problem, we summarise the historical development of FAR regulations at the international level. FAR regulations are imposed in urban areas to limit buildings' floor space in an effort to ameliorate adverse environmental and social problems in urban areas [1,2]. Countries such as the USA [3], Japan [4,5], India [2], China [6–8], and Singapore [9] are at different stages of their urban development and have different FAR regulations [3]. Numerous studies of FAR regulation have emphasised policy approaches, including direct limits on density, on-site density bonuses, land-use variances, and density transfer. This review summarises cases, outlines the background and progression of FAR regulatory systems, recommends future research directions, and updates practitioners on recent findings [10]. In our review of various TDR policies, we concentrate on the most advanced policies; we believe that TDR is an effective solution to FAR-related issues and can be greatly improved in Hong Kong to suit local conditions.

Finally, we distil the factors necessary for successful TDR and individually compare them with Hong Kong's current shortcomings based on our assessment of its most recent TDR case, that of the Sheng Kung Hui Compound. Thus, to ensure the feasibility and sustainability of Hong Kong's urban renewal policies, we develop optimisation strategies for redevelopment projects that are subject to FAR regulations. Specifically, we summarise the international experience to argue that the TDRs can be used as a tool to address that challenge. However, the success of TDRs depends on appropriate TDR legislation, TDR management, TDR programme design, and TDR social support. Accordingly, we also rely on an established case in Hong Kong to conduct a targeted analysis and develop suggestions for improving the practice of TDR in Hong Kong.

This paper is organised as follows: Section 2 reviews the practice of FAR regulation in Hong Kong and distils its most pressing challenge, namely the lack of private sector participation. Section 3 introduces the international development of FAR policies and practices, providing a reference for market-based policy formulation in Hong Kong. Section 4 identifies the factors that contribute to the success of FAR regulation, further verifies Hong Kong's current shortcomings by highlighting real-life cases, and proposes targeted improvement strategies. Section 5 concludes the paper.

2. FAR Regulation in Hong Kong's Urban Renewal Process

2.1. Stylised Facts of High FAR and Urban Decay

Although Hong Kong covers an area of 1106.3 square kilometres, most of the population and urban development is found on Hong Kong Island and Kowloon, which cover only 132.8 square kilometres [11]. Due to its many hills and islands, Hong Kong has very little terrain that is suitable for construction. Twenty percent of Hong Kong's land has slopes of more than 30% and is therefore undevelopable, and there is a shortage of suitable land for construction. Hong Kong's built-up area covers only 24.3% of its land [12]. In contrast to its small amount of built-up territory, Hong Kong has a large population that increased from 7,072,000 in 2011 to 7,413,000 in 2021, an increase of 4.8% in 10 years [11]. Because of this increase, Hong Kong is one of the most densely populated regions in the world.

Hong Kong's need for densely populated housing and the increasing number of ageing buildings recently accelerated urban redevelopment. According to the Monthly Digest of the Building Department, Hong Kong's Building Authority authorised the destruction of 1705 buildings since January 2005 [13]. In 2011, Hong Kong's Urban Renewal Strategy predicted that 9000 structures would be at least 50 years old by 2021 [14]. Similarly, according to Urban Renewal Authority statistics posted on 28 September 2021, by 2047, approximately 80% of the building stock in the Yau Ma Tei and Mong Kok redevelopment areas will be more than 70 years old, with more than 20% of the building stock classified as having either no or negative redevelopment potential [15]. These practical cases and official forecasts reveal the urgent need for redevelopment strategies.

An important approach to address urban decay under high FAR is urban renewal, which is essentially a process of dynamic optimization of human land systems through resource reuse and land redevelopment, with the fundamental goal of building sustainable cities [16]. It can enhance the sustainable development capacity of cities by optimizing the physical and functional space of the city, and then realize the sustainable development goals in social and economic dimensions [17].

Specifically, at the physical and functional level, urban renewal projects encourage the construction of high-quality housing [18], the rehabilitation of crumbling structures, and the efficient use of the city's land and building stock [19]. Moreover, urban renewal accompanied by energy retrofit of existing buildings presents a chance to upgrade cites' energy performance in order to increase energy effectiveness and decrease household energy cost [20,21], which allows for a higher density of use with limited resources. Further, the compact and mixed-use development around stations can increase the centralization of jobs, and generally favour public transport in cities with low density and very high growth rates that minimize sprawl [22–24]. Hence, urban renewal allows the renewal of physical space, which supports the adjustment of density and achieves a new balance of functional structures within the city [25].

At the same time, urban renewal for strategic and special spaces further promoted the sustainable development of the city at the social and economic levels [26]. On the one hand, many urban renewal projects with public attributes, including rail transit construction [27], waterfront development [28], and historic and cultural district preservation [26], have strong socioeconomic spatial effects [26] Particularly in Hong Kong, one of the goals of urban renewal is to provide adequate community facilities [14]. Hence, urban renewal can provide opportunities to address social issues and to address social integrity and social integration [29] and can promote sustainable public service attributes in cities.

On the other hand, urban renewal, which aims to create employment opportunities and enhance urban attractiveness, has caused many commercial real estate projects [30], waterfront revitalization projects [28], and other projects that effectively promote high-quality economic development and industrial transformation [31]. Redevelopment is framed by the state and much of the general populace as positive and necessary to boost economic growth [32]. In general, urban renewal can effectively improve the physical, social, and economic conditions of the city to improve the quality of life and promote sustainable urban development.

2.2. The Policy Evolution of Hong Kong's Urban Renewal Process

2.2.1. Period of Spontaneous Market Renewal (Pre–1987)

Before the 1950s, the Hong Kong government rarely intervened in the urban renewal of old districts, and its attitude towards urban renewal was basically laissez-faire. In the 1960s, the government became aware of the deterioration of the old urban districts and attempted to improve their physical environments through special initiatives. However, due to the ad hoc nature of these initiatives, along with the fact that these policies (and the implementing institutions) did not provide effective support and protection mechanisms, there were many problems with their implementation and management, resulting the urban renewal piecemeal [33,34]. The initiatives did little to improve the environment of the old districts. By the 1970s, the Hong Kong government made the construction of new towns a key element of urban development, but urban renewal at the strategic level did not receive sufficient attention [35].

During this period, urban redevelopment activities were largely market-driven, primarily advanced by private developers who actively sought out projects for demolition and construction. To achieve profitability, their main target was the redevelopment of low-density projects into high-density housing. In this period of urban redevelopment, number of developers even have become giant corporations, and almost all the older low-density areas were renewed [36], but the older high-density urban areas, which presented numerous economic and operational difficulties, were neither renewed nor improved.

2.2.2. Period of Limited Government Involvement Premised on Market Profitability (1988–2000)

Beginning in the 1980s, many buildings in Hong Kong, including public housing projects, began to deteriorate. Market-regulated mechanisms alone were inadequate to address the ageing of Hong Kong's urban structures. In 1988, the government responded by establishing the Land Development Corporation (LDC), an independent statutory department dedicated to urban renewal, to promote the regeneration of Hong Kong's older districts [35,37]. The establishment of the LDC marked the beginning of the Hong Kong government's (limited) formal involvement in urban renewal activities.

Although the LDC was a semi-private–semi-public statutory body, it did not have any statutory resumption power [38]; furthermore, it did not receive strong financial support from the government when it was established, only small loans [34]. To ensure its long-term viability, the LDC's business model focused first and foremost on its own financial balance. Accordingly, the LDC operated no differently from private developers, which sought out urban redevelopment projects with profit potential rather than addressing the problems of renewing old, high-density areas.

By the time the next phase of the Urban Redevelopment Authority was established, the LDC had undertaken 26 projects, but completed only 16, 80.5% of which were commercial buildings with the possibility of profit; only 19.5% of the projects were used for residences, public facilities, or community recreation [39]. During the 12 years of the LDC's operation, only 0.44% of the 639 hectares that the 1991 metropolitan plan designated for regeneration were renewed [38]; thus, the LDC failed to meet its original purpose of improving old districts and it was widely criticised by both citizens and the government.

Thus, it is evident that the LDC maintained the characteristics of a commercial operation, and the LDC's approach to urban renewal, with economic viability as the primary consideration, was no more successful than private developers' approach in promoting the improvement of old districts. By 2000, the LDC's renewal activities were widely questioned and criticised while the number of redevelopment projects by private developers was declining [37]. The government recognised that it must increase the level of public-sector intervention to fundamentally improve the appearance of Hong Kong's old districts and enhance the efficiency and effectiveness of urban renewal.

2.2.3. Period of Increased Government Intervention in Renewal (2001–Present)

The Urban Renewal Authority Ordinance was approved in June 2000 and the Urban Renewal Authority (URA) replaced the LDC in May 2001, with a goal of completing 225 redevelopment projects in 20 years [40]. The establishment of the URA marked the entry of Hong Kong's urban redevelopment activities into a phase led by a statutory body with governmental support. Unlike during the LDC era and the URA era, the Hong Kong government shouldered additional responsibility for urban renewal. First, the government issued the Urban Renewal Strategy to guide urban renewal activities. Second, the government increased its financial support by providing HKD 10 billion in start-up capital to the URA and offering concessions in land premium reductions. Third, the government made corresponding arrangements in the areas of planning, acquisition, and public participation [14,38,41,42].

Since the above transformation, the government increased its intervention in urban renewal in Hong Kong and became fully involved in urban regeneration activities [41]. The government has a clear plan to guide regeneration activities from top-level strategies to financial support policies, and it constantly adjusts its strategies before introducing new guidelines. However, Hong Kong's current regeneration of old districts cannot keep up with the speed of urban ageing. The current approach is insufficient to solve the problem, and its sustainability is questionable [43]. Table 1 lists the implementation rules of Hong Kong's three urban renewal periods and summarises their main features, the problems they solved, and their residual problems.

2.3. The Challenges of Insufficient Private Sector Participation

A variety of factors have slowed redevelopment in Hong Kong, creating an increasingly large gap between the urgent demand for and the production of new residential units. One of the most important factors is the lack of incentives for developers to participate in redevelopment projects in high-density areas [38]. At present, almost all the old, low-density and easily redevelopable districts in Hong Kong have been renewed by private developers, as these were profitable projects. However, developers' participation in urban redevelopment activities has steadily declined because of the low profitability and high economic risk of urban redevelopment in high-density areas [38].

Hong Kong's planning system includes both discretionary between development control and the respective plan, and strong legislative power on development control when making decisions on planning applications [44]. Hong Kong's legal system, with its strict restrictions on building density, has been unable to adapt to developers' preferences for high-density projects, decreasing developers' participation in urban renewal.

On the one hand, Hong Kong's FAR has reached the upper limits of development [14]. The redevelopment of old high-density areas can result in zero gain (or even less square footage than before redevelopment) if redeveloped buildings comply with the current regulations, directly leading to the low profitability of the redevelopment of old high-density areas. On the other hand, due to the nature of redevelopment, project sites are normally located in old city centres with high land prices and high population density, imposing an additional burden on developers who must negotiate with residents about the transfer price of their property rights [14]. The competing demands to create additional public open spaces and preserving old sites in redevelopment areas also require developers to design low-density products at the expense of profits [45,46]. In addition, parts of Hong Kong have an existing plot ratio equal to or even greater than the maximum permissible level under the Outline Zoning Plan and Building (Planning) Regulations [47], further limiting developers' ability to make a profit and reducing the economic potential of redevelopment projects. With respect to the government's financial support, according to the Urban Renewal Authority, HKD 20.8 billion land premium payment exemptions were provided by the government for 48 projects by May 2022 under the Urban Renewal Authority [48], indicating that the expansion of direct financial support for redevelopment incentives imposes a huge additional burden on the government's finances. Under the circumstances, additional incentives in other forms are necessary to encourage private sector developers to participate in redevelopment projects.

Table 1. Evolution and comparison of Hong Kong's urban renewal strategies.

	Period 1 (before 1987)	Period 2 (1988–2000)	Period 3 (2001–Present)
Main features	Private developer-led.	Limited government involvement, maintained a market mechanism.	The government increased its intervention and established a clear plan from top-level strategy formulation to financial support policies.
Problems solved	Mainly regeneration of low-density projects in old areas.	Urban renewal attracted the attention of the government which pursued targeted solutions.	The URA replaced the LDC to address the problems of inefficient urban renewal.
Problems remaining	No willingness on the part of private developers to participate in renewal of high-density projects.	LDC lacked a profit incentive, and urban renewal was inefficient.	There has been a lack of participation in the renewal of high-density projects necessary for urban regeneration.
Implementation rules			
• Guidance Platform	None.	None.	Urban renewal strategy.
• Public Accountability	None.	None.	The URA is accountable to the Legislative Council.
• Financial Support	None.	Hong Kong's government provided HKD 31 million loan as start-up capital (subject to repayment).	The government injected HKD 10 billion in rolling funds. There is a right to a land premium waiver. Exemption from relevant taxes and fees.
• Approval Process	None.	LDC's redevelopment projects were submitted to the government for approval on a case-by-case basis. Details of the projects were not announced.	A one-off submission by the URA to the Financial Secretary for approval. Details of the projects are announced.
• Compensation	None.	Market price of '10-year-old' residential properties in the same area was the benchmark for compensation. No special rehousing compensation for tenants.	Market price of '7-year-old' residential properties in the same area as the benchmark for compensation. Special rehousing compensation for tenants.
• Community Outreach and Public Engagement	Lack of consideration of social factors and public participation.	Lack of consideration of social factors and public participation.	Social impact assessment with public opposition and appeals against the development.

3. International Policy Development and Recommendations

Different countries have introduced various policies to address the dilemma of FAR in urban renewal. The most important of these policies involves the lack of incentives for developers to participate in redevelopment projects in high-density areas. We examined international policies to see if they can provide inspiration for Hong Kong. Our review covered the 1960–2022 period and focused on the implementation of TDRs. We searched reliable research databases (Emerald Insight, Web of Science, ProQuest, Google Scholar, and ScienceDirect) using keywords such as 'floor area ratio', 'floor area ratio regulation', 'density regulation', 'density relaxation', 'density transfer', and 'transfer of development rights' to find research on FAR regulations. We screened out papers that were not peer-reviewed or in languages other than English and excluded papers that did not focus on the theme of FAR regulation. Eighty appropriate publications on the development of FAR regulation were found.

3.1. Common FAR Regulation Practices

3.1.1. Traditional FAR Regulation Practices

Traditionally, a government uses direct intervention methods, such as regulatory instruments in the form of zoning, development control, acquisition, and eminent domain, along with the purchase of development rights (PDRs) programmes, to plan and supervise the FAR [49–51]. Some nations use maximum and minimum FAR regulations, in which maximum FAR regulations indirectly control the size and height of buildings and affect building density and the urban spatial structure, whereas minimum FAR regulations can be enforced to increase building density or prevent underdevelopment [4]

However, many studies have criticised the above methods for their low levels of efficiency and effectiveness [52–55], high implementation costs [53,54], and probability of triggering conflicts between the public and the private sectors [56]. Therefore, they cannot achieve the goals of regulation and optimal land-use patterns [57]. To solve these costs and problems, land-use policies have introduced market-based adjustment tools and gradually shifted from regulatory tools and comprehensive planning to voluntary and market-based planning strategies, such as public–private partnerships, infrastructure investments, and incentives [58,59].

3.1.2. On-Site Density Bonuses

Different countries use different incentives for FAR control, but the most common are density relaxation and density transfer. For density relaxation, density bonuses involving quid pro quo arrangements have a long history and continue to be widely practiced. In this system, the government trades additional density for funds and public facilities. For example, Boston's South Bay project increased the permissible FAR from 2.0 to 3.0. In return, the developer pledged to provide new public space, affordable housing, and HKD 1.2 million in community beautification funds (City of Boston, 2016). In Chicago, neighbourhood opportunity bonus grants provide additional development capacity in exchange for funds from developers. In Toronto, the density bonus is known as Section 37 of the Planning Act, pursuant to which the developer must provide community facilities or other benefits in return for additional height or density allowances. Market-based increases in the allowable density of future developments in exchange for developer concessions have been widely adopted by the public sector [60–64] and have incentivised investment. To encourage developers to provide public space and affordable housing, New York and Seattle have developed Incentive Zoning programmes. Seoul's National Land Planning Law states that when developers dedicate a portion of their land for public amenities, additional construction land may be permitted. Arlington, Virginia, allows developers to build at higher densities than would otherwise be allowed for projects that provide housing for low- or moderate-income households. To encourage regional revitalisation, Arlington also provides special density bonuses for specific revitalisation areas. To stimulate land assembly, Hong Kong and Singapore offer a bonus plot ratio as an incentive for developers to assemble larger urban redevelopment sites [65,66].

The findings on the utility of density bonuses and their ultimate effect on the public interest have been mixed. In addition, such bonus provisions have been severely criticised as sacrificing design quality for the sake of urban vitality, in the case of Sydney [67], or as overbuilding to take advantage of the bonus, in the case of New York City [68].

3.1.3. Land-Use Variance

In addition to density bonuses, land-use variances can be used to achieve density relaxation. Jou et al. (2012) investigated four case studies in Taipei and observed that land-use codes can be flexibly changed to legalise some commercial property development to satisfy the needs of the market [69].

3.2. Adoption of Market-Based Instruments: Density Transfer

A density transfer allows the owner to sell unused floor area from a 'donor site' to one or more 'receiver sites' at a market- or city-determined price [70]. TDRs are the most common method of density transfer. TDRs rely on the market to compensate landowners, which encourages developers to invest in more projects [71] and balances the pressures on administrative bodies [72].

The first application of TDRs is New York's 1916 zoning ordinance [73]. Following their first use in the USA, TDR programmes spread to other Western countries, such as France [74], the Netherlands [75], Germany [76], Switzerland [77], and Italy [78], and to Eastern countries, such as mainland China [49,79], South Korea [80], and Taiwan [81]. Many countries and cities have established legislation to promote TDRs [82,83], and there is no world standard or norm. As a result, TDRs raise numerous questions, including the difficulty of assessing the value of development rights in the absence of reliable mechanisms [84] and the inefficiency of the system in residential areas [85].

We compare the advantages and disadvantages of different FAR regulations in Table 2. All three types of FAR regulations can stimulate private sector participation. However, both on-site FAR bonus and land-use variances have inherent problems that are difficult to circumvent. For example, on-site FAR tends to encourage developers to over-develop, and land-use variance is ill-suited to setting a fixed conversion pattern. Furthermore, TDRs are the target of a substantial amount of criticism. The main problem with TDRs is that designing TDR programmes is costly for local governments due to TDRs' complexity, and such programmes are unlikely to result in an efficient land allocation [86,87]. The disadvantage of TDRs is due to their temporary immaturity, resulting in imperfectly implemented programmes in different regions and controversies about their effects. In the future, together with the promotion and maturity of TDR systems, there will certainly be more opportunities for the development of TDR systems.

Table 2. Comparison of FAR regulations.

	On-Site FAR Bonus	Land-Use Variance	Transfer of Development Rights (TDRs)
Maturity	Mature	Immature	Immature
Popularity	High	Low	Low
Advantages	Market-based investment incentives, with low government cost	Increased flexibility to meet market needs	Encourage developers' investments in more development and balance the pressures on administrative bodies
Disadvantages	Sacrifice of design quality for the sake of urban vitality, or overbuilding to take advantage of the bonus	Difficulty in changing land-use norms according to local conditions	In the absence of reliable mechanisms, assessments of the value of the right to development may create conflicts and cause poor operational efficiency

3.3. The Basic Elements of TDR

3.3.1. TDR Pricing

The specific form of density transfer used by governments varies. There are generally two types of pricing: (1) via a pure free-market mechanism; and (2) via a TDR 'public bank'.

With the first type of pricing, TDRs are freely traded on the market and the price is determined by supply and demand. The problem with market-based TDR pricing is that the extensive use of TDRs priced in this manner can change the land value, causing the market price for all land to fluctuate. Taipei's strategy for preventing this negative impact is to fix the price of the development rights rather than allowing them to fluctuate with the market [83].

With the second type of pricing, the local government creates a TDR public bank that operates as an intermediate public agency in TDR exchanges. For example, King County, Washington, used general fund money and the proceeds from a dedicated portion of county property taxes to buy the TDRs to more than 90,000 acres of forested land and open space. The primary goal of TDR banks is to reduce price uncertainty and ensure stable and fair pricing [88,89]. However, some have criticised TDR banks on the ground that they distort the price determination of TDR [90–92].

3.3.2. Designation of Sending and Receiving Areas

The primary issue related to the location of TDRs involves the question of whether to designate a specific receiver site. There are generally two types of TDR designations: (1) dual transfer districts; and (2) single transfer districts.

Dual transfer districts usually have separate, pre-zoned sending and receiving areas. The planning agency can guide development to the areas that are the best suited to increased density. Single transfer districts allow the market to decide where transfers occur. For example, the Lake Tahoe basin and the Malibu/Santa Monica Coastal Zone have no clear spatial boundaries between sending and receiving areas. Some TDR systems allow more freedom to choose the receiving site. Taiwan's TDR enabling statute does not require planning authorities to designate specific areas as receiving areas eligible for higher-density developments. Livermore, California, allows the community to select the receiving sites [89].

3.3.3. TDR Transfer Ratio

The two types of TDR transfer ratios are as follows: (1) a one-to-one transfer ratio, and (2) an n-transfer ratio [93]. With a one-to-one transfer ratio, for each dwelling unit that is precluded from development at the sending site, one bonus dwelling unit is allowed at the receiving site. To create market incentives for sending area landowners and receiving area developers, many TDR programmes use an enhanced transfer ratio. In the Montgomery County, Maryland, programme, one TDR allows one bonus single-family detached residence or two multi-family units [94]. In Livermore, California, two TDRs are required for each bonus single-family residence, but only one TDR is required for two multifamily attached units. Dade County, Florida, has 18 zoning districts that are capable of receiving TDRs. In these districts, a TDR allows for various density bonuses and other exceptions from standard development requirements [95].

With an n-transfer ratio, the determination of the transfer ratio depends on the evaluation of the affected land's development potential. For example, in the Pinelands in the State of New Jersey, several factors determine the transfer ratio, including land type and location, past and present uses, and prior development history; evaluations take approximately 6 weeks [96]. The Malibu/Santa Monica programme uses acreage and slope in determining the transfer ratio; for smaller lots in old subdivisions, the programme also considers the square footage of buildable space [97].

3.3.4. Use of Receiving Areas

In terms of the use of receiving areas, some programmes allow the conversion of land use. For example, in Warwick Township, Pennsylvania, TDRs are granted to sending area landowners for farmland preservation, but they are used by receiving-site developers to achieve greater lot coverage within industrial zones [98]. In Burbank, California, the Media District TDR programme allows conversions from one land use to another if the reduction in vehicular trip generation achieved at the sending site equals the increase in trip generation created by the bonus development at the receiving site [99].

3.3.5. Other Incentives

There are also other incentives for developers to participate in redevelopment projects, such as the provision of additional development volume. In Pacifica, California, developers using TDRs can receive exemptions from open space, setback, coverage, landscaping, and parking requirements [99]. In the Pitkin County programme in Colorado, TDRs granted for the preservation of sending area land are used by receiving area developers to achieve bonus residential floor area [93]. It is also possible to obtain a development license. For example, Morgan Hill, California, provides priority to building permits for developments that include TDRs [100]. The Tahoe Regional Planning Agency, which covers a region in California and Nevada, allows landowners to create an 'allocation' by removing non-conforming structures from a sensitive stream environmental zone.

Table 3 illustrates and compares density policies in various countries/cities in terms of their general implications, partial implications and exceptions. However, only a few countries and cities have successful TDR programmes, a situation that has sparked international interest and created a need to address common, yet controversial implementation issues [101].

Table 3. Density policies in various countries/cities.

	On-Site Density Relaxations		Transfer of Development Rights (TDRs)					
			Receiving Sites Location		Price		Time	Main Type
	On-Site FAR Bonus	Land-Use Variance	City-Determined	Developer-Determined	City-Determined	Market-Determined	FAR Reserve	
United States								
New York State	●	●	●	×	×	●	○	(a)(b)(d)(e)
Washington, DC	●	-	●	×	×	●	●	(a)(d)(e)
Washington State	●	-	●	×	×	●	●	(c)(e)
Nevada	●	-	×	●	○	●	-	(b)(c)
Los Angeles, California	●	-	×	●	×	●	-	(b)
California	●	○	○	○	○	○	-	(a)(c)(e)
Florida	●	○	○	○	×	●	○	(c)(d)(e)
Maryland	●	-	●	×	●	×	-	(c)
Canada	●	○	●	×	×	●	-	(a)(e)
Australia	●	○	●	×	×	●	-	(a)
Mumbai	●	○	●	×	×	●	-	(d)
Singapore	●	●	×	×	×	×	×	×
Japan	●	×	●	×	×	●	-	(a)(f)
Taiwan, China								
Taichung	●	×	●	×	×	●	-	(a)(e)
Taipei	●	●	×	●	●	×	-	(a)(e)
China								
Guangzhou	●	×	●	×	×	×	-	(a)
Chongqing	×	×	●	×	○	○	-	(c)
Hong Kong	●	×	●	×	×	×	×	(a)

Notes: ●: general rules; ○: partially implied rules; ×: not applicable; -: uncertain. (a) Heritage protection; (b) environmental protection; (c) farmland protection; (d) affordable housing; (e) urban public facility; (f) transportation facilities.

3.3.6. Types of TDR

The objectives of TDR differ from programme to programme. Based on the different objectives of TDR, we divide TDR into six main types, which are (a) heritage protection; (b) environmental protection; (c) farmland protection; (d) affordable housing; (e) urban public facility; (f) and transportation facilities.

Traditional TDR programmes have been implemented to protect urban characteristics, as well as to preserve environmental and agricultural [89], namely types (a)(b) and (c). Historic preservation TDR programmes (a) originally emerged in large cities, including New York, and Washington, DC. Later, medium-sized cities, such as California, and some small cities have applied TDR to preserve historic sites [99]. Similar to heritage protection are environmental protection (b) and farmland protection (c). They are all transfer of development potential from nature reserves or rural to urban areas, focusing on the protection of agricultural and environmentally sensitive lands, including wetlands, slopes, forests, natural landscapes, animal habitats, and open spaces [95].

The focus of these types of TDR is on protecting the sending area, rather than developing the receiving area. Moreover, compact development along smart growth principles is a common secondary goal or co-benefit. These TDR implementation sites tend to be in more developed cities. They have a mature urbanization stage, a strong welfare conscious government, and urban renewal policies that take into account diverse social, environmental, and cultural demands [102,103].

There are also some innovative types of TDR that are emerging, including Affordable housing (d), Urban public facility (e), and Transportation facilities (f). These programmes place greater emphasis on incentivizing development because they set their sending areas to urban buildings or facilities where private sector participation is urgently needed, while designating receiving areas in marginal areas where the need for new development is higher.

In affordable housing projects, the government is often eager to enhance the quality of life of people by improving housing [104]. Therefore, private developers receive incentives in the form of TDRs that allow additional housing construction in other parts of the city [105]. Such projects are focused in developing countries with immature urbanization and are in the initial stage of physical renewal [106], such as Mumbai [107], to improve the well-being of residents and enhance social satisfaction. There are also some such projects in countries where privatization is prevalent, represented by the United States, which focus on embedding the private sector in urban regeneration to drive urban tax revenue and employment [102].

TDR projects of Urban public facility and Transportation facilities are derived from the government's public service attributes and industrial development needs. The most prominent of them are in Asian countries/regions such as Japan and Taiwan, China. They have developed rapidly during economic globalization, with distinctive state-led characteristics of urban development [108], and urban renewal revolves around the needs of industrial activities [109,110]. Meanwhile, some developed countries have gone through rich urban renewal development stages [25,111,112] and have also extensively experimented with diverse applications in the types of TDRs [103].

The implementation of FAR regulations varies from country to country and city to city. In general, on-site FAR bonuses are the most common, whereas land-use variances are relatively rare. Most notably, TDRs have increased flexibility and effectiveness in different settings depending on whether the receiving site's location is city- or developer-determined, whether its price is city- or market-determined, and the programme's FAR reserve. Currently, the most commonly used form of TDR is a combination of city-determined receiving locations and market-determined prices. Cities with long-standing policies and a high level of policy maturity, such as New York and Washington, DC, have provided a higher degree of freedom by allowing FAR reserves as part of their TDR policies. Cities in China that have only been implementing the policy for a short period of time (or they have just started to pilot it) are more restrictive, providing the government the power to decide the receiving site's location and price and to liberalise FAR reserves. With the accumulation of practical experience in cities, there is an opportunity to implement TDRs that are both flexible and market-oriented. Hong Kong can use this flexibility to adjust its TDR policies to achieve a high level of efficiency.

4. Policy Outlook and Recommendations to Meet the Challenges of Insufficient Private Sector Participation

4.1. Adaptability of TDR in Hong Kong

TDRs are an efficient solution to the inefficiencies of urban renewal in Hong Kong and can provide developers with an effective incentive to participate in the urban renewal of high-density projects. The Hong Kong government has explored TDRs as a solution to the problem of insufficient private sector participation in urban renewal. The concept of TDRs was proposed by the Secretary for Planning and Lands in 2001 and has been successfully applied in nine heritage preservation projects [112]. However, TDRs in Hong Kong are not formalised instruments and have only been used for projects in which the sending areas are heritage-preservation sites and the receiving areas are alternative sites where additional density can be obtained through the acquisition of development rights [71,113]. In these cases, the receiving sites are contiguous, leaving the potential flexibility and feasibility of non-contiguous receiving site selection in TDRs in Hong Kong unexplored [114].

According to the literature, TDR programmes such as that used in Hong Kong incur high transaction costs, as the government is required to spend a substantial amount of time and money to find suitable receiving sites, assess the value and capacity of the land, engage in public consultation, and conduct site assembly. The programme can also affect surrounding owners' property values, leading to lengthy negotiations to assemble smaller lots into larger redevelopment sites [115].

Although Hong Kong's initial TDR programme, as proposed in 2001, followed the practice of TDRs in the USA and Canada of providing tradable permits, freely tradable TDRs have not been available in Hong Kong due to the absence of TDR certificates under the current legislation [116]. TDRs are provided on a case-by-case basis without publishable transfer procedures or preliminary permitted transfer area planning, the latter of which depends on negotiation between the government and the property owner [117]. Furthermore, no TDR market has been established [118].

In a more general sense, because the urban structure of Hong Kong is significantly different from the urban structures of cities in the USA and Canada, the feasibility of comprehensively copying their experiences remains questionable. However, concepts similar to the Hong Kong TDR certificates with unspecified development dates date back to the 1960 Letter B system, indicating the potential dimension of time flexibility in TDRs [119].

In summary, the application of TDRs in Hong Kong's redevelopment zones is not widespread despite their potential to boost the economic viability of redevelopment projects and accelerate the pace of urban transformation. In the future, the Urban Renewal Authority can recommend TDRs as a planning tool for common redevelopment projects other than heritage preservation projects to permit the transfer of development rights from sites with extremely limited redevelopment potential to sites where expansion or increased intensity is anticipated. The key to achieving rapid urban renewal is learning how to create an appropriate and efficient TDR market that also considers Hong Kong's unique market conditions.

4.2. Key to the Successful Use of TDRs in Hong Kong

Research on the evaluation of density transfer programmes has been relatively limited and has primarily consisted of cases studies that analyse and summarise the factors that contribute to success [74,82,114,116,120]. Some of the more authoritative studies include Machemer and Kaplowitz, who developed an evaluative framework consisting of 13 elements found in 14 TDR programmes, including the political foundation, a consistent regulatory process, a sense of place, resources in the area that are seen as valuable, a rapidly growing area, public acceptance, appropriate receiving areas, TDR leadership, mandatory programmes, TDR banks, a TDR programme that is compatible with PDR, simplicity and cost efficiency, and knowledge of development, local land use demands, and patterns [80]. Ostrom further summarised these elements into five criteria: economic efficiency, social equity, adaptability and resilience, accountability, and conformity with general morality [121]. Pruetz and Standridge divided the common traits of TDR success factors into the three major aspects of sending area success factors, receiving area success factors, and incentive success factors [93].

Our review of the literature identified the three commonly mentioned factors: institutional and regulatory issues, TDR programme design, and social support. The specific categories and references are shown in Table 4. Institutional and regulatory issues are the foundation that anchors and sustains TDR and include TDR legislation and management.

TDR programme design requires TDR programmes first to be simple enough for developers and owners to understand and easy for government personnel to manage and operate. TDR programmes must also have sufficient incentives to attract developers, such as low transaction and management costs, receiving areas with the maximum development potential and economic incentives for participation. Because it can be challenging to implement a project without social support, TDR projects need to ensure the timely and transparent disclosure of information to the public to obtain support under effective social scrutiny.

Table 4. Key factors in TDRs' successes and shortcomings in Hong Kong.

Factors	Standards	References	Hong Kong's Shortcomings
Institutional and Regulatory Issues			
TDR Legislation	TDR is anchored and sustained through a strong policy and political foundation	[80,82,93,114,116,120–125]	Lack of systematic legislation and norms; case-by-case application
TDR Management	Smooth TDR implementation through strong leadership and clear assignment of responsibilities	[74,80,82,93,116,120,121,123–125]	Unclear authority between departments and low management efficiency
TDR Programme Design			
Simplicity	Projects are easy for developers and owners to understand; projects are easy for government personnel to manage and operate	[80,82,93,114,116,120,121,123–125]	Case-by-case application, low efficiency
Incentives	Attracts developers through market mechanisms such as low transaction and management costs, maximum development potential for receiving areas and economic incentives for operations	[74,80,82,93,116,120–122,124,125]	Possible over-incentives
Social Support			
Public Support	Timely and transparent information disclosure; community monitoring mechanism	[80,82,93,114,116,120,121,123–125]	Lack of openness and accuracy of information

We analysed a recent TDR case in Hong Kong to uncover its shortcomings in terms of the factors set forth above and determine how a TDR programme can better match Hong Kong's characteristics. The case was that of Sheng Kung Hui Compound, an important religious landmark in Hong Kong. To reduce the landmark's overall density, the government agreed to transfer 11,000 square meters of its floor area to another piece of land. However, many conflicts were revealed during the TDR project application and implementation process. These included a lack of prior consultation about the project, which led to dissatisfaction among residents due to noise and traffic; the developer's overly strong focus on obtaining private profit; the vague information provided by the TDR programme; and the unclear responsibilities of the various departments involved.

In the Sheng Kung Hui Compound case, the institutional and regulatory issues involved opposition arising from the lack of authoritative regulation of the receiving areas and their FAR ceilings. To make a case for the use of TDRs, it is critical to explain to a difficult-to-convince public that the additional FAR in the receiving area will not exceed its environmental carrying capacity. Moreover, it is difficult for all the relevant departments to agree on the communication, recognition, and cooperation needed for TDR management procedures, resulting in public confusion and questioning of the legitimacy and reasonableness of the TDR programme. The TDR programme design issues in the Sheng Kung Hui Compound case were caused by the lack of clear regulations and standards governing

Hong Kong's TDR programme, which uses a case-by-case approach. This approach is inconsistent with the standard of simplicity and ease of operation and can incur significant transaction costs. Furthermore, the TDRs used for the Sheng Kung Hui Compound case exceeded the usual incentives for commercial developers, defeating the programme's original purpose of using such incentives to encourage developer participation. The social support issues raised by the Sheng Kung Hui Compound case were evident: the case project met with strong public opposition. The public's lack of access to timely, transparent, and accurate information about the project and the lack of clear channels to participate in monitoring it undermined the principle of social equity.

4.3. Optimisation Strategies for TDRs in Hong Kong

Hong Kong currently uses TDRs only to a limited extent to manage historic preservation, and if it is extended to more universal urban renewal projects, the sectors and stakeholders involved are more complex. Furthermore, the projects may involve other new issues, such as challenges to the government's right to control, damage to the natural environment, and undesirable social conflicts. Therefore, we propose optimal strategies for TDRs in Hong Kong in response to the shortcomings reflected in current practice.

First, good institutional and regulatory support must be established. Legislation is the key to controlling urban planning and land development and utilisation. The government should take sustainable urban development as its guiding principle and continuously establish and improve a feasible TDR system that includes implementation processes, steps and methods, all supported by a strong enforcement mechanism. In addition, the TDR management agency should be empowered to clarify its responsibilities and powers, thus facilitating its future communication and coordination with various departments and reducing transaction costs.

Second, a scientific TDR programme design is necessary to make the TDR programme clear and easy to understand. The implementation of new TDR projects must be accompanied by reasonable and science-based TDR pricing, designation of sending and receiving areas, transfer ratios, usage of receiving areas, and other incentive policies.

Third, a higher level of social support is required. It is necessary to establish an information disclosure mechanism for the TDR programme. In addition, the public should be made aware of its role in TDRs. This can be achieved by educating the public about TDRs, publicising the programme's benefits, monitoring the development and construction of receiving areas and sending areas, and maintaining fairness to encourage public monitoring of TDR projects.

5. Discussion and Conclusions

5.1. Discussion of the Research Questions

5.1.1. Outputs of the Three Research Questions

We proposed three research questions: (1) What is the core obstacle in Hong Kong's urban renewal process and potential solution of density schemes under various FAR regulations? (2) Which density scheme outperforms based on successful precedents in the international arena? (3) How to ensure the incentive policy targeted to improve the current deficiencies in Hong Kong?

We completed in-depth research and argumentation on three research questions. For the first question, we sorted out the historical policy evolution of Hong Kong and argue that at this stage, the most important obstacle in the process of urban renewal in Hong Kong is the insufficient participation of the private sector. There is an urgent need to stimulate the participation of private developers in the urban renewal process through certain policies. Through literature review, we found that the solution to this obstacle is the stimulation of density schemes, including on-site density bonuses, land-use variance, and density transfer. This answer captures the fundamental contradiction for the complex proposition of urban renewal and provides the set of policies to be used to solve it. For the second question, we compared the maturity, advantages, disadvantages, and room for improvement of various density scenarios. The answer concludes that TDR has better results and stronger application promotion value at present. This answer is a very relevant choice of a cutting-edge option in the policy set, and points to a new urban renewal path for Hong Kong. For the third question, we sorted out the success factors of the selected incentive policies and evaluated the existing cases in Hong Kong accordingly. We answered three key shortcomings of Hong Kong's current TDR approach, namely the lack of a well-developed system and regulation, the absence of a design system for TDR, and the low level of community participation and support. Their targeted solutions are to accelerate the legislative and regulatory system, to emphasize simplicity and science in TDR design, and to increase the public transparency of TDR information. This answer provides concrete guidelines for implementing TDR policies on the ground in Hong Kong.

5.1.2. Future Research Outlook

Further research can carry out more targeted localization research on the success factors and key performance indicators of TDR policy in Hong Kong by in-person interviews with different stakeholders. As for success factors, the purpose of the interview is to gather opinions from representatives of the government (planning department, buildings department, and lands department), business sectors (developers in the residential and commercial real estate industry with or without experiences in certain districts), and academia (experts in the fields of urban economics, urban planning, and housing studies) in order to determine the relative importance of the various factors. As for key performance indicators, stakeholders include members of industry sectors (professionals in the residential and commercial real estate industry) and members of the general public (households living in the ageing building and their neighbourhoods). Hence, the further research based on the assessment from stakeholders should identify a set of success factors in FAR regulations as precautionary measures to ensure the efficiency and effectiveness of policy implementation, and develop the performance indicators to help monitor and control the delivery of redevelopment project.

5.2. Conclusions

We explored feasible options and optimisation strategies for urban renewal policies in high-density cities such as Hong Kong. We first reviewed the evolution of Hong Kong's urban renewal policies and identified increasing government involvement in urban renewal. The participation of the government in urban renewal has alleviated some of the difficulties associated with promoting urban renewal in a fully market-oriented environment, specifically the low returns associated with the renewal of old high-density areas. However, it has also imposed a considerable financial burden on the government and has not overcome the problem of weak private sector participation. Therefore, Hong Kong should introduce more incentive-based policy instruments to accelerate the urban renewal process in high-density areas by encouraging public–private partnerships.

To this end, we conducted a literature review of studies of FAR regulation that spoke to a policy solution for Hong Kong. We found that FAR regulations tended to transform over time from direct regulation to incentive policies. The core issue of FAR regulation is the need to address developers' unwillingness to participate. This unwillingness is attributable to the contradiction between developers' desire for profitable high-density development and cities' need for low-density planning to improve quality of life. Direct regulation does not increase developers' willingness to participate, and thus slows down the process of urban renewal. In contrast, incentive policies can attract the participation of the non-government sector through a market-based approach. TDRs, a new instrument available under the current FAR regulations, permits development rights to be moved from one zone to another. The application of TDR has been effective in many countries and regions because they have established comprehensive policies and systems to establish scientifically based pricing to designate sending and receiving areas, to define the transfer ratio, and to choose receiving areas according to local conditions.

The literature has fully affirmed the effectiveness of TDRs in stimulating developer participation and achieving appropriate FAR. The reason for TDRs' international success lies in sound TDR legislation and regulations, a strong management body, a simple and motivating programme design, and strong social support. However, judging from the practical case in Hong Kong, all these aspects are underdeveloped. To better promote the application of TDR, we propose the following three targeted improvement measures: (1) create and enhance a workable TDR programme, together with a series of implementation procedures, actions and techniques, all backed by a powerful enforcement mechanism; (2) ensure that the TDR programme is designed scientifically and includes acceptable TDR pricing, designations of sending and receiving areas, a transfer ratio, the use of receiving areas, and other incentive programmes; and (3) increase social acceptance of TDRs by promoting the public oversight of TDR programmes.

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Article

Climate Shocks and Local Urban Conflicts: An Evolutionary Perspective on Risk Governance in Bhubaneswar

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Abstract: In this paper, we explore the complex entanglements between ongoing land conflicts and climate shocks, and their implications for risk governance paths and evolution. We focus on ways in which concepts of shock and conflict can be incorporated into social–ecological systems thinking and applied to risk governance practice in a southern cities context. Through a qualitative inquiry of two slum redevelopment projects in Bhubaneswar city in India, we trace the origin and evolution of conflict around land tenure and eviction in informal settlements, as well as its interaction with local manifestations of climate shocks. Climate policies, as responses to climate shock and intended to mitigate climate risk, are observed as constructed, interpreted, framed, and used strategically by formal actors to further urban development objectives, while the local knowledge systems, risk perceptions, and adaptations are ignored in practice. This study helps to re-think the complexities of climate risk governance in southern urban spaces where multiple risks overlap and interact within the diverse realities of informality and vulnerability. A singular focus on one type of risk, on the formal order to manage that risk, is likely to overlook other risks and opportunities. Hence, shocks are likely to produce more unanticipated effects, conflicts function as the unobserved middle term, and the formal policies and plans to mitigate climate risk contribute to the creation of new risk.

Keywords: social–ecological systems; shock; conflict; southern urbanism; local climate governance; urban planning

1. Introduction

In recent decades, climate change in the face of fast urbanization has provoked new forms of interventions and risk governance within southern cities as a key imperative action. Scholarly studies continue to stress the importance of examining resilience and adaptation policies beyond their performativity toward developing a combined understanding of complex riskscapes and associated vulnerabilities [1–4]. Other scholars have called for different frameworks to understand the external hazards or systemic shocks as well as scrutinize governance strategies and tools that engender internal social conflict [5–8].

The idea of shocks can be traced to ecology, and later to social–ecological systems and resilience thinking, wherein systems (such as urban systems) are assumed to be stable, and expected to cope, bounce back, or bounce forward after a shock event to maintain equilibrium, or end up collapsing in events of disruption emanating from its environment. In this study, we begin with the assumption that social–ecological systems never collapse completely when they experience shocks [8]. We refer to shocks in this study as specific events attributed to climate change that disrupt the city system when a coordinated governance response is not possible. These events can have a significant impact on already existing disturbances within, and provide opportunities for the emergence of conflicts. Studies within the planning and governance scholarship continue to frame conflict through a negative bias, as a phenomenon to be avoided in practice [9–12]. Most policy attention thus goes into determining the cause of conflict to resolve it [10,12–15]. In the context of many southern cities, the conflict is predominant between formal and informal systems, and consequently, plans and policies operate through conscious forgetting [16,17], or a system of deregulations and maintenance of power relations through territorialized flexibility by state institutions [18].

In this paper, we offer theoretical and empirical insights into the role of climate shocks and social conflicts in climate risk governance. We focus our attention on southern cities to understand how climate shocks and social conflicts around eviction dynamics influence climate risk governance paths. The sites of inquiry are two slum settlements in the city of Bhubaneswar in India, where there are ongoing tensions between state-led development goals on one hand, and increasing climate risk on the other. The aim of the paper is to understand the combined effects of climate shocks and urban conflicts in risk governance in southern cities. In the context of Bhubaneswar, we conduct this study with the following research question: how do existing urban conflicts in informal settlements interact with climate shock events to influence climate risk governance? Specifically, we examine the decisions and implementation of recent Smart City initiatives as well as the State Climate Action Plans in Bhubaneswar which tend to employ slum redevelopment as an urban land rejuvenation and climate adaptation strategy, its manifestation within existing local urban practices, as well as its entanglements with climate shocks. We investigate two slum redevelopment projects in which there are ongoing tensions between continuous eviction attempts of formal state authorities and self-organization strategies of local slum residents to achieve land tenure.

We employ a qualitative lens, undertaking an in-depth ethnographic inquiry of two slum redevelopment projects in the study area to provide insights into an alternate understanding of risk including its governance and management within informal settlements at the local scale. Through this study, we argue that the combined effects of climate shocks and existing formal/informal conflicts manifest in multiple overlapping risks that become easily observable and clear, while also limiting climate action to more ad hoc, spontaneous, and short-term adaptation practices. The existing planning and governance decisions around risk have a tendency to contribute to naturalized social conflicts that reduce the chances of long-term adaptive capacity and perpetuate vulnerabilities of slum residents. This study contributes to the discussion on risk governance and southern urbanism, highlighting the presence of modernist planning legacies manifesting through fantasy visions for urban spaces, and cautions toward the unintended effects of not integrating formal/informal tensions within governance frameworks.

We refer to fantasy visions of urban space in the sense that what is projected into the future is not informed (enough) by knowledge of local problems and potential, but structured by desires. The structure of the visions enables us to discern the nature and the source of such desires. These are not merely imaginaries, which always exist, and which are needed for future-oriented governance, providing narratives enabling coordination around particular futures [19]. In order to speak of fantasy visions, we need to discern a disjuncture between vision and current reality, a blindness for aspects of the present which ought to inform visions for the future [20,21].

In the rest of the paper, we elaborate on the various aspects of the paper. We begin with a short introduction of the concepts of shock and conflict in Section 2, along with a brief on the study framing within an evolutionary perspective in the environmental governance literature. This will be followed by the methodological aspects of this study in Section 3. In Section 4, we introduce the main findings and observations from the two cases, followed by a brief discussion in Section 5 in light of possibilities and theories around the vulnerability and adaptation of urban communities. We provide some reflections on our study in the concluding thoughts in Section 6, also highlighting some limitations and future explorations based on our findings.

2. Climate Shocks and Social Conflict

We frame this study broadly building on the perspectives provided by social–ecological theory and resilience-based approaches in planning that aim to understand cities associal–ecological systems. Systems constantly try to be resilient and adapt to their changing environment, while undergoing a transformation in the process [22–29]. Adaptation in this sense is broadly finding ways and means to find a 'fit' between the city and its environment, while a lack of adaptation can create disruptions to the internal functions within the system [30–33].

We use an evolutionary perspective on environmental governance, specifically, an EGT lens (Evolutionary Governance Theory), which argues for continuous observation, strategizing, and coordination to identify limited options available at a particular time for achieving governance goals [7,34–37]. Governance here refers to a form of coordination among actors and institutions in taking collectively binding decisions within a community and place. We make a clear differentiation between government and governance, which means that governance is never the domain of just the formal governments, but a combination of decisions by formal and informal actors and institutions [35]. There is no perfect procedure or design for governance, since it is heavily dependent on the time and context where it is observed.

EGT sees governance as constantly evolving, within which its various elements, i.e., actors, institutions, discourses, power, and knowledge are co-evolving with each other. Using this perspective, shocks and conflicts are seen as related and influencing each other, and both in turn can combine to influence governance contexts. This paper uses these perspectives to observe Bhubaneswar city and identify how specific shock events induced by climate change, particularly cyclone events, combined with existing social conflicts (between slum resident groups and formal planning institutions) to influence planning and governance.

The specific events of systemic disruption when a system fails to find a coordinated governance response are referred to as shocks [8]. We do not use other conceptualizations of shocks within SES literature such as tipping points, equilibrium and collapse, and critical transitions [25,27,38–42] that are rooted within ecological studies and assume that phenomena within natural systems can be mirrored for observations within the social systems. The shocks can emanate from inside or outside the social–ecological system (in this study, the city of Bhubaneswar), such as political coups and wars (internal origins) and climate-induced events and stresses (external origins) [43,44]. As described earlier, we focus our attention on the latter, and more specifically on climate shocks that often manifest in the form of crystallized disaster events that cause temporary or threaten to make permanent changes within the city governance system, and are easily observable [45,46]. At the same time, we recognize that shocks are socially constructed events, meaning they do not occur in isolation from their social and ecological context, and often have far-reaching impacts on other social systems such as economic and political systems [47,48]. Shocks can further influence future risk interpretations and ways to observe and cope with them from within the system, through the creation of new meanings, risk and governance objects, and power/knowledge configurations [49–55].

We refer to conflict in this study broadly as prolonged disagreements, incompatibilities, and struggles between different actors and organizations within a social system concerning the use of resources, organization and development of spaces, or processes of response to shocks [56]. Unlike shocks that emanate from the environment (of an SES), conflicts always have discursive origins within the social system. Conflicts are ongoing processes (not episodic events) that can be observed, resolved, and managed through governance and planning. Conflicts can exist between formal and informal actors and organizations and are dependent upon history, governance context, and degree of trust between actors [8]. Conflicts can be also between different stories and imaginaries about the past, present, and future of communities and their shared spaces. Stories and imaginaries in our governance perspective cf [57,58] are necessary for governance to function, as part of the power/knowledge configurations that drive governance. They can enter governance from the community, from elite actors, and they can be produced in governance and used to persuade residents of a particular policy or a particular future.

In the context of the climate change literature, conflict is conceptualized within the cause-outcome approach in multiple ways, ranging from the focus on direct influences (of changing climate) in the form of security threats at international and national levels [59–64]; to ecological threats [37,65,66]; and to indirect influences such as climate shocks creating space for conflict [67,68]. Other scholars however argued that these linkages are rather over-simplistic and positivist, and conflict needs better understanding through alternate interpretive lenses [6,69,70]. Our orientation in this study is towards the latter proposition, hence the search for new ways of understanding and interpreting shocks and conflicts.

Both shocks and conflict can be productive as well as destructive. In their theoretical paper, Van Assche et al. [8] highlight how shocks and conflict can be useful in the creation of new narratives within communities, new institutions, new landscapes, and reflective governance insights. Their combinations can potentially spur innovation in governance and sometimes result in fast evolution. Yet, shocks and conflicts, when combined, have negative effects if they force decision making that forgets particular identities and discourses around previous shocks. Within governance, scholars have highlighted how the adoption of short-term coping responses to climate shocks can be potentially maladaptive in the long term [52,71–73].

Despite the theoretical advancement of shocks and conflict in social–ecological systems and resilience theories, their application in southern cities, particularly in informal settlements (such as slums) remains scant. The links between informality and climate change are complex, yet understudied in cities worldwide. Informality in planning practice in general has largely remained outside the scope of formal plans/policies, and this legacy has continued in the formal climate plans [18,74]. Informal settlements are usually seen from an order/disorder lens, thus conceptualized as chaotic, illegal, and unwanted spaces within a city that need revival for meaningful development in cities [75–78]. Due to the ongoing struggle for a city's spaces, its resources, legitimacy (both in practice as well as in formal plans and policies), as well as access to socio-political networks, the informal settlements within cities are naturally prone to conflicts with the formal planning system [79].

Recent emergent scholarship has however critiqued the above approach, highlighting that existing plans and policies on climate change fail to capture the various drivers of vulnerability in informal settlements [78,80–82]. Studies advocate focusing on the existing realities that exist within the informal settlements, including local risk knowledge, self-organization, and transformative potential of the residing communities, as well as the possibilities around creating seemingly formal institutions and adaptations to multiple overlapping risks emanating from climate change and non-climatic issues. We study the informal settlements in Bhubaneswar through the latter lens on informal settlements—that they are always in flux, always self-organizing in relation to multiple risks (livelihood, political, social, and climate change risks), and in constant interaction with the formal system of actors and institutions. The interactions between the informal and formal systems are never ending, and may result in collaboration and increased participation in some cases and projects, and it may result in conflicts and mistrust in other cases due to disagreements over the organization of urban space. We apply an EGT lens to understand the emerging conflicts in informal settlements in the study area, while also mapping the effects of how the nature of conflict changes when it overlaps with acute climate shocks.

3. Cases, Data, and Method

3.1. Background and Study Area

This study was carried out in Bhubaneswar city, the capital of Odisha state in India. Bhubaneswar has a history that goes back over two thousand years; the city was a religious center, and gradually turned into the administrative capital of Odisha in 1948 after India's independence. The city grew sharply in the late 1990s and 2000s, with the rapid growth of public and private corporations and infrastructure projects [83,84]. This growth has been complemented by a rapid in-migration of population groups and a rapid growth in the local economy in the last two decades. At present, the city has a population of 840,834 [1], with 163,983 persons (19.5 %) in 436 slum settlements [85,86]. The two relevant formal planning actors in Bhubaneswar are the Bhubaneswar Municipal Corporation (BMC), which is the elected urban local body responsible for the implementation of planning initiatives, and the Bhubaneswar Development Authority (BDA), which is the parastatal body responsible for planning activities. Other state organizations such as the State Climate Change Cell, Odisha State Disaster Management Authority (OSDMA), and State Pollution Board (SPCB), along with local and international organizations (World Bank and United Nations Development Program), also coordinate on matters of risk management, adaptation, and resilience along with other general urban development goals.

Bhubaneswar city (and Odisha state in general) has a history of experiencing disaster events; thus, disaster risk reduction thinking has been deeply entrenched in public and institutional memory for decades. Throughout the 2000s, there was a sharp growth in the city, with multiple development projects emerging. During this time, the frequency and intensity of rainfall, as well as disaster events such as cyclones, floods, and heatwaves have increased, as noted in the State Action Plan for Climate Change (SAPCC) that was formulated in 2010, and subsequently revised in 2015 and 2018 [87]. The SAPCC identifies multiple responses through a combination of mitigation and adaptation actions to balance the economic developmental interests with the climate goals of the state. These actions range from industrial pollution and GHG emission reduction to rainwater harvesting and resilient infrastructure toward improved disaster risk communication and updating existing institutional capacity. The state departments and the city municipal body in Bhubaneswar are at the forefront of most climate action in the city. The SAPCC attributes various climate risks in Bhubaneswar to multiple factors that include growing rural-to-urban migration and proliferation of slums in the city, which are making the city less resilient, while acknowledging that these spaces are the most vulnerable themselves to the effects of climate change [87].

Since 2011, owing to the framing within the SAPCC as well as other plans and policies, slums have gradually become a spatial object of governance [2] in Bhubaneswar. The new city masterplan in 2011 and SAPCC in 2015 subsequently contributed to the discursive construction of slums as climate risk objects and governance objects, by framing slums as high-vulnerability areas that needed intervention. Consequently, the policy responses within the SAPCC identified affordable housing projects, including various slum redevelopment projects, as a relevant adaptation strategy to reduce climate risks in Bhubaneswar.

In the absence of a city-wide redevelopment plan, the BDA has formulated several slum redevelopment projects throughout the city (as of December 2022, 11 projects are in progress in several parts of the city) to implement the various plans [88]. These projects are guided by central and state-level policies as well as legislations. Noteworthy among these is the central vision of a slum-free India that was launched through the flagship program viz. Rajiv Awas Yojana (RAY) in 2013. In Odisha, the Land Rights for Slum Dwellers Act (LRSD Act) was passed in 2017, which guaranteed limited land rights to all slum dwellers in the state. Consequently, the Odisha Livable Habitat Mission (also known as the JAGA Mission) was launched to provide land titling to slum dwellers in Odisha. The LRSD Act in 2017 did not initially cover large municipal corporations including Bhubaneswar, but eventually was amended in 2022 to include all urban areas in Odisha state, including Bhubaneswar. It is noteworthy here that prior to its introduction in Bhubaneswar, the JAGA Mission has been considerably successful in several towns and cities in Odisha, and has received wide recognition internationally [89].

The 'slum-free' goal of the state was emphasized within the centrally led Smart City Mission 2015 (slum-free neighborhoods to achieve the goal of climate-smart cities). The SAPCC also identifies the need to integrate cost-effective and resilient buildings in existing slum redevelopment projects [87,90–93]. The projects are built through two main implementation strategies—first, through the process of in situ development (provision of maximum 30 sq. meters of land per household to existing residents) or second, by evictions and resettlement in transit homes [94,95]. The LRSD Act, however, provides limited rights to the slum dwellers (no entitlement, no resale and sub-leasing), and does not specify procedures for implementation [96]. In the absence of clear procedures for redevelopment projects in the legislation or the plans, the actual practice of slum redevelopment is dominated by past approaches of slum clearance and relocation through enforcement. In recent times, the Enforcement Wing within BDA has engaged in the eviction of several slums and other unauthorized settlements throughout the city (335 evictions between 2021 and 2022), as part of its slum redevelopment strategy. While many of the evictions have been largely peacefully carried out, there are also several instances of conflicts between the residents of informal settlements and the formal authorities [88,97–99]. These projects that led to local conflict are the cases chosen for this study due to their relevance to the research question.

Considering the above context, slum redevelopment initiatives in two locations within the city were selected for detailed analysis in this study, viz. Shantipally and Pandakudia (see Figure 1). The redevelopment projects in both the slums are ongoing, involving the relocation of six slum settlements in total. The two sites were selected as cases for this investigation since they have a similar history within the city, have similar risks and practices, have some form of self-organization visible, and, most relevant to this study, were both sites of conflict between the local slum resident group and local planning authorities. These two slums were selected eventually based on extensive media coverage of the eviction process since the redevelopment projects started.

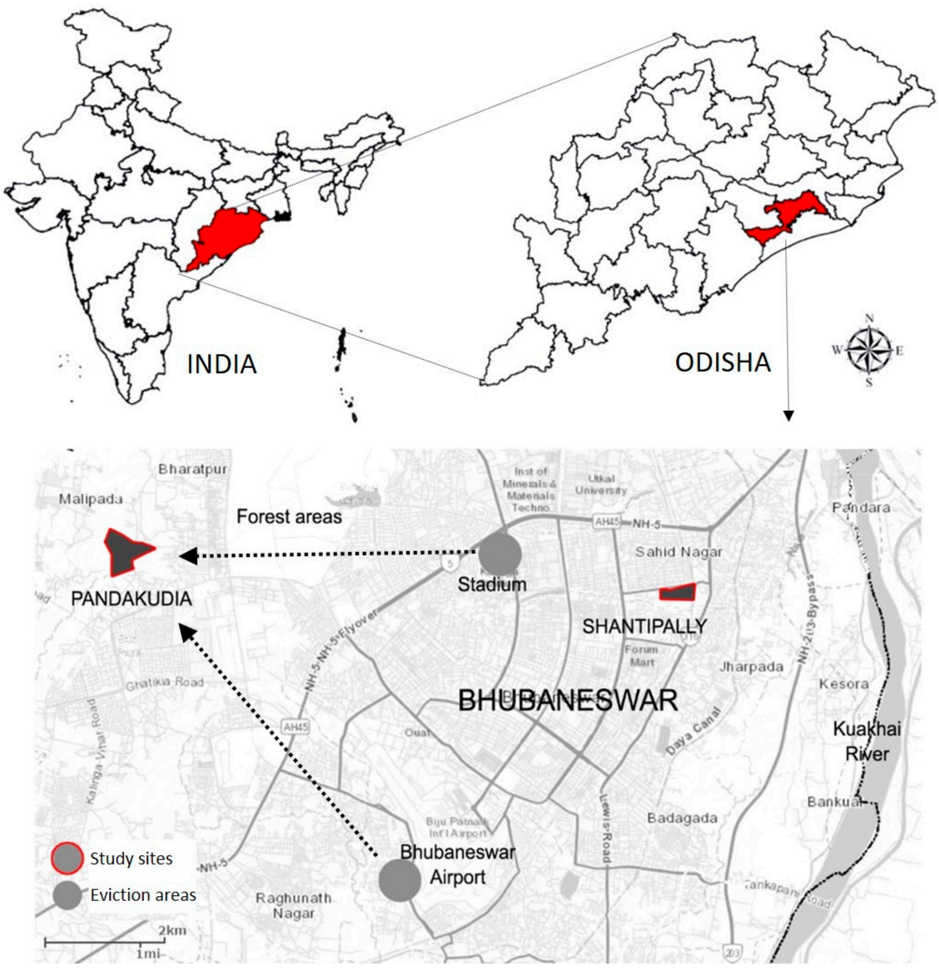

Figure 1. Location of the study area and two slum redevelopment sites in Bhubaneswar (maps sourced from bharatmaps.gov.in and OpenStreetMap (© OpenStreetMap contributors), images collated by authors).

3.2. Shantipally Case

The Shantipally slum has existed since the early 1980s in the center of Bhubaneswar city, and is home to over 1200 households at present. The land is in a low-lying area near a watershed area that was for most of the 1990s uncontested land. By the 1990s, with the economic boom in the city, the slum grew in size in recent times. In the early 2010s, to free up previously occupied public land by slums and squatters, various small-scaled eviction drives throughout the city began by evicting squatters, small roadside shops, and temples, but no significant threats were seen to the Shantipally slum due to its strategic location in a seemingly uncontested and unproductive land in the eyes of the burgeoning real estate market [3].

3.3. Pandakudia Case

The initial eviction drives by the BDA since 2016 had a domino effect throughout the city, with over a hundred evictions of residences, shops, and religious buildings picking up pace in recent years, especially since 2017. Between 2017 and 2021, five slums, viz. Jagannath basti (basti is the local word for slum), Gowda basti, Farmgate basti, Trinath basti, and Laxmi Nagar basti were evicted from various parts of the city and allotted temporary land for rehabilitation in Pandakudia. Of relevance to this paper is the conflict that sprung up between BDA and BMC officials and the residents of Jagannath and Farmgate basti, residents who resisted the eviction attempts for months before eventually being evicted by force to the Pandakudia site in 2018. The reasons for evictions of these slums, as deciphered from various media reports covering the eviction drives, were land acquisitions for airport expansion as well as land clearance for large infrastructure projects as part of the city hosting two international sporting events. During the interviews with slum leaders and residents, the participants highlighted that the slums had a long history of eviction threats since the 1970s (there were conflicts earlier in 1975, 2002, 2006, and 2011 due to eviction threats). However, in 2017, based on our observation and data collected, the eviction threat seems to have been compounded by other powerful discourses in the city, through slum-free policy, climate, and smart city ideas [4].

3.4. Data Collection, Method, and Analysis

We employed a qualitative case study approach in this study. The qualitative case study inquiry is extensively used in planning studies due to its usefulness in exploring 'how' and 'why' questions, and in situations where the researcher has very little control over the phenomena of interest [100–103]. The slum neighborhood is the geographical unit of analysis, while we also analyzed the various stories and statements narrated by the participants of this study based on their content and usefulness to answer the research question cf [103]. This study is positioned broadly within a social constructivist paradigm, meaning that realities are socially constructed through subjective meanings and perceptions of individuals, including the researchers. We also adopt an evolutionist lens that emphasizes the importance of understanding phenomena through the lens of temporality. This means that the governance system in a city is always unstable, and changing. The governance system is also observed—especially in as far as different influential actors take collective decisions affecting the neighborhood (in this case, the slums), but also as a place where discourses originate, enter, and transform the neighborhood itself as well as its relationship with rest of the city.

Data collection was carried out between May 2020 and January 2022 using online mode as well as through fieldwork in Bhubaneswar city (we adapted the overall fieldwork based on the restrictions owing to the COVID-19 pandemic). The methods utilized were semi-structured interviews (28 participants), document reviews (of plans, policies, legal documents, and media reports), and direct observation. In total, 9 state actors, 16 non-state actors (including 3 activists and 13 slum leaders and residents), and 3 academic experts were interviewed after recruitment through snowballing [104–106]. The main approach of interview recruitment and sampling employed in qualitative research was based upon data saturation [104]. The focus was thus on the richness of the data collected as opposed to the quantity, drawing from Maxwell [104]. Guest, Bunce, and Johnson [107], in their exploration of the adequate number of interviews, found that between six and twelve interviews are enough for most qualitative studies. Our sample of 28 respondents is in line with these findings, as well as caters to multiple state and non-state actors. All interviews were conducted either in English or Odia (the local language), following all ethical protocols and data protection standards. The questions during interviews revolved around sharing past and present experiences of the redevelopment project and the existing disagreements between the communities and state officials. The interviews lasted from 45 to 120 min, wherein all questions were open-ended questions.

The interviewees were chosen by us partly by identification of key actors in media and policy documents, and partly by snowballing during the fieldwork, i.e., interviewees pointing at other people as potential interviewees. Interviewees were selected not only because they were 'key actors', i.e., people with influence on decision making and insight in governance, but also, in other cases, because they had a good insight in the processes of shock and conflict locally, or because they represented clearly different perspectives on what happened and what should happen. We ended the process of conducting interviews when we reached a point of saturation, i.e., when patterns of discourse started to repeat themselves, and when the mapping of local governance and the entangling with shock and conflict (the research question) became clear and understandable, and the logic became apparent.

The key data sources were interview transcripts, field notes, memos, and documents. We transcribed all interviews and coded them for descriptive and thematic codes. The codes were both inductive and deductive, based on the existing literature as well as the interview text. Codes were used to capture the emerging themes from the conversations and documents such as self-organization, adaptation practices, risk, and vulnerability. We employed thematic analysis to arrive at the main themes and coding categories relevant to the research question. The findings from the cases are used to arrive at theoretical propositions and generalized theory on SES and resilience theory, as well as policy in similar governance contexts.

4. Findings

4.1. Shanti Pally Redevelopment Case

4.1.1. Emergence and Persistence of Conflict

A major turning point in city planning in India came in the form of the introduction of the new Smart City Mission at the national level in 2015. A hundred cities were selected from the list of proposed smart cities throughout India based on a competitive ranking system between cities, with Bhubaneswar city leading the list. Consequently, a smart city proposal and strategies were formulated by 2016, which had overall goals to create specific smart and climate-resilient neighborhoods through area-based development through urban design approaches, as well as digital governance system introduction as the key implementation strategy [84,90,108,109]. Bhubaneswar city's proposal involved multiple slum redevelopment projects (with the aim to build smart and resilient development) in the city that included a large 2232-household redevelopment project near Shantipally, through a PPP (Public–Private Partnership) mode. With the introduction of the new Smart city discourse, new stories were introduced within the city system. Slums became a governance object owing to politics around evictions, and new planning goals were introduced in planning in the form of slum redevelopment that became an active governance strategy. These projects were framed as having co-benefits of being climate adaptive action in the revised Climate Action Plan in 2015 [91]. There was an acute shift in the prevailing stories and imaginaries among planning and municipal institutions, from 'slums as illegal encroachments' to 'slums as illegal as well as risk to climate change and city image'. Interviews with slum leaders in Shantipally revealed that the slum dwellers initially looked up to the new Smart City Initiative as a positive change that could potentially provide them with opportunities. A resident, for example, described the following:

"When the BDA did the Smart City survey, we were overjoyed that we would get all facilities like hospitals, grounds for our kids to play, and many other facilities. It came so suddenly; people here were very happy. We were just happy that our lives will improve."

As the surveys started for the construction project in 2017, there were severe disagreements that emerged within the slum community itself, with one group of nearly 200 households agreeing to move to the redeveloped apartments in the future, while another disagreed with the terms of displacement, demanding either land ownership or larger apartments. Consequently, as interviewees revealed, the local political parties seemingly entered the scene, and internal conflicts brought out political allegiances to the forefront. There were initial eviction notices and informal coercion that proceeded. A slum leader in an accusatory tone described the following:

"That time there was party politics, they (the authorities) threatened us that they will remove us by force. Due to these threats, we decided to file a legal case to get a stay order from the High Court."

The residents revealed that they decided to seek help from Right to Information (RTI) activists [5] who helped the community self-organize through the internal election of leaders as well as provided them with necessary legal assistance to challenge the eviction in court. The conflict became codified when the residents secured a 'stay order' from the court, which directed all stakeholders to maintain the status quo at the project site [6]. Meanwhile, due to evictions that continued in other parts of the city, we observed that the conflict became normalized, as stated by an interviewee (a municipal planner) as "quite natural for these slum dwellers to keep coming at us in one way or the other", and that the state must be "tough to develop the public land in the public interest".

4.1.2. Entanglement with Climate Shocks

While the existing social conflict was ensuing, the residents refused to be temporarily shifted to a nearby lowland area till the construction of the proposed housing project was completed, citing risks of waterlogging in the area compared to the safety of their present location, which they "made habitable" on their own. A slum leader reflected the following:

"We didn't trust their words. We would not have survived there. That year (2018) there were floods, and the water reached chest height. Later many of our neighbors who used to oppose us also agreed that if we did the right thing and not moved there, we would have been in big trouble. Our houses would have got flooded."

Local risk knowledge was likely being ignored in the adaptation frameworks by formal organizations, leaving space for more vulnerability of already at-risk communities. Following this event, the city administration faced a climate shock when the powerful cyclone Fani struck the city, bringing the physical infrastructure and service to a complete standstill for over a week and the social infrastructure for many months. For the slum residents, this meant the exacerbation and entanglements of multiple risks (health, livelihood, and housing risk), as well as the struggle for basic resources. The legacy of mistrust and unequal power relations between actors also likely deepened the conflict over the nature of post-shock recovery. A slum leader reflected on the post-Fani experiences as follows:

"There was no electricity for seven days throughout the city. When the BMC finally restored the electricity in nearby areas, they ignored Shantipally at that time. Only after we protested in front of the electricity Department office did they finally restore it for us after many days."

With limited help from the authorities during the recovery phase, residents described that they had to rely on local private NGOs for relief, as well as to fix their damaged houses, and had to deal with waterlogging due to incessant rains. This also meant low motivation to invest in any future meaningful household-level adaptation actions, citing that they "will be removed from this location anyway" [7].

4.1.3. Current Status

The community in Shantipally is hanging on to their existing land, while the case is still pending in court. The old disagreements remain among the actors, and based on our interviews, we interpret logically that the room for negotiations is seemingly narrow at this point. With several other projects within the smart city proposal in various parts of the city going on in full swing, the pressure of holding on is getting more complicated. The emergence of local slum leaders through the help of activists has provided a greater voice to the community, and space for future possibilities for a shared vision for the redevelopment project. Yet, we observed that local knowledge remains ignored in the implementation of the projects, especially in the management of risks as prescribed in the climate action plan that seems to be biased towards expert knowledge on resilience and adaptation, and also tends to have a narrow focus on risk assessment; i.e., a wide range of risks may be identified in the plans, but their overlaps with each other and with other elements of governance are not easy to decipher and are even more complicated to observe and interpret as they unfold in practice. From the case observations, it was clear that chronic social conflict has reduced trust between actors, making even short-term adaptation actions self-contradictory and difficult to implement.

4.2. Pandakudia Case

4.2.1. Emergence of Conflict

The BDA had an incremental approach to large evictions in recent times, as revealed by senior authorities within the BDA. The BDA managed to displace nearly 80 houses in July 2017 before the sporting event commenced. Following this, in early 2018, they demolished nearly 20 shops and the temple that was located at the center of Jagannath basti. This triggered unrest among the slum residents, who decided to protest [8]. A slum leader remarked the following:

"They (authorities) wanted to divide the shop owners from the rest, assuming that the Basti Sanghatan (Slum Committee) will weaken–this is because the shop owners were providing financial support as well as food for our community during emergencies. We (the slum committee) didn't let them divide us, though. We collected money from all households in our slum to tackle the absence of shops."

As the evictions continued incrementally, the slums started to reduce in size. The residents revealed that they eventually decided to organize formal protests to negotiate with the BDA and BMC believing they "will find a way to stop the evictions just like in the past" [9]. At the same time, local old rivalries seemingly emerged, with the slum leaders opining that local politicians and leaders who were waiting for electoral gains likely saw this conflict as an opportunity for demographic change (through the removal of the slum) within the area, and thus supported or opposed the eviction informally based on their interests.

Local risk knowledge was yet again likely ignored by the authorities in the redevelopment project, thus increasing the vulnerability of the slum residents due to poor land use decisions. As mentioned earlier in the paper, neither the masterplan, the SAPCC, nor any local policy of the BDA and BMC specifies any rational process involved in the selection of land for relocation of slums. Senior BDA officials within the Enforcement Wing confirmed this during our interviews, while also mentioning that they take decisions "on the ground" regarding relocations, depending upon the degree of cooperation by the slum community and the nature of the conflict. The proposed Pandakudia site is itself in a flood-prone area next to a reserve forest land on the outskirts of the city with a poor access road (revealed during interviews with senior BDA officials, and corroborated through a personal visit to the site). These potential new risks of displacing the community were ignored by the state organizations during the planning process; yet, the slum community was aware of this before relocation. Apart from the usual demands related to property rights and livelihood opportunities, the slum leaders emphasized in our interviews that they conveyed to the authorities the local risks associated with flooding and human–wildlife conflicts (the site is close to an elephant reserve). A slum leader during an interview remarked the following:

"When we got the news that they were planning to shift us to Pandakudia, some of us had visited these places out of curiosity. Just like they were surveying our slum, we were surveying their proposed site. We saw that the area was almost a forest with wild snakes and elephants. We also saw that the main access road was always waterlogged, even on non-monsoon days."

4.2.2. Negotiations in a Context of Conflict

As the dates of the Hockey World Cup in 2018 got nearer, the eviction drives of the BDA and BMC intensified, likely due to the pressures of achieving major development milestones before the event. While the authorities began their surveys of the households to be rehabilitated, the slum committee organized protests demanding land tenure. There seems to have been informal coercion by the authorities by deploying the police force "that looked like from outside the state since they did not speak the local language" as a strong deterrent against any potential violent protest. The residents on the other hand threatened the authorities with further protests during the sporting event to "protest and embarrass the authorities" as a countermeasure [10].

Eventually, the residents agreed to negotiate with the authorities over the details of compensation to be provided to the affected families. Upon negotiation, the authorities helped the community move to the new location by providing them with transportation and basic needs for a few weeks (such as water supply and temporary roofing material). A slum leader recalled the following:

"First they said they will settle us in another site on the outskirts of the city. We refused. After much arguments back and forth, finally, the Mayor and the Municipal Commissioner said that they will offer 35,000 rupees. They promised to construct one toilet for 10 houses; also they gave each house 120 square feet in Pandakudia. We did not agree, but what choice did we have".

4.2.3. Acute Shocks and Spontaneous Adaptation

Only a month after the residents were displaced, the community was exposed to a major climate shock (Cyclone Titli in 2018) that created further precarity, since the residents had not yet recovered from the displacement. A slum leader in the Pandakudia site recalled the experience as follows:

"The two cyclones (Titli and Fani) hurt us badly. Due to heavy rains, the water flew downstream here from the jungle area and washed away many of the walls since they were merely built. All the sand that was accumulated here for construction was washed away. We lost a lot of valuables such as a TV, refrigerator, and fans. So basically, the 35,000 that we received as compensation, we lost most of it to the cyclones."

Another slum resident highlighted how local coordination among volunteers and community leaders was instrumental in temporary and spontaneous recovery actions:

"During cyclone Fani, the roofs of our houses started flying in the air. All the electric poles were bent during the storm. The Electricity department initially did not respond to our complaints. How long could we wait? After a few days without electricity, we organized volunteers from all the slums here and restored it ourselves. It took us 7–8 days of constant hard work. Even the houses, we had to reconstruct by ourselves. They just gave us 10 kg rice and 2000 rupees after the cyclone."

The double exposure caused due to overlapping risks (from climate shocks, and development projects, plans, and policies) also brought about spontaneous coordination among formal and informal actors, a positive effect of the combination of shock and conflict. For example, during the cyclone events, the government disaster community officers collaborated with the residents to effectively communicate risk and manage the evacuation and post-disaster relief process, as revealed by several interviewees. This local coordination helped the community cope with shocks with the loss and damage limited to material assets and livelihood threats. A slum committee leader described how lower-ranked officials from the BMC "contacted us informing about the cyclone 2–3 days before it came, and also helped a lot by arranging relief materials". Yet, these collaborations were mainly with the state departments about whom the slum leaders spoke positively during the interviews, suggesting that the conflict may be a legacy of past local antagonistic relationships. Further, the collaborations were also limited to post-disaster relief, while the long-term recovery was left in the hands of the local governance system. Many new risks increased, such as loss of old social networks and linkages, as well as weaker access to schools and hospitals due to increased distance (many interviewees reported that school dropouts increased after the cyclones). Apart from these, interviewees revealed unanticipated effects of the original conflict in the form of the emergence of smaller conflicts, several smaller clashes occurring among the newly displaced communities and older urban villages nearby related to the construction of religious buildings and access to resources.

4.2.4. Current Status

As the communities focus on recovery from the recent shocks and adapt to the continuous and intertwining risks, conflict seems to be naturalized from both sides, thus reducing possibilities for long-term resolution or management. A senior planner expressed the larger public interest behind going ahead with evictions, during an interview:

"Every eviction meets with resistance. The government has to go ahead, and the proposed projects have to be built in the greater interest of the city. At times, the officials have been attacked. This is natural, it happens all the time."

In Pandakudia, while the conflict between the BDA and slum dwellers remains unresolved, the prolonged nature of conflict has also resulted in certain unexpected yet very useful outcomes in the form of local NGOs [11], often with organizational and financial support from international agencies, now helping the residents by providing livelihood support (facilitating financial loans, enrolment of children in nearby schools, retrieval of lost documents, access to jobs, etc.). As a result, local adaptive capacity has improved in recent times, although uncertainties over future evictions remain a possibility due to a culture of mistrust between the formal and informal actors. While newer government guidelines around the provision of land to the slum dwellers have been proposed, it remains to be seen how they play out in improving the adaptive capacity and dealing with future risks of the residents, and especially how they are implemented in the context of existing relationships.

5. Discussion

In this section, we shall discuss the above observations from the cases presented through a reflection on the complex and contextual interactions between conflict and shocks within a particular governance and policy domain. We make three broad observations based on the cases and link them with the existing literature. Following this, we point at several implications for climate risk governance in theory and practice, and finally provide some reflections on future possibilities.

First, the cases discussed demonstrate that the slum redevelopment initiatives in Bhubaneswar city rely on three strategies, viz. through eviction, demolition, and displacement; active and passive coercion to negotiate land tenure; and passive neglect in the aftermath of the shock events [110]. Both the Shantipally and Pandakudia cases highlight that slum demolition and relocation remain the most active and favored risk governance policy by formal organizations and institutions. This is based on the objective observation and assessment of slums as a governance risk (including climate governance risk), and consequent attempts to formalize them as a policy response.

Second, this study highlights how particular policy domains (in this case climate risk and smart development policies) can engender local conflict, when specific aspects of formal–informal interactions are not sufficiently addressed in the formal plans/policies and when implementation faces resistance [6,111–113]. Consequently, the possible pathways to observe risk, the vulnerability of marginalized groups, and options to respond to climate shocks are influenced. The dominant planning and governance approaches, as we inferred through our analysis of Bhubaneswar's plans, policies, and legislations, are inspired by modernism, through prescriptive ideas and discourses associated with climate change, resilience, and urban development. We refer to 'modernism' here as an approach to policy, planning, and administration where strong state administrations and their experts practice the belief that they can objectively map out society, define problems, and articulate, with scientific help, neutral and optimal solutions. In this case of planning, this can be linked to a belief in 'the best' possible organization of space through design or institutional procedures [114,115]. We argue based on the synthesis of our findings that the state-led smart city projects and large image-building infrastructure projects are a manifestation of these policies, which are in this case based on a biased and only partial observation and judgment of risk (including climate risk), resulting in selective use of governance tools and instruments. In doing so, the governance tools continue with a chronic ignorance of contextual factors such as local risk knowledge (based on history and lived experiences of previous disaster events), existing nature of conflicts, informal institutions within slum settlements as well as the plans themselves, livelihood networks, and local vulnerabilities that determine urban practices and adaptation choices of slum dwellers.

Third, this study revealed how climate shocks and their entanglements with existing social conflict made the overlaps between different climatic and non-climatic risks more visible and easily observable [116]. In the cases discussed, local risk knowledge and associated discourses that were previously not part of the land conflicts came to the surface after the shock events, with the slum resident groups highlighting local risks as a key factor in their refusal to relocate. Both the residents of Shantipally and Pandakudia, in the reflections on the current status of conflict as well as future aspirations, brought up flood and cyclone risk knowledge into the discussion. Risks from climate shocks also increasingly became inseparable from livelihood and social risks that the residents faced due to the shocks and the conflict. We further reflect and add that important climate shock events can be crucial sites of scholarly inquiry to use analytical tools to observe risks and help identify and open up 'black boxes' within existing risk governance approaches. We point to a dominant methodological challenge for risk governance, that is related to managing overlapping risks [3,117–120]. In the present cases, conflict increased the slum community's vulnerability to a plethora of risks (climate, non-climate, and risks from the decisions based on fantasy and imaginaries of smart-resilient neighborhoods). Old narratives of conflict and mistrust between the slum residents and the authorities limited the possibility of adaptive response to the cyclone event, even though interdependencies improved momentarily during the cyclone-preparedness phase with evacuation and relief work carried out seamlessly by the coordination of formal and informal actors.

Implications for Climate Risk Governance

Based on the case findings and discussions, we identify two implications for climate risk governance. First, based on our interviews of state and no-state actors, as well as direct field observations, there is a strong indication of the permanence of conflict within climate risk governance [6]. This is corroborated in theory, because conflicts never die in social–ecological systems, and resolving them may be theoretically impossible [8,53]. Since conflicts are inherently discursive, they are never stable, and with time become temporarily dormant, normalized, or evolve into disagreements between different narratives and discourses. This was observed in the cases presented, wherein the discourses used by the formal and informal actors changed abruptly after the shock events, so the conflict did not die, but evolved into new narratives. In spite of their best interests, we contend that the existing plans and policies have clear assumptions about future development; and by not specifying the nature of redevelopment, the plans directly affect the informal system through forced evictions and hence create the potential for local conflicts.

Second, as presented earlier, certain aspects of social conflicts may be productive from a climate governance perspective. This was observed specifically in the Pandakudia case, which highlighted how the conflict between the formal and informal actors resulted in improved self-organization strategies developed by the slum residents to adapt to the various perceived risks from formal imaginaries. These coordination mechanisms (for example between the Pandakudia community and the BMC officials) become the backbone of the community in dealing with climate shocks, by helping coordinate better local adaptation actions during the crisis, even though they are short-term and spontaneous. When conflicts combine with shocks, they provide room for opening up of previously hidden black boxing of notions about risk, reflections on existing institutions, new power relations between actors (possibly through more formal and informal recognition of local knowledge by the planning institutions, increased media attention, and help through social entrepreneurship such as the NGO in the Pandakudia case), and the emergence of new discursive directions in policies and tools. In this sense, conflicts and their complex entanglements with shocks can hold important governance and planning lessons.

In practice, we contend that much planning and risk governance tend to focus on either ending or resolving the conflict as an end goal. This is faulty due to the reasons discussed above. We argue for plans, policies, and risk management approaches to be more conflict-sensitive. We recommend that the focus thus should be on what happens when the conflict is seemingly temporarily managed, especially its implications on the vulnerability of the communities involved and reflecting on the long-term adaptation capacity through policy and governance. Avoiding or partially acknowledging social conflicts in the formal governance frameworks and tools is a futile exercise, especially when observed within local informal settlement communities. In this context, we argue that prescriptive governance frameworks based on clear assumptions of a top-down and expert-driven modernist approach as seen in Bhubaneswar have too many blind spots by failing to acknowledge local complexity and conflict. They may rather benefit from being more reflexive about their potential contribution towards an exacerbation of existing conflicts, the emergence of new vulnerabilities, as well as undermining of existing locally scaled adaptation possibilities. Based on document analysis of existing plans as well as interactions with the state actors, we further advocate for the inclusion of conflict management approaches within risk governance frameworks and risk reduction policies [121,122]. In the case of informal settlements as those studied in this paper, the inclusion may be approached by being more reflexive about the historically dominant narratives and imaginaries about informality in formal plans; focusing on the inclusion of alternate discourses, stories, and local risk knowledge; and striving towards stable institutional arrangements within informal settlements to identify, assess, and reduce risk.

6. Conclusions

We set out to understand the effects of the combination of social conflict and shocks and conflict on risk governance, in the context of informal settlements in Bhubaneswar. Based on our study findings, we strongly argue that conflict is rather permanent and certainly prevalent in social–ecological systems—even though conflicts may become dormant—and thus cannot be ignored in climate risk governance. Shocks are crystallized events where climate change manifests itself materially and socially within social–ecological systems. At the same time, shocks make existing and past conflicts more visible in certain contexts, while in others, they may blur conflicts. In the cases discussed earlier, on the one hand, shocks exposed the conflicts emerging from the existing affordable housing initiatives-related eviction attempts of the local state authorities, and on the other, the formal–informal boundaries temporarily became blurred due to small-scaled local attempts at adaptation and response that relied on local knowledge and support to absorb the effects of shocks.

This study demonstrated that slum redevelopment in Bhubaneswar as an adaptation strategy and risk governance tool through its modernist tendency is accompanied by the baggage of unwanted outcomes such as the patterns of exclusion by being blind towards existing and anticipated conflicts, by focusing on particular risks while ignoring others, and through the construction of new risks and opportunities and associating them with particular spaces within the city. Although this may not be the norm across all redevelopment projects, this observation is made based on the cases that result in conflict. In this context, an abrupt change in the form of forced evolutions and spontaneous adaptation can be brought about through sudden experiences with shocks, which adds uncertainty to risk governance.

We provided insights into the complex entanglements of conflict and shocks within particular risk governance and urban development contexts. This is useful for social–ecological systems and resilience theory in general, which tend to obscure the role of local conflict. We argue for a reassessment of local narratives around risk and conflict within the climate governance literature that tends to focus on conflict in the context of the global climate crisis also see [3,73,123]. The analysis is immediately useful for southern contexts marked by informality, slum clearance, and self-organization, all contributing to risk exposure under climate change, but it has considerable implications for other parts of the world where the planning system is based on hybrid combinations of modernism and institutionalism. The Bhubaneswar cases reveal the myriad risks coming with risk governance approaches in a modernist paradigm, i.e., relying on expert discourses, specialized and segmented governance domains constructing their own risks, blindness for local knowledge, hostility towards informality, aversion to conflict, and linear relations between risk perception, assessment, and management. Such a modernist paradigm of risk governance can be recognized across the world and seems reinforced by the feeling of urgency, sometimes panic, engendered by climate change.

Bhubaneswar shows us that blindness to conflict in the formal system can engender new conflict during planning interventions and reduce resilience when responding to shocks. The cases demonstrate that ignoring existing forms of self-organization, local knowledge, and adaptive formal–informal relations can undermine resilience and increase risk. They reveal that, as noted above, risks never exist in isolation from each other, and are never detached from perspectives on the future. Comprehensive approaches to risk management, such as slum evictions, can thus never be comprehensive if they focus on one type of risk (development risks for example), and they will be blind to alternative strategies and opportunities while creating new and invisible risks and most likely new and evolved conflicts.

Climate change adaptation discourse, and the associated risk governance ideas, in many places, come with a risk of reviving and reinforcing modernist policy and planning fantasies. This often leads to a renewed blindness for alternative interpretations of place, opportunity, and risk, and reinforced positions of power of bureaucratic, political, or economic elites seeing the potential of the new climate risk discourses to pursue old goals [124,125]. This then can create or maintain social conflict, especially in places with a history of groups having been excluded and marginalized in governance, where opportunities are scarce and scarcity is a real problem [126]. In this sense, we recommend that future climate and development plans/policies in Bhubaneswar and beyond need to be more conflict sensitive, and not just be driven by resilience frameworks which in our interpretation borrow from modernism, and tend to ignore local knowledge and local risks in informal settlements, a dominant part of the urban landscape in many southern cities.

By acknowledging the existence and permanence of local conflicts in cities, climate plans and policies can also focus on incorporating experiences around productive aspects of combined shocks and conflict that may provide space for new forms of local collaboration between formal and informal actors. This may help sustain these short-term collaborations by not being limited to post-disaster recovery and spontaneous adaptations, but by promoting sustained resilience in the long term. Furthermore, we also recommend that formal plans and policies around climate risk take cues from the framework and results presented in this study to become more reflexive in the future by asking critical questions about why and how slum redevelopment has been accepted as a climate adaptation and smart development strategy, as well as the risks associated with such decision making.

Resilience and adaptation in cities can be planned and unplanned, it can be the result of routine responses in governance and by a group of individuals, and it can be the result of intentional responses to change in planning and long-term strategy, when these activities are not under the label of 'resilience'. Nor does a contribution to de facto resilience need to be a type of response to a type of change that is also recognized in the community as relevant for resilience. In fact, the response itself, planned or unplanned, might not be closely connected to any easily recognizable feature of resilience, but only very indirectly contribute to the resilience of the system [37]. This brings us to the basic idea, compatible with General Systems Theory [127], that resilience cannot be a list of system features that can be the end goal of planning and policies, but has to include a consideration of fit between the system and environment. In our cases, the resilience of the informal settlements hinges on internal features and on the relation with the rest of the city, while the resilience of the city as a whole can be seen in a similar way, in relation to the state. Our cases strongly indicated that the legacy of shock and conflict increased the opacity of the governance system for itself, as well as the opacity of the environment for the governance system. If we can consider governance as a basic feature of a resilient system, and a relation with its environment whereby opacity is a problem for resilience, then the observed situation does undermine resilience in the longer term.

We conclude the paper by making a final argument that it is more fruitful and realistic to present the relations between risk perception, assessment, and management as non-linear and as multiple and competing. We contend that risk governance has to be at the foremost 'governance', that is, the deliberation and taking of collectively binding decisions to address the risk (to mitigate, ignore, compensate, etc.) and this has to fit the overall principles and direction for the development of the area adopted in the relevant governance arena. Focusing on risk rather than opportunity is a decision that ought to be taken in governance, as is the privileging of one type of risk over others, or of one relation between risk factors over others. Not recognizing these principles is de facto de-politicizing not only climate and risk governance but governance as such [128]. The relations between risk perception, assessment, and management, moreover, will be affected by shock and conflict, and vice versa [129]. A shock event potentially engenders shifts in risk perception which are never entirely predictable; it can create conflict, while existing conflicts are very likely to frame the perceptions of risk and opportunity by actors, as well as the perceived options for risk management. In many southern cities, where there often exists a mistrust between the formal and informal systems, the risk perception of slum dwellers is always likely to be affected by the anticipation of conflict and make them suspicious of new resilience initiatives [54,108]. Shock and conflict are thus inextricably linked to climate risk governance, and a modernist delineation and isolation of such risk through plans, policies, and actions from the rest of governance is bound to make the formal system blind to these essential intricacies.

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Notes

1 The last Census in India was held in 2011.

2 Objects of governance in the EGT lens are produced through discourses and practices of thinking and action, though the processes of reification (conceptual surfacing through discourses and action), solidification (internal differentiation and articulation of elements within the system), and codification (creation of distinct system/environment boundaries).

3 Based on interviews, personal observation during field visit, as well as informal discussions with residents.

4 Sources: interviews with slum residents and key informants within BDA, media reports, and document analysis.

5 The Right to Information (RTI) Act, 2005 in India mandates timely response by state officials to citizen queries and requests related to government information. The Act was brought to empower citizens and promote accountability and transparency in the governance process at all levels (central, state, and urban/rural bodies). RTI activists use the RTI Act as an instrument to legally challenge eviction attempts by state authorities.

6 Based on legal case documents shared by participants during interviews.

7 Source: interview with slum resident.

8 It is interesting to note that the slum residents here did not decide to pursue a legal stay order like the Shantipally residents; when probed about it during the interviews, several residents leaders noted that such an approach "wouldn't work in the long run".

9 Source: interviews with slum residents and leaders.

10 Source: interview with slum leader.

11 In Pandakudia, the CSNR (Centre for the Sustainable use of Natural and Social Resources), a local NGO, has been instrumental in providing livelihood support to the displaced residents.

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Article

Living on the Edge—Mismatches and Expectations in a Changing Landscape

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Abstract: This paper deals with the confrontation between the forms of urbanisation of Lisbon, Portugal, that extends its fringes over the Alcântara Valley. This same Valley—topography and hydrography—plays as determinants of the occupation that will assume distinct narratives. This gradual process is explained through three narratives about (1) the urbanisation of the margin driven by industrialisation and the construction of a stigmatised periphery, (2) the imposition of large capacity infrastructures far beyond what is local, (3) the system of open spaces and landscape projects and the urban brink that the valley claims. The debate focuses on the answers that the urban and landscape project, necessarily going through urban planning and its practical and theoretical scopes, i.e., Urbanism and urban planning thinking, especially in a broad present seeking to discuss both sides of the coin: on the one hand, an urban rehabilitation with public space for all, on the other hand, a qualified and central space that attracts real estate investment that may bring effects contrary to those expected. The article seeks to contribute (1) to a broader perception of the superimposition of processes that transformed the Alcântara Valley, (2) to a fuller dissemination of the urbanistic experiences in the city of Lisbon since this city is still vastly underrepresented in the international (primarily Anglo-Saxon) literature, (3) to deepen the debate between urban rehabilitation, urban regeneration, consequences and opportunities practiced is still trying to cope with.

Keywords: urbanisation; landscape; urban rehabilitation; public open space system; Alcântara-Lisbon

1. Introduction

In the Alcântara Valley, the urbanisation process reveals the growing clash between a striking topo-hydrographic occurrence and mid-19th century western borders of the City of Lisbon and the urban development constrained by it but impelled by the industrial upsurge associated with the substantial harbour infills most extensive quay of the city and the railway belt.

Three narratives can be identified from the transformation processes. Albeit their different beginnings in time, they persist entangled until the present:

- Industrialisation at the end of the 19th century with new landfills and industrial perimeters, precarious urbanisation along the old Alcântara Stream, and further housing needs.
- In the first half of the 20th century, overlapping high-capacity road and rail infrastructure, such as the bridge link.
- From the 1990s onwards, the need to restore urban continuity, the qualification of public and open spaces, urban rehabilitation interventions, and the Alcântara Green Corridor under the aegis of the Lisbon Green City 2020 award.

The Alcântara Valley shows the many facets of a residual city marked by each period's avant-garde urbanistic thinking. However, in this study, it was verified that, despite remarkable development in the Lisbon urban planning and management field, there is still some room for integration between these narratives and respective approaches. This condition opens the debate proposed in this article, about the effectiveness—social, environmental, and economic—of urban rehabilitation and regeneration, in the present context. The article unfolds in sections: 1. Introduction, 2. Materials and Methods, 3. Results: Alcântara: three narratives, one story, 4. Discussion and Conclusions: Three decades of urban planning and design, 1990–2020: Genealogy and insights.

The work is built from an urbanistic perspective, as framed in the romantic European countries, such as France, Spain, Italy, and Portugal, which led the movement in the creation of a new discipline called *Urbanisme* (FR) *Urbanisttica* (IT), *Urbanismo* (ES and PT), since the late 19th century [1–3], addressing the conception and design of the industrial city. This particular design and place-grounded perspective of the urban, as the result of distinct landscapes and cultures [4,5], would only later be included in the policy and framework European Union (EU) [6,7]. Recent perspectives in the public space design, especially in the fringe areas, often adapted to linear parks, allowed to encompass, as well, references to the *landscape ecology* [8] and the *landscape urbanism* perspective [9,10]. In its own character, the main focus of the Alcântara Development Plan, having its stream, the need to interweave urban fringes with the open space system and the infrastructures, might take the linear park concept as a backbone.

This view encompasses the territorial transformative phenomena and their changing processes, whatever their kind, in this case, a blend of marginal urbanisation and increasing derelict areas and abandoned rural structures. It addresses the material adjustments that continuously shape the fabrics.

A Valley as the Boundary of A City

Lisbon's urbanisation is deeply marked by the opportunities offered by physiography, geostrategic location, and long-time settlement. Time, place, and people shaped the city's facets, from vernacular to the most erudite and innovative today.

The stepped topography shapes the city, where valleys convey streams and main roads to smaller rural and riverside settlements and the main centre—earlier in Castle Hill and within the 14th-century walls. After the 1755 Earthquake, the urban design of a modern downtown (Baixa) introduced the Enlightenment's novelties, and the city grew way off the former walls and fused with *extramuros* villages (see Figure 1).

Water and land constrained the urban development, casting natural territorial boundaries: to the Eastern Side, the Chelas' system of Valleys, and to the west, the Alcântara Valley, this study's subject. The contrasts in these then outskirts would become more emphatic, where incipient yet consistent industrial-led urbanisation encroached on former rural estates and villages in the Valleys of Chelas and Alcântara. The profoundly transformed waterfront along the Tagus Estuary offered a protected natural deep-water harbour allowing the evolution of overseas capital. These conditions would impel a fundamental waterfront axis, running the city from east to west.

By the mid-19th century, the city boundaries consisted of a ring road adapted to this topography. Such valleys and urban-related areas would turn into critical industrial nodes. They were strategically and geographically positioned to the waterfront and, later, with direct links to a goods railway belt around the city.

Lisbon Historic Cartography allows us to observe at the first stance that those were the boundaries of the city (see Figure 2a–d) and at a later one (see Figure 2e,f) that the Municipality would incorporate the adjacent municipalities, notably, starting at Chelas towards the Eastern side. Belém starts at the Alcântara Valley, towards the west. The annexation of neighbouring municipalities (Belém and Olivais) enlarged the Lisbon municipality to nearly the current boundaries, and a second ring road would wrap around.

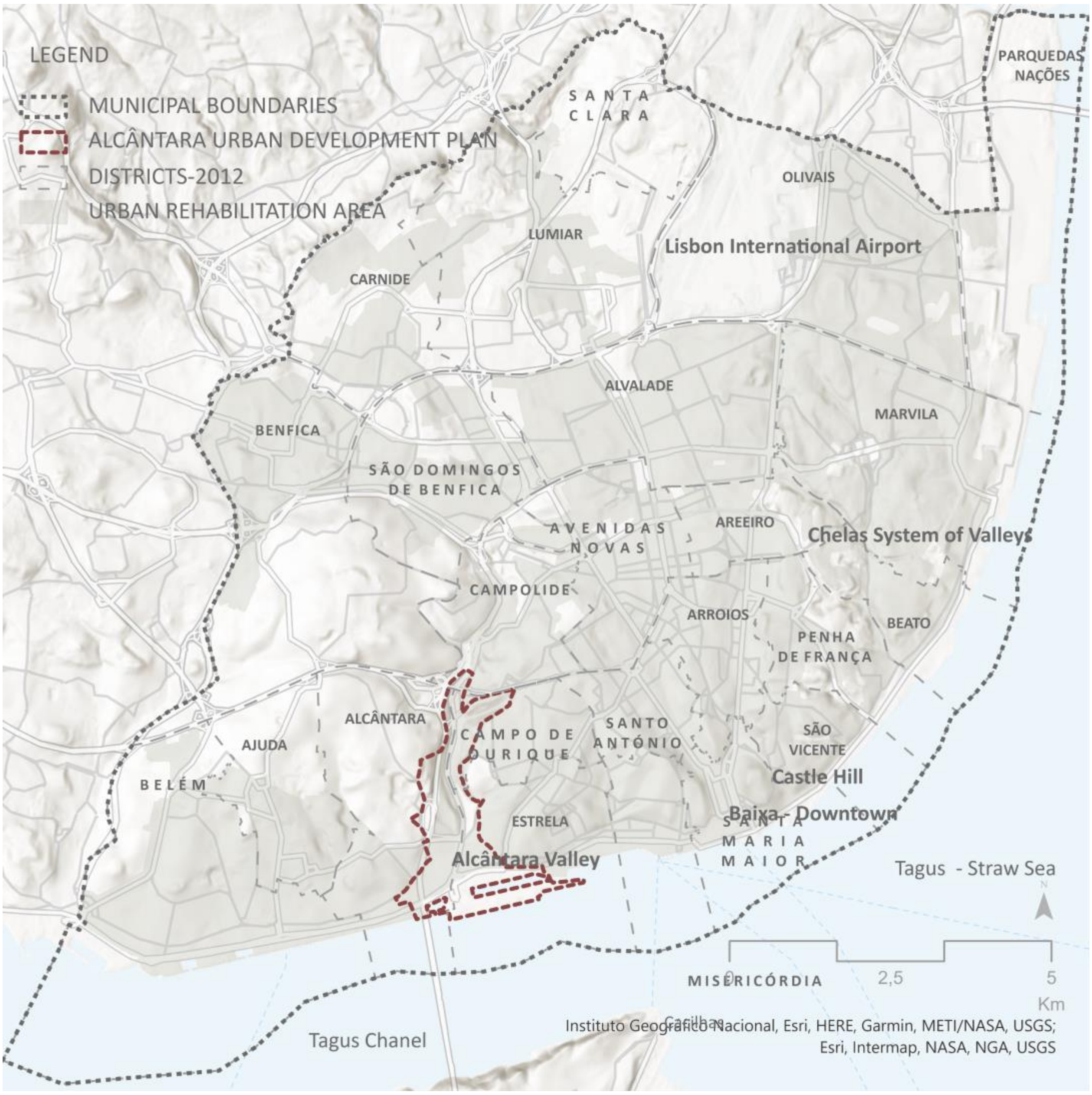
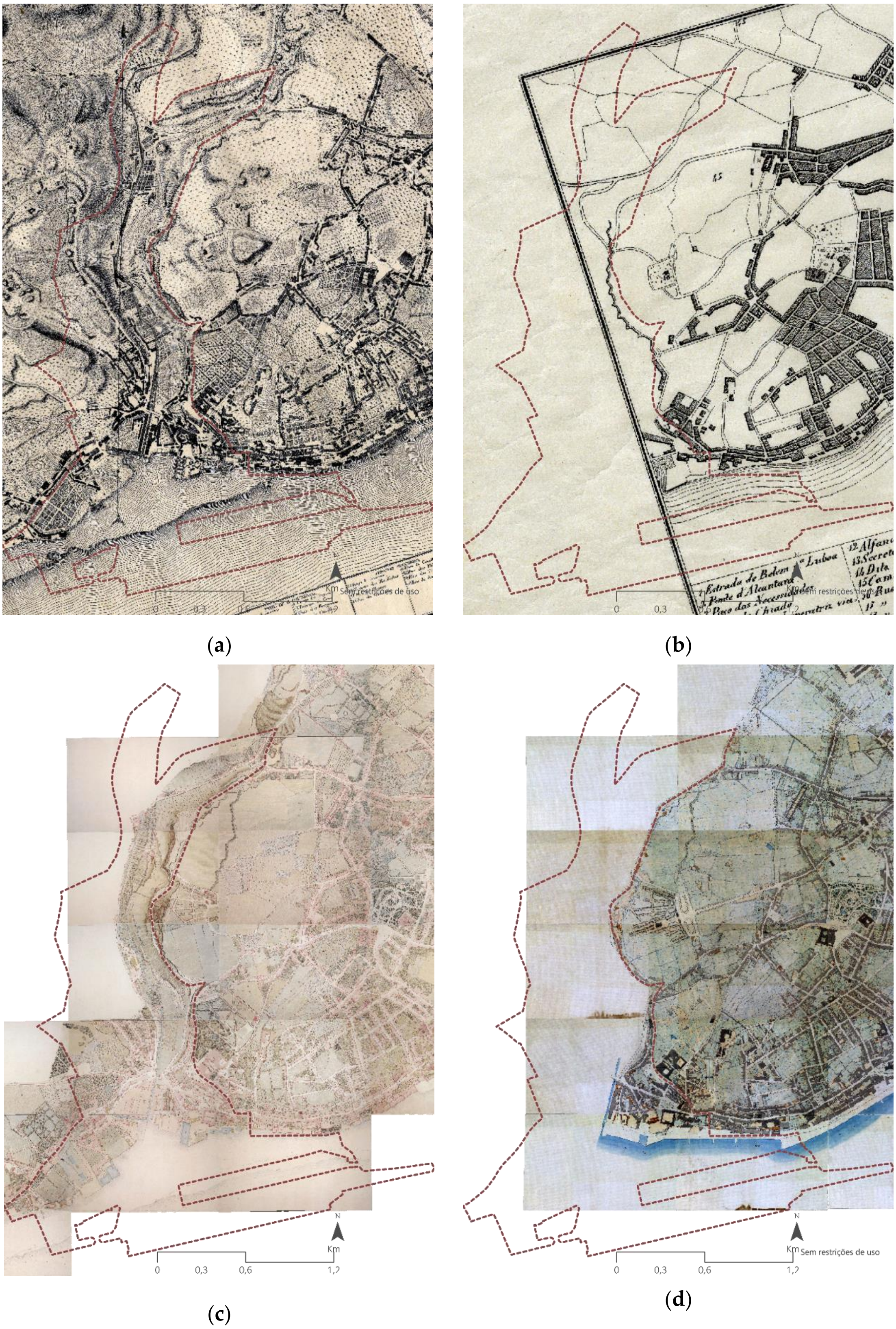


Figure 1. The Municipality of Lisbon, municipal and district boundaries, Urban Rehabilitation Area, Development Plan for Alcântara. Sources: Own production adapted from CML open-source databases (see Backmatter).

City gates on main roads to the city centre are now embedded within the fabric or lost. Nevertheless, as soon as that threshold is crossed towards the inner side, the urban character reveals itself through the late 19th-century/early 20th-century renewal in the public space—pavements, public water-supply fountains, furniture, and trees, notably at Praça da Armada and main Alcântara main street, along with the building typologies and architectural elements, such as facades covered in pattern-tyles, iron-casted balconies and mansard rooftops. (see Figure 2c–f; Figure 7d).



(a) (b)

(c) (d)

Figure 2. *Cont*.

(**e**) (**f**)

Figure 2. Historical Cartography of Lisbon (excerpt superimposed by the active Urban Development Plan (dashed line, dark red) for Alcântara. Sources: Own production over CML open-source databases (see Backmatter) (**a**) Duarte Fava Lisbon Map—1807. (**b**) Lisbon Map—1855. (**c**) Filipe Folque Lisbon Map—1855–56 (**d**) Francisco & Cesar Goullard Lisbon Map—1878. (**e**) Lisbon Map—1855 [superimposition in red with the Ressano Garcia Plans; Vieira da Silva collection]. (**f**) Silva Pinto Lisbon Map—1904–11.

2. Materials and Methods

The study design results from a long-standing observational experience, strengthened by urban design studios and amplified by primary sources (cartography, iconography, legal documents), and follows a patchwork ethnographic methodology [4,5] and the narrative theory approach [11–16], from a qualitative and cultural methodology [14,17–19] to the evolution of the rural-urban fabrics, i.e., place and time. Lisbon is one of the oldest continuously inhabited European cities. Besides becoming one of the best-known cultural tourist destinations, it is also the only city, as far as we know, with its own historiographical line called Olisipografia. From the 19th century onwards, a unique approach was developed, with written, narrative, iconographic and cartographic documents drawn up by illustrious figures who played essential roles in interventions in the city that have lasted until today. The many documents gave rise to the Gabinete de Estudos Olisiponenses/Olisiponenses Studies Office [20–23]. This work owes much to the 30 years of observation, reading, and identification with the spirit of Olisipography, which is still little known.

Hence the usage of the materials usually involved in such research fields—historical cartography, iconography (e.g., photographs, and others), and various documents (legislation, plans, and designs included in architectural and urban design), whose outcomes are featured, mostly as follows:

1. Literature Review (see all sections)
2. Desktop research at the Lisbon Municipal Archive (Arquivo Municipal de Lisboa), historical cartography and iconography, notably photographs and correlated documents linked with the site, since the late 19th century (see Section 3 Results).

3. Experimental methods by design in Urban Planning and Design Studios and Workshops 2019—Workshops: (1) 2009/10, Scientific and Teaching Responsibility, Urban and Territorial Design Studio II, Master in Architecture specialising in Urbanism, with the support of the Lisbon City Council, in the provision of material, technical monitoring Urban and Spatial Planning, in the provision of material, technical monitoring, and development of the students' work. (2) 2013, Coordination and organisation, From splinters to parks, 2nd [Urban + Landscape] design international workshop, 7–10 May, endorsed by the ISOCARP. Published [20]. (3) 2019, Coordination, *Cidade [n]a Margem//City on the Edge. Alcântara: infrastructures, fabrics, landscapes*, Futures Workshop, with participants from masters' and doctoral programs in Urbanism at the Lisbon School of Architecture. Joint organisation: Lisbon School of Architecture, Universidade de Lisboa, and CIUL/Lisbon City Council with urban and landscape design senior officers. 8–15 May, CIUL.
4. Observational methods through field trips and photographic documentation (August 2020, September-November 2021, March 2022) (see Section 3 Results).
5. Review of urban planning-related legislation in Portugal, INE-Statistics Portugal (see Section 3 Results and Section 4 Discussion).
6. Review of urban planning documents (policies, plans, and programmes), Urbanism and public spaces design promoted by the Lisbon Council's Urban Planning, Environment and Green Spaces, existing local plans, and projects for units at the local levels of intervention and media (Newspapers and Documentaries) (see Section 3 Results, and Section 4 Discussion).

3. Alcântara: Three Narratives, One Story

Etymologically, the word 'Alcântara' comes from Arabic and means "bridge" [21], a bridge made of stone, thus, an important one. However, documents refer to a possible prior existence in the Roman period, which aligns with the city's archaeological findings along the waterfront. Alcântara was the main entrance from a Royal area, the former Belém Municipality, towards *Intramuros*. Even today, roads and other paths converge at that point, once a marsh and lagoon. One must, nevertheless, acknowledge that the most common way of displacement before the harbour infills was by cabotage from the pier to the pier, which most waterfront buildings had. Even today, the district boundaries are consistent with the Alcântara Valley morphology (see Figure 1).

3.1. Fringe Urbanisation in Former Rural Environs: The Birth of Stigma

In the Alcântara Valley, the urbanisation process reveals the growing clash between a top-hydrographic occurrence that defined the western border of Lisbon, contained in the first ring road, until the mid-19th century. With the arrival of industrialisation and new port and railway technologies, it was on this riverside periphery that warehouses were progressively installed to support the docks of Alcântara, reinforced by the arrival of the Lisbon railway belt. This strategic point of the anchorage from the deep waters of the Tagus Canal acquired a fundamental preponderance (1) in the context of the international maritime routes also led by the Port of Lisbon, (2) in the connection to the national railway line to Oporto and (3) in the transformation of the city.

Thus, we witnessed the progressive transformation, by successive embankments, between the lagoon and mouth of the Ribeira (Stream) de Alcântara and the coastline that acquired an industrial and Port character. This transformation occurs with the partial urbanisation of the Royal Palace of Alcântara, gone, today Calvário, along the main street of Alcântara, promoting the riverside urban axis towards Belém to the west (see Figure 2a–f, see Section 3.3).

The *locus* of a mixture of proto-industrial installations, mainly associated with textiles and dyeing, powered by the force of the water and rustic occupations still related to an agricultural lifestyle, unravels perpendicular to the coast and along the Ribeira de Alcântara.

Along this axis, very precarious housing buildings were located, and families occupied natural caves as well, housing a population between industrial day labour and subsistence farming. These incipient fabrics extended northwards in a multiplying process (see Figure 2e,f). It is not surprising that the northern fringes of Alcântara have become synonymous with poverty and that, over time, a social stigma has been attached to it that still persists today [22].

3.2. The Sectoral Superimposition of Modern Features: From A City Boundary to A Robust National-Level Centrality

It was then the time for 'artificial creation' [23] to plough the land and tunnel the Alcântara Stream. In front of the former river mouth, specialised quays grew. High-capacity infrastructures were progressively superimposed onto the Alcântara Valley decline - a water underpass, viaduct for the first motorway linking Lisbon first to the National Stadium complex (the 1940s) and later to Cascais (1990s), a bridge over the Tagus (1966), railway ring (late 1800s) and later underneath the Bridge (1998) (see Figure 3a–f), more powerful motorways interlinking metropolitan levels (Eixo Norte-Sul), and even a vital flight corridor towards the Lisbon international airport up north.

Despite an apparent confusion, the transformation of Vale de Alcântara calls for interventions of two fundamental types: as a channel space, prone to infrastructural linearity, or as a hiatus, a limit or an obstacle to be overcome.

The first perspective, channel space, is revealed in the urbanisation and progressive transformation and finally, the canalisation of the Alcântara river, along which road and rail routes stretched and connected to the Alcântara docks, assuming a progressive protagonism with the construction of the Bridge 25 de Abril. Later with its intensification with the passenger rail connection (1998) and the subsequent insertion of the North–South axis at the end of the 20th century, which would transform the north of this Valley into a junction of supra-metropolitan reach [23].

However, the links to the Port allowed the Alcântara and Rocha Conde de Óbidos Docks, contiguous to the deepest water trench of the Tagus Estuary, to perform highly contributing to the fundamental role Lisbon played in the international maritime routes. At the same time, liaising between the Railway Station Alcântara-Terra (Alcântara-Land, primarily for workers coming from the Sintra–Lisbon suburban line and working transposition of goods to the harbour from the railway belt) and the Railway Station Alcântara-Mar (Alcântara-Sea, in the Cascais–Lisbon suburban line) (see Figures 3a–f and 4), maintained the pedestrian access to workers and inhabitants.

As an obstacle from the outset, the Valley of Alcântara holds the character of urban protection and containment of the urban on the first ring road, a natural moat defended a city at a higher elevation, with secure access through the Alcântara Bridge and Gate.

This obstacle was conquered by the monumental Aguas Livres Aqueduct, promoted by King João the 5th in the 18th century [24,25]. However, the new water supply network to the city of Lisbon, notably the Aqueduct, is said to be more scenic and an exercise in architectural virtuosity than supplying enough water ('Aqueduto das Águas Livres, Lisboa', 2018).

These trims of the rustic and proto-industrial mixture would be, again, crossed by the Duarte Pacheco viaduct that introduced the first motorways, in this case, the Cascais one, in the context of the Costa do Sol Plan and together with the plantation of the Monsanto Forest Park (late 1930s) [26]. From a perspective of the modern city expanding over the rustic, Meyer-Heine, in his Plano Geral de Urbanização de Lisboa—PGUCL (Plano de Meyer-Heine, 1967) [27], would consider this Valley an "obstacle to urban life" (author's translation, [28,29], i.e., to urban expansion. Launching broader territorial links at the national level raised barriers to former urban continuities between settlements and brought urban decline to the local population and urban fabric.

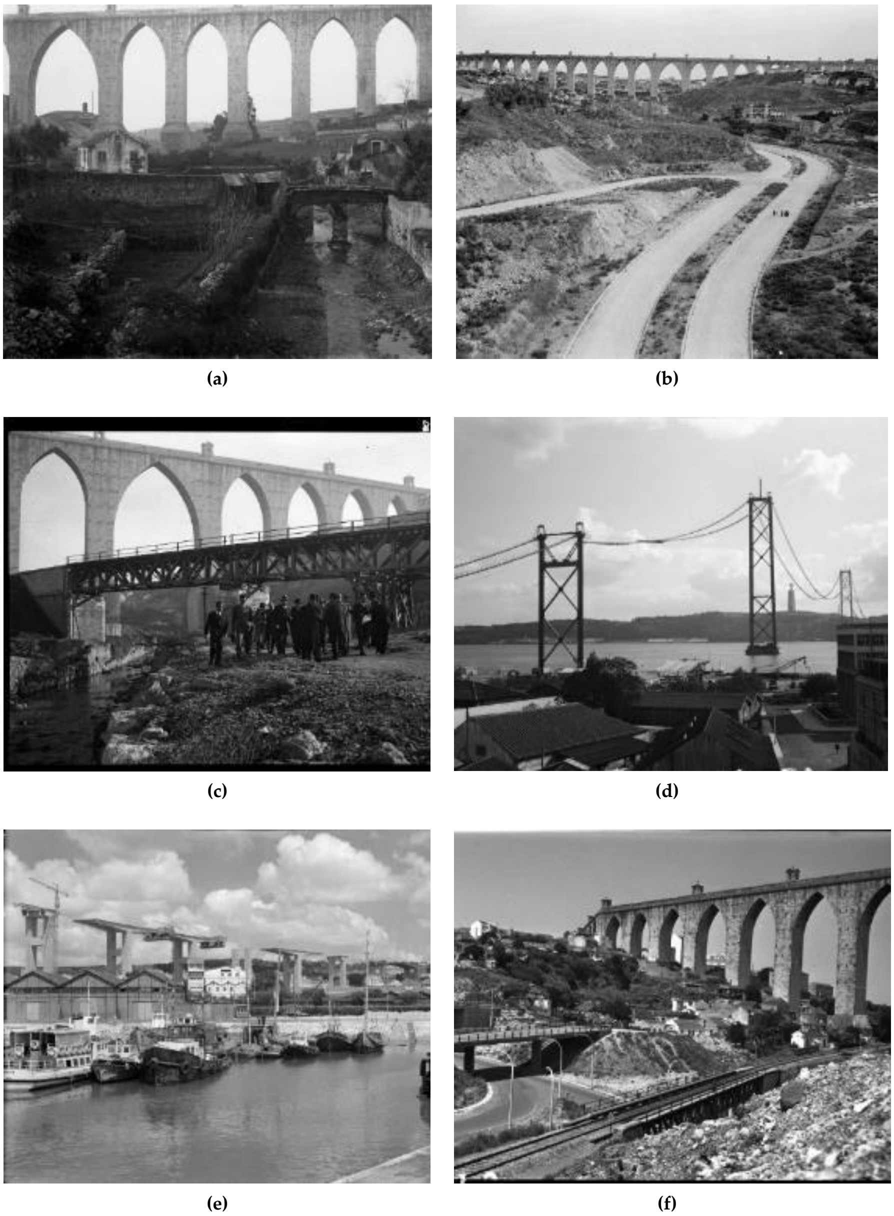


Figure 3. Historical Photographs—courtesy of the Lisbon Municipal Archive. (**a**) Aguas Livres Aqueduct and Rabicha bridge over the Alcântara Stream—Source: [Aqueduto das Águas Livres e ponte da Rabicha, sobre a Ribeira de Alcântara], [c.1912], Paulo Guedes, photographer, PT/AMLSB/CMLSBAH/PCSP/004/PAG/000396; (**b**) Águas Livres Aqueduct over Ceuta avenue—Source: [Aqueduto das Águas Livres sobre a avenida de Ceuta], [c. 1949], Horácio Novais, PT/AMLSB/CMLSBAH/PCSP/004/HNV/000050. (**c**) Visit of the Lisbon City Council to the opening works of the Avenida de Ceuta near the Santana de Cima viaduct -Source: Visita da vereação da Câmara Municipal de Lisboa às obras de abertura da avenida de Ceuta junto ao viaduto de Santana de Cima, 1949-01-22, Câmara Municipal de Lisboa. Repartição dos Serviços Culturais. Secção de Propaganda e Turismo, PT/AMLSB/SPT/000007, (**d**) Construction work for the 25th of April Bridge -Source: Obras para construção da Ponte 25 de Abril, 1964, Casa Fotográfica Garcia Nunes, PT/AMLSB/CMLSBAH/PCSP/004/NUN/000651. (**e**) 25th of April Bridge under construction -Source: Ponte 25 de Abril em construção, 1964, Casa Fotográfica Garcia Nunes, PT/AMLSB/CMLSBAH/PCSP/004/NUN/000659. (**f**) Avenida Calouste Gulbenkian and accesses to 25th of April Bridge and the Santana de Cima viaduct—Source: Avenida Calouste Gulbenkian e acessos à Ponte 25 de Abril e o viaduto de Santana de Cima, 1967, Artur Inácio Bastos, PT/AMLSB/CMLSBAH/PCSP/004/AIB/001664.

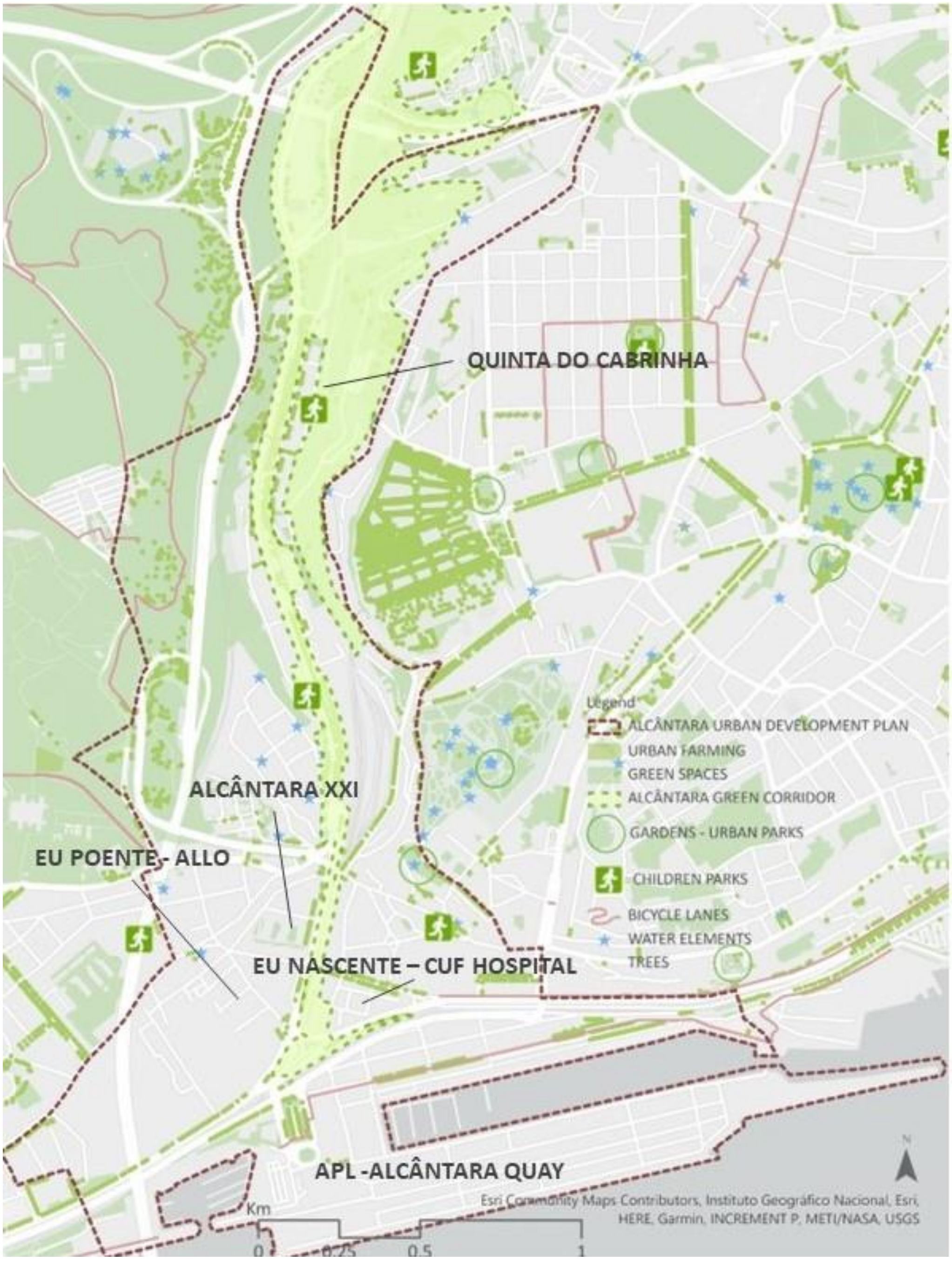


Figure 4. Urban Green Spaces, Alcântara Green Corridor, and the active Urban Development Plan (red) for Alcântara. Source: Own production adapted from CML open-source databases (see Backmatter, 07/11/2021).

3.3. Public and Open Space System: Beyond Inequalities or Green Branding?

The Alcântara Valley was part of the Algés Reguengo, where, in the mid-17th century, a Royal Palace and Estates (Paço de Alcântara) and related open space infrastructures were settled [30]. Other noble houses would follow, leading to a certain degree of urban development, even if extramuros. While the royal structures gave place to industrial sites in what now is Quinta do Cabrinha Neighbourhood, this noble Estate would start developing towards a proto-industrial system along the former Alcântara Stream, the current Ceuta Avenue, with the development of the dying industry (Fábrica das Chitas) and the Gunpowder Factory.

These structures and correlated housing rows would expand until the late 19th century [31]. Some places are still marked by toponymic and pre-existent shapes and buildings. Tapada da Ajuda is a botanical park with pavilions, woods, and gardens, and was a critical leisure place until the end of the monarchy (1908) [32]. Later, it would become the current Agricultural School of the University of Lisbon, under the context of the 1st Republic, since 1910.

Monsanto Forest Park would introduce a new level to the landscape value. The climate and landscape in Lisbon are barely compatible with lavish greenery. Hence, Monsanto hill was practically covered with bushes, devoid of forest traces [26] (see Figures 2 and 3). The Forest Park, entirely created and planted, goes back to early 20th-century ideas then integrated by de Gröer's garden city approach to Lisbon [27].

The Green Corridor in Alcântara aims, and to a certain extent manages, to create an open space continuity designed for different users and distances, thus increasing active and soft mobility modes (see Figures 4, 5 and 6a,b). Moreover, it works as a fundamental green infrastructure providing vital support as part of an ecosystem service to the city.

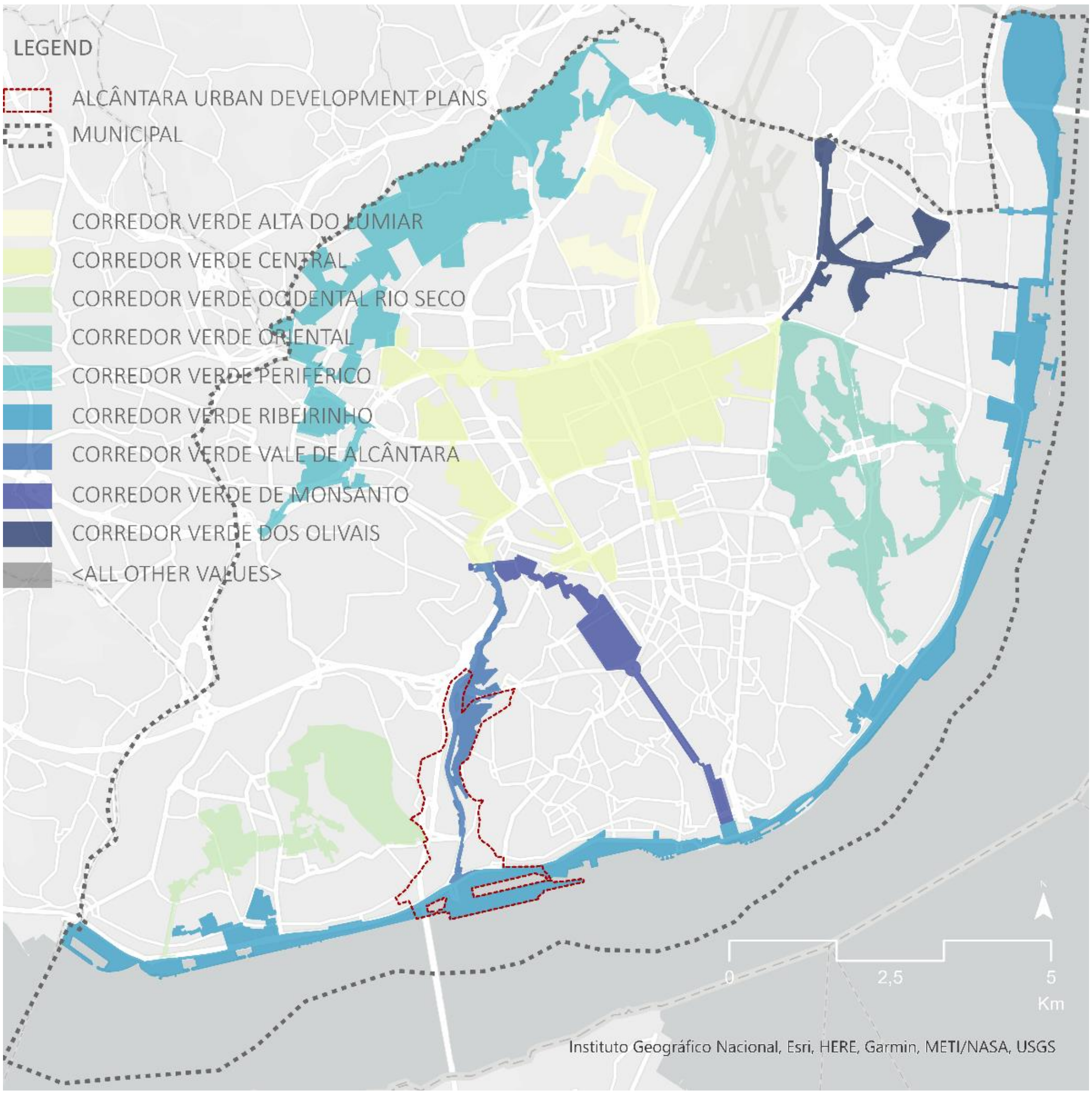


Figure 5. Green Corridors and Green Spaces, Green Spaces and Environment Department/Lisbon City Council, and the active Urban Development Plan (red) for Alcântara. Sources: Own production adapted from CML open-source databases (see Backmatter, 07/11/2021).

In the northern section of the Valley, the Museum of Water reopened the 18th-century Aqueduct as a public bridge (as it used to be until the mid-19th century) to cross the Valley between Campolide and Serafina Neighbourhood by the Monsanto Forest Park on Sundays. This decision was undertaken within the decisions embraced by Lisbon Green Capital 2020, allowing, for the first time, the use of bicycles in close connection with the new bicycle lanes promoted by the Alcântara Valley Green Corridor. The first pedestrian and bicycle bridge were inaugurated in 2018 (during the workshop *City on the Edge. Alcântara: infrastructures, fabrics, landscapes*), and it is becoming increasingly usual to see people use it daily.

(a)

(b)

Figure 6. *Cont.*

(c)

(d)

Figure 6. Alcântara Valley, November 2021. Source: Sofia Morgado. (**a**) Alcântara Green Corridor with the Tagus, towards the south, from the Aqueduct; (**b**) Alcântara Green Corridor and Campolide Train Station, new works, towards the north, from the Aqueduct; (**c**) Alcântara XXI, (**d**) Alcântara main street, former city gate through the Bridge, towards the city mid-19th century Intramuros.

On the night of 07 December 2022, heavy flooding, which has not been known for more than 15 years in the northern Lisbon metropolitan area, resulted from an extreme weather event of excessive rainfall. A few weeks before, an unusual phenomenon, a small tornado, occurred in Valley. A week later, Lisbon, and Alcântara in particular, was hit by extreme climatic and convective phenomena that had never been seen before.

Floods, however, with only one human loss, were extensive and will increase as a climate change consequence, as noted by Filipe Duarte Santos [33]. Oddly enough, in the

1940s, Vieira da Silva, an esteemed Engineer and Olisipographer, was already calling for those risks regarding the reorientation and tunnelling of the Alcântara Streem to insert the railway line onto it [34].

More than *green branding* [35], through the label of the Green European City 2020, the Alcântara Green Corridor, along the Valley interconnected with the others within a green network, is a fundamental green infrastructure in the approach to any city of the present, especially in such conditions as flood risk, as Alcântara.

If qualified public spaces are also offered to the citizens, pre-existing urban fabrics are preserved, and new ones are valued, even if some green and blue gentrification may occur [36]

A green corridor over ruined; precarious rural nuclei; abandoned amidst a sky bleak by viaducts and the roar of dusty pavement; where no one can walk yet between the sparse housing *ensembles* along the heavy infrastructures.

Above all, the urban continuities promoted by the public space through a green corridor or local interventions, such as the Program a *Plaza for each neighbourhood* [37], have not yet proven their ability to overcome the aforementioned segmented reality.

4. Three Decades of Urban Planning and Design, 1990–2020: Genealogy and Insights

The practice of urban planning and design in Portugal has been progressively recognised as being developed within the best parameters of maturity and innovation in international terms. The awards received directly (Lisbon Green European Capital 2020) or indirectly (such as those related to tourist destinations), the technical publications, and the presence in the most relevant networks of cities recognise what, sometimes, the scientific literature still does not.

Each city, each place is unique and concentrates *strata* from various times that, in cases like Alcântara, perhaps require a more comprehensive range of issues related to the transformations of the territory. The morphogenesis of the Alcântara Valley reveals itself in discontinuities of the landscape in its various shades (from rural to urban), administrative and jurisdictional (municipal and national level, such as the Port of Lisbon and other large capacity infrastructures) (cf Section 4.), but also unfulfilled expectations, and projects that never made it.

PEDU/Urban Development Strategic Plan is a programming instrument that encompasses 3 Action Plans that support the investment priorities inscribed in the urban axis of POR Lisboa 2020: Sustainable urban mobility (action) plan (PAMUS), Urban Regeneration Action Plan (PARU), Integrated Action Plan for Disadvantaged Communities (PAICD) [38].

In Lisbon, particularly in Alcântara, PEDU is translated into interventions led by BIP/ZIP [39], a local participatory instrument that allows interventions within PAICD and the total overlap of the Urban Rehabilitation Area with the PARU (see Figure 1.). Under the remit of the national legal framework [40], the latter was defined as "systematic", allowing the use of different urban planning and design tools.

The first version of the Alcântara Development Plan (PUA) mainly focused on providing social housing for those living in highly precarious conditions. The area of the PUA was subdivided into Urban Detail Plans, addressing a high density of housing, except for "Casal Ventoso", a notorious slum with origins in the late 19th century, as a consequence of housing demand from the industrial areas along the Alcântara Stream [41]. It evolved in the sense authors refer to "slum" as a place with which stigma becomes associated with the people who live in those places [42,43]. The population would then be rehoused in *Quinta do Cabrinha*, under the remit of the PER—Special Rehousing Plan (see Table 1.) [44,45]. One must refer to that the proposals by Leopoldo de Almeida were not taken fully to the end [46–48], neither in the area nor any other of the city, leaving the PUA waiting for the following proposal led by Manuel Fernandes de Sá based on three fundamental elements: landscape, infrastructures, and re-establishment of pre-existing urban continuity, leading to a revised perspective of the PUA [49–52].

Table 1. Urban Planning and Design in Alcântara—a genealogy. Sources: own production Cf. References inline.

<table>
<tr><th></th><th>Master Plan for the City (PDM)</th><th>Urban Development Plan (PU)</th><th>Urban Detail Plan (PP); Urban Design, Housing or Execution Units (EU)</th><th>Programs and Related Strategies and Action Plans</th></tr>
<tr><td>1992</td><td>PEL (Lisbon Strategic Plan) [47]</td><td rowspan="2"></td><td rowspan="3"></td><td rowspan="2">1987–1994—Municipal Medium-Term Intervention Programme (PIMP) [28]</td></tr>
<tr><td>1994</td><td>PDM [27]</td></tr>
<tr><td>1995</td><td></td><td>UOP (operational planning unit) 18—Alcântara Valley corresponding to an Urban Development Plan (PUA – Plano de urbanização de Lisboa), subdivided into several Urban Detail Plans (PP), including the Casal Ventoso, aiming at housing reconversion and green protection area, including demolition of slum and rehousing at a new neighbourhood under the remit of PER—Avenida de Ceuta(under consideration by the CML, Cf [41]
All by Leopoldo de Almeida</td><td rowspan="3">National Special Programme for Housing (PER) [45]</td></tr>
<tr><td>1998</td><td></td><td></td><td>Quinta do Cabrinha Municipal Social Housing Project, under the remit of PER [31,41]</td></tr>
<tr><td>2005</td><td></td><td></td><td>Alcântara XXI (revoked 2008) [45,53]</td></tr>
<tr><td>2011</td><td></td><td></td><td rowspan="2"></td><td rowspan="3">ERU—Strategy for the Urban Rehabilitation [49]</td></tr>
<tr><td>2012</td><td>PDM approval [54]</td><td>PUA Alcântara [44]</td></tr>
<tr><td>2015</td><td></td><td>PUA approval [55,56]</td><td>EU Alcântara Nascente—CUF Hospital [46,57]</td></tr>
<tr><td>2016</td><td></td><td></td><td></td><td rowspan="4">PEDU/Urban Development Strategic Plan [38]</td></tr>
<tr><td>2017</td><td></td><td></td><td rowspan="3">EU Alcântara Poente—Allo [47]</td></tr>
<tr><td>2020</td><td>PDM Alteration by adaptation [58]</td><td></td></tr>
<tr><td>2022</td><td></td><td>PUA Alcântara Alteration by adaptation [59,60]</td></tr>
</table>

Although socio-political, economic, and environmental disparities have increased, the fundamental axes of the Plan, whose perimeter, scope, and programme have evolved, remain and have come to be implemented.

The PUA—Alcântara Urban Development Plan is inclusive of this variety, including Urban Design Alcântara XXI (2005, revoked in 2008) [45] and also the specific possibility of resorting to two primarily private-led Unidades de Execução/Execution Units (UE): Alcântara Nascente/Eastern [46] and Alcântara Poente/Western [47] (See Figures 4, 7 and 8; See Table 1).

(a)

Figure 7. *Cont*.

(b)

Figure 7. Alcântara EU Nascente—CUF Hospital Source: Sofia Morgado. (**a**) View from the 4th floor of CUF Hospital, November 2021; (**b**) view from the road junction, November 2022.

(a)

Figure 8. *Cont*.

(b)

(c)

Figure 8. EU Poente—Allo, Source: Sofia Morgado. (**a**) The recently clean plot, seen from Rua da Junqueira, August 2020 (**b**) Work in progress, new office buildings Allo, November 2022 (**c**) Allo and CUF Hospital, the new urban facet towards Avenida 24 de Julho, November 2022.

The Legal Regime of Urban Rehabilitation [40] establishes the various options each Municipality can implement on its land according to their corresponding needs and strategic guidelines. Given the diversity and complexity of the urban area, the Municipality of Lisbon had already identified practically all its areas requiring Urban Rehabilitation in the previous Strategic and Municipal Master Plan 1994 [47]. With the ratification of the Municipal Master Plan in 2012 [48] and subsequent legal diplomas, the Urban Rehabilitation area increased, and, as a strategic option, the Systematic Urban Rehabilitation Area option was selected [49]. The option allows greater flexibility in the type of intervention, allowing the existence of Execution Units, which are more punctual than the Detailed Plans that are dependent on the municipal public structure and the legal framework of the IGT—Territorial Management Instruments [50,51]. Even if abiding by the general guidelines required for the places of intervention, the implementation of Execution Units (EU) might provide a faster result, through private-public partnerships, with more robust real-estate development (see Table 1).

The preliminary data of the Census 2021 to the civil parishes are in line with the observation and the review of documents. In this case, it should be noted that the PUA area covers a small percentage of the total area of four Parishes (Alcântara, Campo de Ourique, Campolide, and Estrela), from which is subtracted a substantial area of the green space associated, namely, with the Monsanto Forest Park (see Figures 1 and 4). The data show us a population decrease accompanied by a slight increase in the number of households, corresponding to a change in the family structure, which is becoming smaller. It is noteworthy, especially in Alcântara, a slight decrease in residential dwellings and yet a more substantive drop in the number of buildings, most likely corresponding to the extensive demolition of industrial buildings and others, such as smaller residential units (See Table 2). The real-estate promotion is also leaving its footprint, and the statistics already demonstrate it, especially in the plots in Estrela.

Table 2. Population and Buildings Variation, Census 2011–2021. Lisbon Municipality and the Districts partially affected by the PUA—Alcântara Urban Development Plan. Source: Adapted from INE/Statistics Portugal, INE/Statistics Portugal, Preliminary data, Census 2021, available at https://censos.ine.pt/, consulted 23 November 2021).

Municipality [1]	**Population Variation 2011–2021**	**Households 2011–2021**	**Dwellings 2011–2021**	**Buildings Variation 2011–2021**
	%	%	%	%
Lisboa	−1.4	−1.5	−2.1	−5.90
Civil Parishes [1]	%			%
Alcântara	−0.80	1.3	−0.8	−7.8
Campo de Ourique	0.20	−1.4	−1.3	−6.70
Campolide	−4.40	−1.2	−1.5	−8.30
Estrela	0.60	−4.3	−3.8	−1.80

[1] Only the districts encompassing the Alcântara Urban Development Plan (PUA) Campo de Ourique and Campolide are irrelevant in this respect, as the area that overlaps is primarily open space included or contiguous to the Alcântara Green Corridor. NB: Concepts definitions, available at https://smi.ine.pt/, accessed on 24 November 2021, in Portuguese. NUTS Levels and national administrative units: LAU Level 1—Município = Municipality, LAU level 2—Civil Parishes = Freguesia) [52].

In 2019–20, the Covid-19 pandemic settled, followed by lockdowns and effects yet to be fully assessed. On 08 December 2021, after 150 years, on one of the most revered holidays in the Portuguese catholic tradition, the Procession of Our Lady of Quietude [*Quietação*] returned to the streets of Alcântara, organised by one of the old 19th-century Royal Brotherhoods [61], housed by the Monastery and Church with origins in the 17th century [62,63]. People were invited to decorate windows and balconies, a community's expression of Alcântara in the Public Space.

Back to daily life in the city, we found them like other European cities, almost on building sites. The Lisbon skyline is populated by cranes and hoists; current or more singular buildings are daily reconditioned as elegant condominiums. Holes open up in urban fronts over unexpected private terraces, giving way to a more compact and distinct occupation—in population and uses.

The waterfront is under refurbishment, but it might also become resistant to regular Lisboners. In a strip of land formerly hidden by ruined industrial storage and other facilities abandoned several decades ago (see Figures 7 and 8), powerful and wealthy real estate companies openly advertise the lifestyle the city's upgrading, in dedication to the public cause, now offers them: views of the Tagus, qualified public spaces, and an excellent public transport network.

An almost identical proposal, in concept, was set in motion by the Lisbon Port Authority (APL) in 1995, in parallel with visionary illustrations for a new compact city by Terry Farrell. This approach was supported by a well-known worldwide change reconversion and revitalisation of Port Areas, driven mainly by neoliberal choices (see Docklands, London), which was the political frame then, aiming to increase roll-on roll-off actions. Thus the usage of large container vehicles by land and the reductions of harbour works on the docks. The Plan would become known by its acronym POZOR [64]. POZOR offered a first attempt to integrate the interests of the Lisbon Port Authority, the Lisbon Municipality, and private stakeholders. POZOR would be vigorously contested during public consultation even if the Strategic Plan (March 1995) [64] presented an approach to a clear waterfront that would offer over 14 km of waterfront public open space to all that did not exist then. According to Sousa & Fernandes [65], the contestation would prevent POZOR from effective approval.

Despite the mediatic dispute that resurfaces from time to time, the containers parking in the Alcântara Dock persists. Together with the harbour cranes, they have acquired an industrial heritage personality associated with local imaginaries of the former industrial neighbourhood. This will soon change under the Lisbon Port Authority' 's remit to rehabilitate its valued urban areas. Public spaces inhabited by cranes, co-working spaces (e.g., LACs), and other light buildings will join the well-known recreational site for restaurants in Doca de Santo [66,67]

Reconversion of the brick storage building would revitalise the waterfront by introducing leisure activities like restaurants and public space. The waterfront would become a flagged area until these days. It is still worth mentioning the Expo'98, later the new central area Parque das Nações in the Eastern end of Lisbon.

With the gradual change of jurisdiction from the Lisbon Port Authority to the Municipality's [68], this open space strip, now almost totally public, would become pinpointed by exquisite architectural designed public museums and other amenities, like the MAAT. A lively space for all, enjoyed by locals and of touristic interest with a growing number of visitors. The containers' park at the Alcântara dock persists up to these days.

Paradoxically, the containers' park in Alcântara remains and can be matched, in size and view-blocking by the common perception, by the massive buildings in the Eastern and Western Execution Units [46,47]. That specific site results from the progressive infill of a former lagoon and is under flood risk. Moreover, the area is included in the PUA perimeter under the municipality management.

Altogether, the monofunctional urban areas, which are mostly housing or correlated, aiming each at a single socio-economic group, do not seem to offer the land-use mix and the inclusive social-economic blend an actual urban centrality should call for. From lower to higher incomes, and also from the innermost noisy areas toward the waterfront and with urban functional diversity: Quinta do Cabrinha (Social Housing), Alcântara XXI [16] (see Figure 6c), and recently, the Eastern and Western Execution Units—CUF Tejo Hospital and Allo-Alcantara Lisbon Offices [69] (see Figures 7 and 8, Table 1).

The current wall of wealthy housing benefits from that public space, and the view over the Tagus is there. Employing urban regeneration that allows, in this case, demolishing to build new. However, these privileged condominiums are for a few and not necessarily for permanent living. Commerce, amenities, and facilities on the same socio-economic level will follow and interfere in the adjacent diverse urban areas [70–72].

Although much has been done so far, recent approaches aiming at sustainable urban planning and implementing a network of environmental and landscape green corridors motivate new reflections and the side effects of rehabilitation programmes that address the "greater good". In this case, public space was also regarded as an opportunity to overcome such inequalities in Lisbon.

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Article

Coupled and Coordinated Development of the Tourism Industry and Urbanization in Marginal and Less Developed Regions—Taking the Mountainous Border Areas of Western Yunnan as a Case Study

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Abstract: Promoting the coupled and coordinated development of China's tourism industry and urbanization is of great significance for its marginal and less developed regions. Taking a typical marginal and less developed region, the mountainous border areas of Western Yunnan as the research object, this study analyzed the spatial and temporal characteristics of the coupling coordination degree of the tourism industry and urbanization, as well as their influencing factors, in this region from 2010 to 2019 using the coupling coordination model, spatial gravity model, and panel Tobit model. The study results show the following. (1) The development level of the tourism industry and urbanization in the study region had significantly increased, but there was an obvious polarization phenomenon in its spatial distribution. (2) The coupling coordination degree of the tourism industry and urbanization showed a good development trend of steady growth, and the areas were ranked according to the average annual growth rate as follows: West Yunnan > Southwest Yunnan > Northwest Yunnan. (3) The regional differences in the coupling coordination degree had expanded, reflecting an "agglomeration phenomenon" and "distance decay effect", and the tourism industry lagging (obstructed) subtype was dominant. (4) The industrial structure, transportation accessibility, capital effect, consumption capacity, and talent support had significant positive effects on the coupling coordination degree, but the role of openness to the outside world was not obvious. This study can provide a useful reference for further studies on the marginal and less developed regions of China.

Keywords: tourism industry; urbanization; coupling coordination; panel Tobit model; the mountainous border areas of western Yunnan

1. Introduction

Many countries around the world face the problem of uneven urbanization [1], especially developing countries [2]; these countries' uneven urbanization is mainly reflected in the fact that the development of some of their less developed regions tends to be hampered by various development difficulties [3]. Tourism is a less demanding economic sector than other industries, but as a comprehensive industry, it can have a significant impact on regional development [4–6]. Many studies have confirmed the positive effects of tourism on the alleviation of regional imbalances [7–9], and its improvement of urbanization imbalances is one of the industry's most important aspects [10]. From a "core–periphery" perspective of a country's regional development levels, it can be seen that some of its less developed regions are generally located in the interior periphery of the country [3,11] and are characterized by a negative migration balance, low living standards, ageing populations, few employment opportunities, low levels of education, low regional investment [12], and difficulties in implementing the traditional urbanization model, which has disadvantages, such as "adventurous urbanization", "pseudo-urbanization", "urban disease", and "urban–rural imbalance" [13]. In contrast, urbanization in the new era is people-oriented and quality-oriented, and it aims to integrate urban and rural and green development [14]. In this era, tourism is seen as an effective way to promote economic and local development, especially in marginal areas, such as mountainous regions [15,16]; therefore, using tourism to promote urbanization [17] is one of the best options for the development of marginal and less developed areas [18,19]. However, due to the particular realities of marginal and less developed regions [20], the inherent relationship between tourism and urbanization in these regions may exhibit different characteristics to other regions. It is important, therefore, to examine the relationship between the tourism industry and urbanization, as well as to identify the interactive evolutionary process of the two in order to guide the development of marginal and less developed regions.

In 1991, Mullins first proposed the concept of "tourism urbanization", which is a kind of urbanization based on consumption that is different from traditional industrial urbanization [21]; after this, the relationship between tourism and urbanization began to attract academic attention, and the characteristics [22], driving mechanisms [23], types [24], models [25], and impacts [26] of tourism urbanization have been richly discussed. The relationship between tourism and urbanization can be summarized into three main types: first, tourism promotes urbanization [27], accelerates the expansion of towns and cities through tourism development [28], leads to population concentration [29], changes the regional industrial structure [30], and becomes a new engine of urbanization [31]; second, urbanization that promotes tourism development [32], urbanization based on the combined effect of consumption and investment, and driving the expansion of the scale of the tourism industry [33] will all promote increases in tourism output [34]; third, tourism and urbanization are considered to have a two-way interaction [35], with tourism development and urbanization being highly interactive and dependent [36]. Mass tourism has been found to cause an increase in land consumption, driving urbanization, and urban expansion has consolidated tourism development in subsequent phases [37]. However, in terms of research methods, the relationship between the tourism industry and urbanization has mostly been evaluated by using causality tests [38], regression analysis [39], coupling coordination models [40], and other methods; there are few studies on the mechanism construction, spatial–temporal evolution, and influencing factors of the interaction between the two. In terms of research scales, studies have covered the national [41], regional [42], provincial [43], and city [44] levels, but not enough attention has been paid to marginal, less developed areas.

Some marginal and less developed regions in China are rich in tourism resources, but they lag behind in their urbanization construction. Therefore, in the context of urbanization construction, how to effectively articulate the relationship between the tourism industry and urbanization and how to more effectively promote the synergistic development of the two are of great significance for promoting the development of marginal and less developed regions. In view of this, based on the analysis of the mechanism of coupling and coordination between the tourism industry and urbanization, we selected a typical marginal and underdeveloped region, the mountainous border areas of western Yunnan, as the research object, and analyzed the coupling and coordination between the tourism industry and urbanization in this region, as well as the spatial–temporal evolution characteristics and influencing factors of the interaction between the two using the panel Tobit model. This study mainly addressed the following questions. 1. What is the mechanism of the coupling and coordination between the tourism industry and urbanization? 2. How large is the tourism industry and the extent of urbanization in the mountainous border areas of western Yunnan? 3. What is the spatial–temporal evolution of the degree of coupling coordination between the tourism industry and urbanization? 4. What are the spatial combination and evolution patterns of different types of coupling coordination? 5. Which factors affect the coupling coordination degree? The study's main conclusions and recommendations will be of reference value for the development of marginal and less developed regions.

2. The Mechanism of Coupling and Coordination between the Tourism Industry and Urbanization

Modern tourism development has begun to turn "people-oriented", and urbanization is also "people-oriented", emphasizing the value of urbanization from perspectives ranging from structuralism to humanism [45]. Thus, the common goal of humanism provides the value basis for the coupling and coordination of the tourism industry and urbanization. On the one hand, tourism, as an intrinsic driving force for industrial transformation, social change, and economic growth, can effectively contribute to the restructuring of urban space, the transformation of urban functions, and the improvement of urban quality [46]. On the other hand, accelerating the construction of urbanization with people as its core can more effectively release the promotion effect of urbanization on tourism economic development and provide adequate support for tourism industry development [47]. Based on this, we constructed an analysis framework of the coupling and coordination mechanism of the tourism industry and urbanization, which is based on the main line of the interaction between the two (see Figure 1).

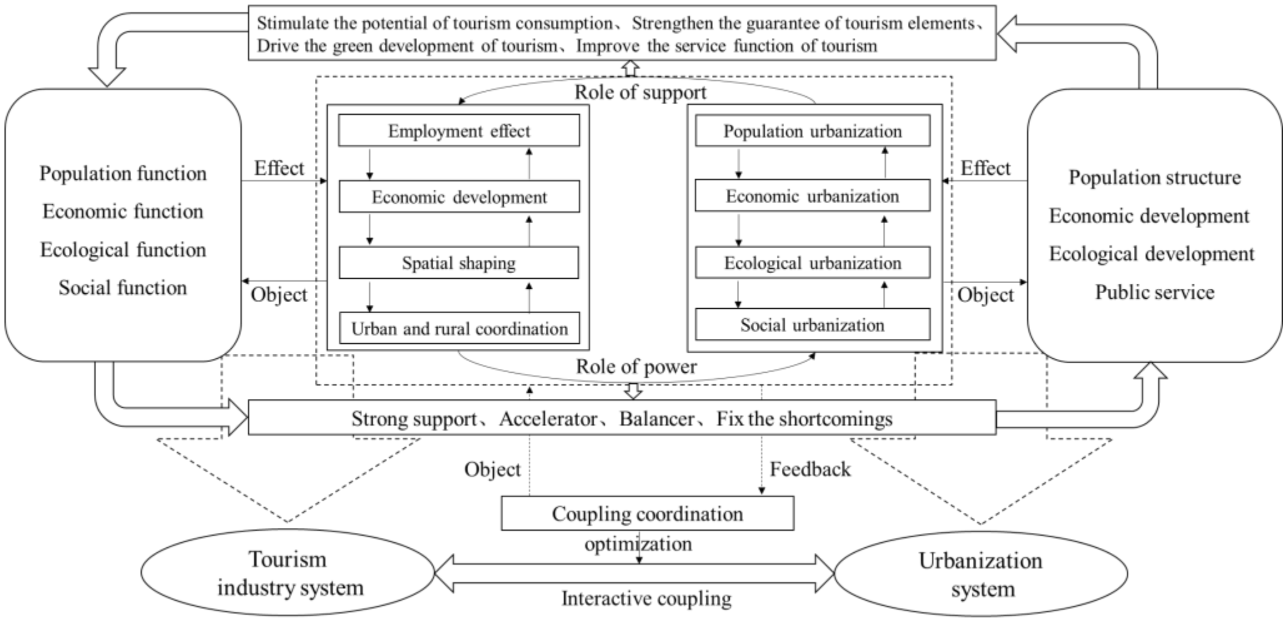

Figure 1. The coupling and coordination mechanism of tourism industry and urbanization.

2.1. Tourism as a Key Driving Force of Urbanization

The tourism industry as a driving force of urbanization is mainly manifested in four aspects. (1) The tourism industry helps create employment opportunities and provides "strong support" for urbanization. Compared with other industries, tourism employment has a large capacity, low threshold, and is inclusive and flexible, along with other characteristics, which are conducive to solving the problem of total employment expansion and structural optimization in the process of urbanization. Tourism development leads to great employment gaps, which help to promote the non-agricultural engagement of the rural migrant labor force [48] and therefore the transfer of populations to urban areas. In particular, tourism employment or entrepreneurship in underdeveloped areas is also conducive to the local and nearby employment of farmers [49], reducing the "migratory bird" migration problem that affects a large number of migrant workers under the urban–rural dual system and providing strong support for population urbanization. (2) The tourism industry can help drive economic growth [50] and provide a "gas pedal" for urbanization. The tourism industry has the characteristics of strong comprehensiveness, high correlation, being a strong driving force, etc. Through the tourism industry's agglomeration and integration, it can directly or indirectly drive the economic growth of a given town. The tourism industry agglomeration process promotes the convergence of urbanization factors, such as human flow, logistics, capital flow, etc. Furthermore, it can accelerate the industrial structure adjustment of a given town. Tourism industry integration refers to the "tourism +" or "+ tourism" method of achieving the integration and interactive development of the tourism industry and multiple industries, as well as of fully releasing the "multiplier effect" of tourism in the construction of urbanization. (3) The tourism industry helps shape environmental space and provides a "balancer" for urbanization. A new concept of tourism development, all-for-one tourism emphasizes a transition from "point-line type" to a more open "plate type" tourism space system focusing on scenic spots [51] to a certain extent, which can eliminate the regional differences caused by non-homogeneous tourism resource backgrounds so as to promote tourism-driven urbanization on a larger scale. At the same time, the "green" attributes of the tourism industry are highly compatible with environmental protection requirements in the construction of urbanization. Firstly, tourism development can ease the environmental pressure brought by urban expansion. Secondly, participation in tourism activities can subconsciously enhance the environmental awareness of tourists. (4) The tourism industry helps balance urban and rural development and "make up for weakness" of urbanization construction. With the rapid development of rural tourism, a large number of tourism flows converge in the countryside, which can improve the income of local rural residents, promote local infrastructure construction, and guide local development [52]. In addition, the market supply of town tourism cannot be separated from rural support. Town tourism consumption also affects the rural economic system through various transmission mechanisms and dynamic effects. Therefore, as a bridge between town and rural synergistic development, the tourism industry can effectively alleviate the dual structure difficulties involved in the construction of urbanization.

2.2. Urbanization as Efficient Guarantee Support for Tourism Industry

The supporting role of urbanization for the tourism industry is mainly manifested in four aspects. (1) With population urbanization as its core, urbanization can stimulate tourism consumption potential. Urbanization not only focuses on increasing the proportion of the non-farm population, but it also pays attention to the "citizenship" status of the population after its convergence in cities and towns [53], which drives tourism consumption in terms of quantity and quality. On the one hand, a large number of people continue to integrate into cities and towns, and their emphasis on leisure and relaxation has increased, leading to an increase in demand for tourism consumption. On the other hand, the overall income level of the residents involved in the urbanization process has increased, and the demand for tourism consumption has become more diversified, thus accelerating the structural reform of the supply side of the tourism industry. (2) Urbanization focuses on economic urbanization, which can strengthen the guarantee of tourism elements. Industrial agglomeration is an essential carrier of urbanization, and the factor agglomeration effect brought about by urbanization also guarantees industrial agglomeration [54]. During urbanization construction, investment and financing channels are expanded, which can provide more financial security for tourism development. Large numbers of people being concentrated in cities and towns can also provide sufficient labor sources for tourism. In terms of technological production factors, the internet, big data, and other information technologies continue to promote the construction of urbanization, and future technological empowerment will further promote the transformation and upgrading of tourism. (3) Urbanization involves ecological urbanization, which can drive the green development of tourism. Urbanization emphasizes the concept of an ecological civilization and pays attention to environmental protection in urban construction [55]. Especially under the guidance of the scientific development concept, ecological protection and resource conservation are essential. Future urban construction will restrict high-polluting and high-consumption industries and support environmentally friendly modern industries, such as tourism. Furthermore, the mode of development adopted for urbanization should be efficient and based on scientific evidence. It should reduce the unnecessary waste of resources caused by inefficiency, significantly contributing to the improvement of the tourism industry's business environment and helping the industry to further exploit the advantages of green development. (4) Urbanization is based on social development, which can improve tourism service functions. The continuous improvement of infrastructure and public services is an essential requirement in the development process of urbanization [56]. The construction of urban facilities, such as accommodation, entertainment, and shopping facilities, guarantees the realization of the tourism elements' functions, and the tourism service functions that rely on urban construction also tend to be optimized, leading to, for instance, more convenient tourism transportation services, increases in tourism information levels, and the continuous improvement of tourism market governance, which is conducive to the creation of more competitive tourism destinations.

3. Research Design

3.1. Research Area

The mountainous border areas of western Yunnan (Figure 2), China, are located in the southern part of the Hengduan Mountains and the intermountain basin of southern Yunnan. The region includes Baoshan, Lijiang, Pu'er, Lincang, Chuxiong Yi Autonomous Prefecture, Honghe Hani and Yi Autonomous Prefecture, Xishuangbanna Dai Autonomous Prefecture, Dali Bai Autonomous Prefecture, Dehong Dai Jingpo Autonomous Prefecture, and Nujiang Lisu Autonomous Prefecture. Our main reasons for selecting the mountainous border areas of western Yunnan as the study area were as follows. (1) Regional typicality. The mountainous border areas of western Yunnan are not only the border areas of western China, but are also contiguous poverty-stricken areas and ecologically fragile areas. They are typical representatives of marginal and less developed regions. (2) Research importance. In 2021, the urbanization rate of the mountainous border areas of western Yunnan was only 47.29%, which was 3.76 percentage points lower than the urbanization rate of Yunnan Province (51.05%) and 17.43 percentage points lower than the urbanization rate of China as a whole (64.72%). The mountainous border areas of western Yunnan account for more than half of Yunnan Province, and the urbanization development of this area is related to the overall promotion of Yunnan's urbanization construction. (3) Urgent need for attention. The mountainous border areas of western Yunnan are rich in tourism resources and have a sound foundation for the development of the industry in these areas. Therefore, with relevant, favorable policy, the mountainous border areas of western Yunnan could see significant tourism development. In order to realize these areas' great-leap-forward development, it is necessary to explore a path of the synergistic development of the tourism industry and urbanization.

3.2. Construction of Index System and Data Sources

3.2.1. Comprehensive Evaluation Index System of Tourism Industry

Two evaluation methods are used to assess tourism industry development levels: the single index evaluation method and the comprehensive index evaluation method. The single index method primarily uses total tourism revenue or total tourist arrivals. However, it cannot accurately measure the tourism industry's development performance, and it cannot easily be used to analyze the internal mechanism involved in the interaction between tourism and urbanization. In this paper, based on the existing research, and following the principles of the representativeness, independence, and accessibility of indicator selection, nine secondary indicators were selected from four dimensions: economic benefits, market scale, industrial scale, and development potential (see Table 1).

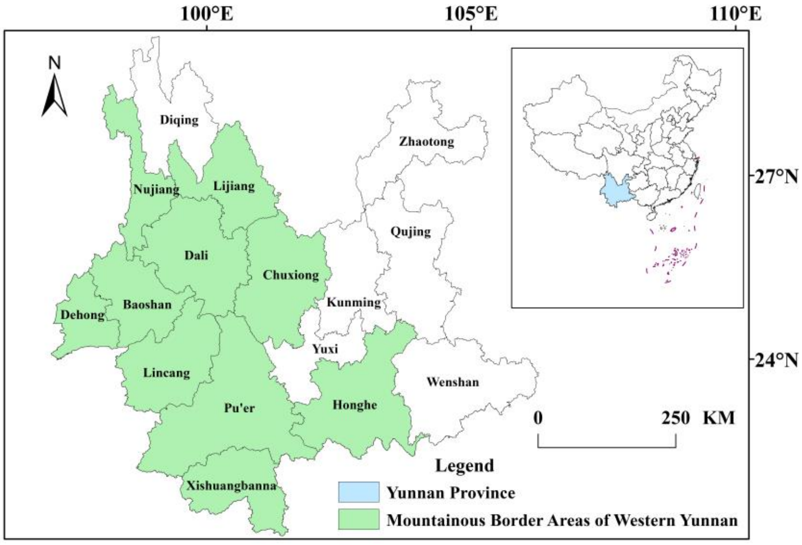

Figure 2. Research area. Note: This map is based on the standard map of GS (2019)1822, downloaded from the standard map service website of the Ministry of Natural Resources. The base map is not modified, and the same applies below.

3.2.2. Comprehensive Evaluation Index System of Urbanization

The evaluation indexes of urbanization levels used in academia mainly involve three dimensions: population, space, and economy. However, some scholars have expanded these indexes to include social services, ecological environment, and lifestyle dimensions [57–60], with these expanded indexes providing a more scientific understanding of the connotations of urbanization. At present, there is scholarly consensus that China's urbanization road has shifted from "land urbanization" to "human urbanization" [61], so it is necessary to establish development-oriented evaluation index systems. In this paper, based on the analysis of the coupling coordination mechanism, and following the principles of the representativeness, independence and accessibility of indicator selection, 20 secondary indicators were selected from four dimensions: population structure, economic development, ecological environment, and public services (see Table 1).

3.2.3. Data Sources

This study examined the interval from 2010 to 2019, and its target region was the mountainous border areas of western Yunnan, with a sample area of 10 cities in Yunnan Province used, namely, Baoshan, Lijiang, Pu'er, Lincang, Chuxiong, Honghe, Xishuangbanna, Dali, Dehong, and Nujiang. The original data were obtained from the Yunnan Statistical Yearbook (2011–2020), the statistical yearbooks of the cities in the mountainous border areas of western Yunnan, and statistical bulletins on socio-economic development and official government websites, and the missing data of some indicators were processed by linear simulation and collated by calculation.

3.3. Empirical Method

The use of quantitative methods to study the relationship between the tourism industry and urbanization can demonstrate the intrinsic link between them more intuitively. Although qualitative methods can show that the tourism industry and urbanization influence each other, there are limitations in the in-depth analysis of the degree of their mutual influence, the evolution of their relationship, and the influencing factors in their relationship. Therefore, this study integrated the entropy method, linear weighting method, coupling coordination model, space gravity model, and panel Tobit model to study the relationship between the tourism industry and urbanization.

Table 1. The comprehensive evaluation index system and weight of the tourism industry and urbanization of the mountainous border areas of Western Yunnan.

Goal Layer	Criterion Layer	Indicator Layer	Unit	Index Attribute *	Weights
Tourism industry	Economic benefit	Total tourism income	Billion CNY	+	0.155
		Tourism foreign exchange earnings	Billion USD	+	0.196
	Market size	Domestic tourist arrivals	Million people	+	0.105
		Overseas tourist arrivals	Million people	+	0.178
	Industry scale	Number of travel agencies	Ind	+	0.161
		Number of scenic spots	Ind	+	0.071
		Number of employees in the accommodation and catering industry	Million people	+	0.086
	Development potential	The growth rate of domestic tourist arrivals	%	+	0.013
		The growth rate of overseas tourist arrivals	%	+	0.035
Urbanization	Population structure	Proportion of urban population	%	+	0.026
		Population density	People/square kilometer	-	0.057
	Economic development	Number of industrial enterprises above designated size	Ind	+	0.066
		Number of key service enterprises	Ind	+	0.047
		Non-agricultural industry as a proportion of GDP	%	+	0.039
		Disposable income of urban residents	CNY	+	0.037
		Per capita GDP	CNY	+	0.046
	Ecological environment	Comprehensive index of air pollution	mg/m^3	-	0.037
		Green coverage rate of built district	%	+	0.016
		Number of days when the air quality reaches and is better than the second level	Per day	+	0.016
		Treatment rate of domestic sewage	%	+	0.021
		Per capita public green space area	Square meters	+	0.028
	Public services	Postal traffic business volume as a proportion of GDP	%	+	0.049
		Public libraries	Ind	+	0.073
		Number of beds in health institutions	Sheet	+	0.070
		Passenger car ownership by city	10,000 trucks	+	0.073
		General public budget expenditure	Billion CNY	+	0.054
		Extent of graded roads	Kilometers	+	0.052
		Number of villages benefitting from tap water	Ind	+	0.081
		Rural electricity consumption	Billion kilowatt hours	+	0.112

* Note: "+" represents a positive effect and "-" represents a negative effect.

3.3.1. Index Pretreatment and Weight Solving

In order to eliminate the influence of the number and scale differences of the indicators in the evaluation system of the tourism industry and urbanization on the calculation results, it was necessary to standardize the indicators to reduce the interference of random factors. Among them, the relevant indicators were divided into positive effect indicators and negative effect indicators, with different treatment formulae being used for these two types of indicators.

$$\text{Positive indicator}: Y_{\text{ij}} = \frac{\left(x_{ij} - x_{ij\text{min}}\right)}{\left(x_{ij\text{max}} - x_{ij\text{min}}\right)} \tag{1}$$

$$\text{Negative indicator}: Y_{\text{ij}} = \frac{\left(x_{ij\text{max}} - x_{ij}\right)}{\left(x_{ij\text{max}} - x_{ij\text{min}}\right)} \tag{2}$$

In the formulae, the following are defined: Y_{ij} denotes the standardized value of the jth indicator in year i; x_{ij} denotes the original value of the jth indicator in year i; $x_{ij\text{max}}$ denotes the maximum value of indicator j; $x_{ij\text{min}}$ denotes the minimum value of indicator j; $i = 1, 2, 3, \ldots, m$ denotes the number of years; and $j = 1, 2, 3, \ldots, n$ denotes the number of indicators.

The indicator weights reflect the indicators' relative importance and affect the evaluation results' reliability and accuracy. The entropy method, an objective assignment method, was used in this paper, which determines the weights according to the magnitude of the variability of the indicators, thus avoiding the subjectivity of artificial assignment. The relevant formula is shown in the literature of Xu (2019) [62], and the specific weighting results for the indicators are shown in Table 1.

3.3.2. Comprehensive Evaluation Value of Tourism Industry and Urbanization

Based on the weights calculated by the entropy method combined with the data after standardization of indicators, using the system index assessment model, the linear weighting method was applied to calculate the subsystem evaluation values of the economic benefits, market scale, industrial scale, and development potential of the tourism industry, as well as the subsystem evaluation values of the population structure, economic development, ecological environment, and public services of urbanization, in order to arrive at the total evaluation value of the tourism industry and urbanization, which is calculated by the following formula:

$$f(x) = \sum_1^n w_i \times x_i, g(y) = \sum_1^m w_j \times y_i \tag{3}$$

$$F(x) = \sum_1^n W_i \times f(x), G(y) = \sum_1^m W_j \times g(y) \tag{4}$$

In the formulae, $f(x)$ and $g(y)$ denote the comprehensive evaluation value of the tourism industry subsystem and urbanization subsystem, respectively; $F(x)$ and $G(y)$ denote the comprehensive evaluation value of the tourism industry system and urbanization system, respectively; x_i and y_i denote the standardized values of the tourism industry evaluation index and urbanization evaluation index, respectively; w_i and w_j denote the weight of the tourism industry evaluation index and urbanization evaluation index, respectively; and W_i and W_j denote the weights of the tourism industry subsystem and urbanization subsystem, respectively.

3.3.3. Coupling Coordination Model

The coupling coordination model is borrowed from the capacity coupling coefficient model in physics to measure the coupling process for two or more systems that interact and influence each other, and its function is to calculate the degrees of coupling and coupling coordination between systems. The coupling degree refers to a given system's strength or the degree to which the system's internal elements act on each other. In contrast, the coupling coordination degree refers to the extent to which this coupling is good or bad. We drew on existing research [63] to construct a coupling coordination model for analyzing the characteristics of the coupling coordination relationship between the tourism industry and urbanization in the mountainous border areas of western Yunnan. The formulae are as follows:

$$C = 2 \times \left[\frac{F(x) \times G(y)}{(F(x) + G(y))^2} \right]^{\frac{1}{2}} \tag{5}$$

$$D = \sqrt{C \times T}, T = \alpha F(x) + \beta G(y) \tag{6}$$

In the formula, C is the coupling degree and D is the coupling coordination degree; $F(x)$ is the comprehensive evaluation level of the tourism industry and $G(y)$ is the comprehensive evaluation level of urbanization; T denotes the coupling coordination development level index; α and β denote the specific weights of the tourism industry system and urbanization system, respectively, and mainly measure the importance of each system. As we believed that both systems were very rich in connotations, and as the contributions of the two systems were not distinguished from each other, we took $\alpha = \beta = 0.5$ here; the values of C and D were in the range of [0, 1]. In order to make a further objective evaluation of the coupling and coordination level of the two systems, we drew on the existing research results [64,65]. We divided the coupling degree type (Table 2) and the coupling coordination degree type (Table 3) into intervals.

Table 2. The classification of coupling degree.

Coupling Degree Value	Coupling Level	Characteristic
$0.0 < C \leq 0.3$	Severe uncoupling	Poor interconnectivity
$0.3 < C \leq 0.5$	Slight uncoupling	Increased interconnectedness with simultaneous inhibition
$0.5 < C \leq 0.8$	Primary coupling	System enters benign coupling
$0.8 < C \leq 1.0$	Advanced coupling	Good resonance, jointly promote development

Table 3. The classification of coupling coordination degree.

<table>
<tr><th>Type</th><th>Numerical Value</th><th>Subtype</th><th>Numerical Value</th><th>Coupling Coordinator Subtype</th></tr>
<tr><td rowspan="6">Coordinated development</td><td rowspan="3">$0.8 < D \leq 1.0$</td><td rowspan="3">Good coordination</td><td>G(y)−F(x) > 0.1</td><td>Good coordination—Tourism industry lagging behind</td></tr>
<tr><td>F(x)−G(y) > 0.1</td><td>Good coordination—Urbanization lagging behind</td></tr>
<tr><td>0 < ∣G(y)−F(x)∣ ≤ 0.1</td><td>Good coordination</td></tr>
<tr><td rowspan="3">$0.6 < D \leq 0.8$</td><td rowspan="3">Moderate coordination</td><td>G(y)−F(x) > 0.1</td><td>Moderate coordination—Tourism industry lagging behind</td></tr>
<tr><td>F(x)−G(y) > 0.1</td><td>Moderate coordination—Urbanization lagging behind</td></tr>
<tr><td>0 < ∣G(y)−F(x)∣ ≤ 0.1</td><td>Moderate coordination</td></tr>
<tr><td rowspan="3">Transformational development</td><td rowspan="3">$0.4 < D \leq 0.6$</td><td rowspan="3">Minimal coordination</td><td>G(y)−F(x) > 0.1</td><td>Minimal coordination—Tourism industry lagging behind</td></tr>
<tr><td>F(x)−G(y) > 0.1</td><td>Minimal coordination—Urbanization lagging behind</td></tr>
<tr><td>0 < ∣G(y)−F(x)∣ ≤ 0.1</td><td>Minimal coordination</td></tr>
<tr><td rowspan="6">Uncoordinated development</td><td rowspan="3">$0.2 < D \leq 0.4$</td><td rowspan="3">Close to imbalance</td><td>G(y)−F(x) > 0.1</td><td>Close to imbalance—Tourism industry lagging behind</td></tr>
<tr><td>F(x)−G(y) > 0.1</td><td>Close to imbalance—Urbanization lagging behind</td></tr>
<tr><td>0 < ∣G(y)−F(x)∣ ≤ 0.1</td><td>Close to imbalance</td></tr>
<tr><td rowspan="3">$0.0 < D \leq 0.2$</td><td rowspan="3">Severe imbalance</td><td>G(y)−F(x) > 0.1</td><td>Severe imbalance—Tourism industry lagging behind</td></tr>
<tr><td>F(x)−G(y) > 0.1</td><td>Severe imbalance—Urbanization lagging behind</td></tr>
<tr><td>0 < ∣G(y)−F(x)∣ ≤ 0.1</td><td>Severe imbalance</td></tr>
</table>

3.3.4. Space Gravity Model

The space gravity model is widely used to analyze spatial linkages. It is a model for measuring the strength of spatial interactions between two regions based on the distance decay principle. To further characterize the spatial linkage pattern of the coupling coordination degree of the tourism industry and urbanization among the cities in the study region, drawing on existing studies [66], we constructed a spatial gravitational model as follows:

$$R_{ij} = K \times \frac{D_i \times D_j}{d_{ij}^b} \tag{7}$$

In Equation (7), R_{ij} indicates the spatial linkage strength of the coupling coordination degree between two cities, i and j; D_i and D_j indicate the coupling coordination degree D value of city i and j, respectively; d_{ij} indicates the geographical distance between the two cities; b is the distance–decay parameter, which took the value of 2 in this paper; and K is the gravitational parameter, which took the value of 1 in this paper.

3.3.5. Panel Tobit Model

The Tobit model, also known as the sample model, as well as the restricted dependent variable model, were first proposed by Tobin in 1958 and are models in which the dependent variable takes on values that are continuous but subject to certain restrictions. In this study, considering that the measured coupling coordination degree of the tourism industry and urbanization had a value range of [0, 1] and belonged to the imputed data, the regression analysis of the restricted dependent variables, which used the panel Tobit model, was able to effectively avoid estimation bias and improve the regression accuracy [67]. The basic form of the panel Tobit model is:

$$y_{it}^* = \beta^T x_{it} + u_i + \varepsilon_{it}$$
$$y_{it} = \begin{cases} y_{it}^*, y_{it}^* > 0 \\ 0, y_{it}^* \le 0 \end{cases} \quad (8)$$

In Equation (8), the following variables are defined. y_{it}^* is the vector of potential dependent variables; β^T is the vector of parameters to be estimated; x_{it} is the vector of independent variables; y_{it} is the vector of observed dependent variables; the perturbation term $\varepsilon_{it} \sim N\left(0, \sigma_\varepsilon^2\right)$, u_i is the individual effect; i denotes the city; and t denotes the time.

4. Results

4.1. Spatial and Temporal Evolution of Tourism Industry and urbanization Levels

The above methods were used to measure the tourism industry and urbanization levels in 10 cities in the mountainous border areas of western Yunnan from 2010 to 2019, and their means, standard deviations, and coefficients of variation were calculated (Table 4) in order to measure the overall levels and their regional differences. In addition, the geometric interval method and the natural interruption point grading method were used to grade the tourism industry and urbanization levels in two-time sections in 2010 and 2019 (Figures 3 and 4) in order to explore the evolution of their spatial patterns.

Table 4. The related statistics of tourism industry and urbanization levels in the mountainous border areas of western Yunnan.

Year	Tourism Industry			Urbanization		
	Mean	SD	CV	Mean	SD	CV
2010	0.117	0.150	1.282	0.300	0.306	1.020
2019	0.451	0.251	0.556	0.530	0.537	1.014

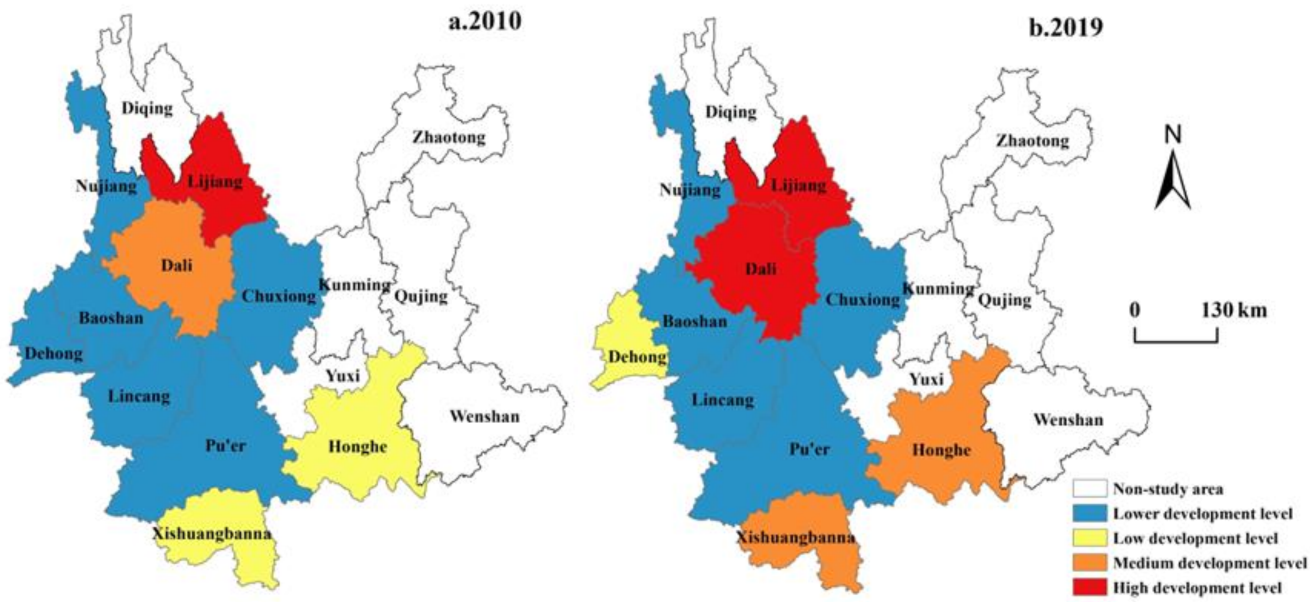

Figure 3. The spatial distribution of tourism industry development levels in the mountainous border areas of western Yunnan.

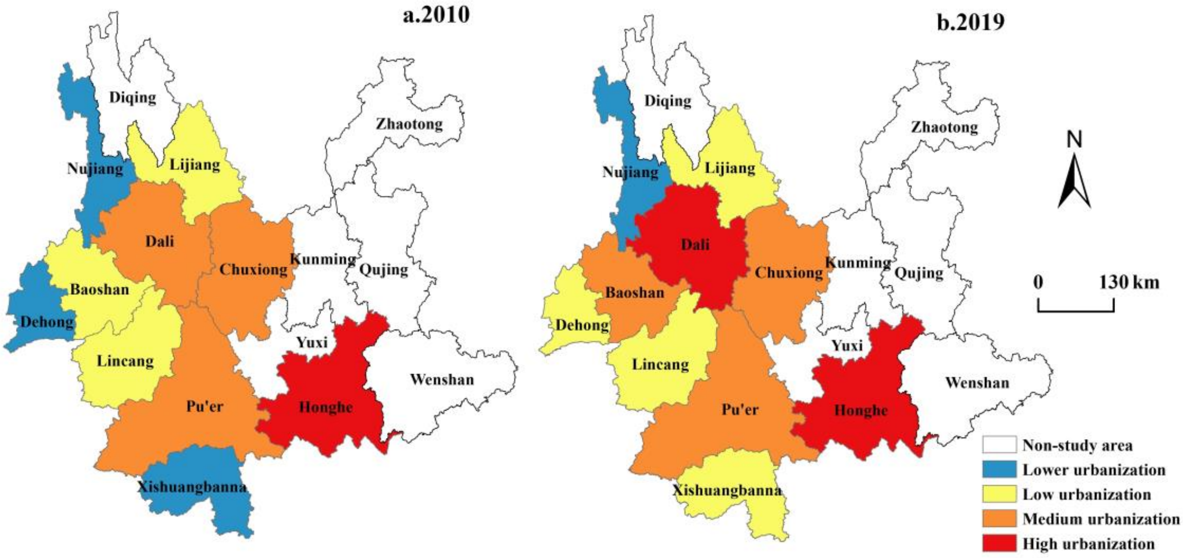

Figure 4. The spatial distribution of urbanization levels in the mountainous border areas of western Yunnan.

4.1.1. Spatial and Temporal Evolution of Tourism Industry Level

The mean values of the tourism industry level in the mountainous border areas of western Yunnan in 2010 and 2019 were 0.117 and 0.451, respectively, with an overall improvement of nearly three times and an average annual growth rate of 16.2% recorded, which reflect the rapid development of the tourism industry in this region. The standard deviations of the tourism industry level in the mountainous border areas of western Yunnan in 2010 and 2019 were 0.150 and 0.251, respectively, with coefficients of variation of 1.282 and 0.556 obtained, respectively. The absolute gap aspect expanded by nearly 68%, and the relative gap aspect narrowed by nearly 1.3 times. In the study period, as local governments increased their support for tourism development, the overall level of the tourism industry in the study region improved significantly. However, due to the differences in the tourism resource endowment, location conditions and economic foundations of each city, the development base and growth rate of the tourism industry were inconsistent, and the gap in the total scale of the regional tourism industry widened. From Figure 3, it can be seen that: (1) in 2010, there were fewer areas with high tourism development levels, with Lijiang standing out as the leading city with regards to its development of its regional tourism industry. Five of the remaining nine cities were in the low development level stage, of which Nujiang was the most backward region in terms of its tourism industry development level. From an overall perspective, the level of the tourism industry in the entire study region formed a spatial pattern characterized by "prominent poles and low value concentration". (2) In 2019, the number of regions with high tourism industry levels increased to two. Dali City achieved a leap from a "medium level" to a "high level", while Honghe and Xishuangbanna achieved a leap from a "low level" to a "medium level". Although the tourism industry development level of each city had improved, more than half of the areas still had low development levels. At the same time, there was a difference of as much as 15 times between the city with the lowest value, Nujiang, and that with the highest value, Lijiang, and the inherent polarization phenomenon remained prominent. From an overall perspective, the tourism industry level in the entire study region formed a spatial pattern characterized by "high values adjacent to each other, medium values scattered, and low values contiguous".

4.1.2. Spatial and Temporal Evolution of Urbanization Level

The mean values of the urbanization level in the mountainous border areas of western Yunnan in 2010 and 2019 were 0.300 and 0.530, respectively, with an overall increase of nearly two times and an average annual growth rate of 6.54% recorded; the process of urbanization was found to have steadily advanced during the study period. The standard deviations of the urbanization level in the study region in 2010 and 2019 were 0.306 and 0.537, respectively, and the coefficients of variation were 1.020 and 1.014, respectively. The absolute gap aspect expanded by nearly 76%, and the relative gap aspect narrowed by nearly 1%. This indicates that, in the study period, with the continuous promotion of urbanization in the mountainous border areas of western Yunnan, the absolute difference in the urbanization level among the cities was increasing, while the relative difference was shrinking too slowly, making the spatial polarization of urbanization in the region expand and slowing the overall development of the region towards being balanced. From Figure 4, we can see that: (1) in 2010, Honghe was the only region with a high level of urbanization, while three of the remaining nine cities had low levels of development, among which Nujiang, due to its geographical location and resource conditions, had an urbanization level of only 17.67%. On the whole, the urbanization level in the entire study region formed a spatial pattern characterized by a "decreasing step from east to west". (2) In 2019, the number of areas with high levels of urbanization increased to two, with Honghe still in the leading position, and Dali, through relying on the synergistic effect of secondary and tertiary industries, achieving a shift in its urbanization level from a "medium" to a "high" level. Dehong, Baoshan, and Xishuangbanna also achieved a "step" in their urbanization levels, while Nujiang was still at a low urbanization level and was growing more slowly than the other cities. From an overall perspective, the urbanization level in the entire study region formed a spatial pattern characterized by "two prominent poles and fragmented distribution".

4.2. Spatial and Temporal Evolution of the Coupling Coordination Degree of Tourism Industry and Urbanization

4.2.1. Temporal Evolution of Coupling Coordination Degree

From Figure 5, it can be seen that the overall tourism industry and urbanization coupling coordination degree in the study region was not high, being between 0.4 and 0.7 during the study period, meaning it was mostly in the primary coordination stage; it therefore still has plenty of room for improvement in the future. From the viewpoint of temporal changes, the coupling coordination degree of the tourism industry and urbanization during the study period showed a good trend of steady growth, and the overall coordination level continued to improve, rising from the primary coordination level (0.405) in 2010 to the intermediate coordination level (0.671) in 2019, with a 65.68% increase in the coupling coordination degree and an average annual growth rate of 5.77% recorded. Alongside the development of the tourism industry and urbanization levels in the study region, the coupling coordination effect of the two tended to be continuously optimized. The level of coupling coordination can be divided into two stages. (1) Firstly, 2010–2016 was characterized by the primary coordination stage, and the coupling coordination degree during this period was low. The reason for this was that the tourism industry and urbanization levels in the study region were not high at this stage, and the interaction between the two was not deeply understood. In addition, the construction of both the tourism industry and urbanization mostly focuses on the pursuit of scale expansion, which is inclined to the rough development mode. (2) Secondly, 2017–2019 was characterized by the intermediate coordination stage, and the degree of coupling and coordination during this period was significantly improved. The reasons for this were mainly the accelerated pace of the construction of a strong tourism industry and urbanization in Yunnan after 2017, the fact that the industrial advantages of the mountainous border areas of western Yunnan as a well known domestic tourist destination began to be highlighted, the construction of the western Yunnan town cluster, which led to a significant improvement in the quality of local urbanization, and the mode of the tourism industry and urbanization integration, which became an important driving force for local economic and social development.

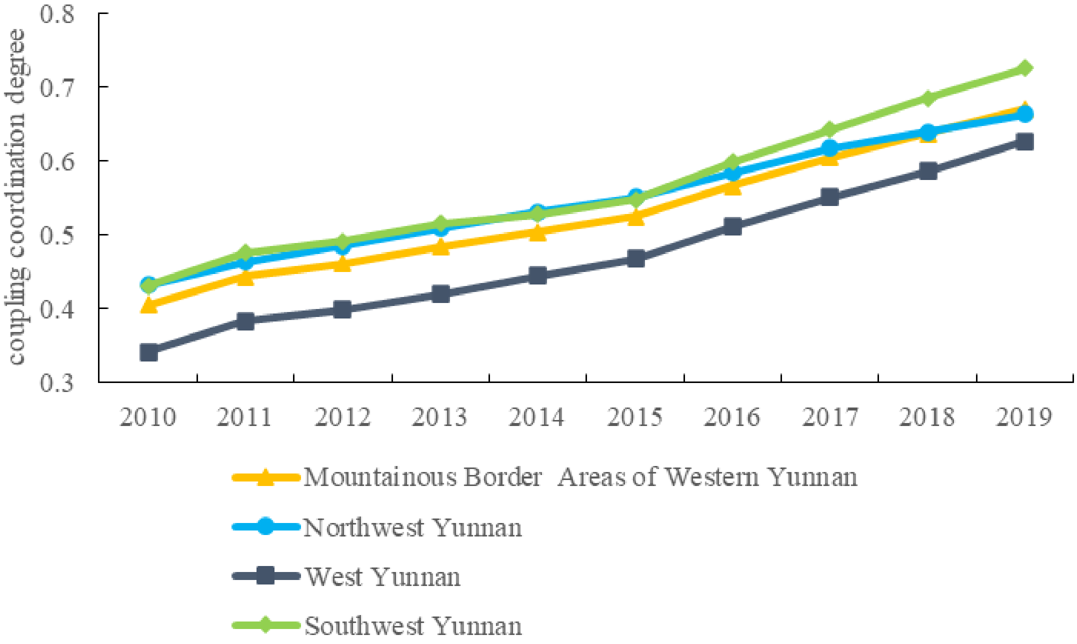

Figure 5. The change trend of coupling coordination degree of tourism industry and urbanization.

At the regional level, the coupling coordination degree of the tourism industry and urbanization in the three major regions of the mountainous border areas of western Yunnan increased during the study period [1], but the internal development level was not balanced. This manifested itself as follows. (1) Regarding the means of the coupling coordination degree, the following ranking was obtained: southwest Yunnan (0.564) > northwest Yunnan (0.547) > west Yunnan (0.473), all of which belonged to the minimal coordination level, with there still being plenty of room for future increases in these values. Among the cities, Dali City had the highest mean value of the coupling coordination between its tourism industry and urbanization (0.721), reaching a moderate coordination level, which was due to the fact that Dali City, as one of the first national pilot areas for urbanization, has gradually explored the development path of integration and interaction between its tourism industry and its construction of central cities and characteristic towns. The mean value of the coupling coordination between the tourism industry and urbanization in Nujiang (0.282) was the lowest, being the close to imbalance level, because the development levels of both the tourism industry and urbanization in Nujiang were relatively low, and the benign interaction mechanism between the two systems had not yet been established. (2) In terms of the average annual growth rate of the coupling coordination in the study period, the following ranking was obtained: West Yunnan (7.00%) > Southwest Yunnan (5.95%) > Northwest Yunnan (4.87%). At the same time, the level of the coupling coordination between the tourism industry and urbanization in western Yunnan experienced three stages: close to imbalance (2010–2012); minimal coordination (2013–2018); and moderate coordination (2019). Further, the potential for the interactive development of the tourism industry and urbanization in the region began to be realized due to the role of post-emergence advantages. The level of the coupling coordination between the tourism industry and urbanization in Southwest Yunnan and Northwest Yunnan underwent an evolutionary course of minimal coordination (2010–2016) to moderate coordination (2017–2019) as Dali, Lijiang, Xishuangbanna, and other cities ushered in a period of transformation and upgrading, each focusing more on the quality of their tourism industry and urbanization. Therefore, the growth rate of the coupling coordination level of the tourism industry and urbanization slightly slowed down.

4.2.2. Spatial Evolution of Coupling Coordination

According to the type division shown in Table 3, ArcGIS10.5 software was used to visualize and analyze the coupling coordination degree of the tourism industry and urbanization in the mountainous border areas of western Yunnan. Further, the spatial evolution pattern of the coupling coordination degree from 2010 to 2019 was obtained (see Figure 6). From Figure 6, it can be seen that the coupling coordination degree of the tourism industry and urbanization in the study region had an obvious spatial divergence pattern and a trend of gradual expansion. In 2010, the overall level of the coupling coordination degree was low, and the cities having the minimal coordination level were mainly located in the east, while the cities having the close to imbalance level were mainly located in the west, with this amounting to not only a certain agglomeration phenomenon, but also a decreasing gradient pattern from east to west. At this stage, half of the cities were at the close to imbalance and minimal coordination levels, which was mainly due to the low levels of both the tourism industry and urbanization in these areas, as well as to the fact that they had not yet formed a good interactive development pattern. In 2019, the coupling coordination degree in the mountainous border areas of western Yunnan had greatly improved, with only Nujiang still being at the close to imbalance level. The number of cities in the minimal coordination level had reduced to one, and there were six new cities at the moderate coordination level, as well as two at the good coordination level. However, in terms of spatial patterns, the gap between the cities was still large. Dali and Honghe had gradually become the "poles" with high levels of coupling coordination. However, as the distance between the cities increased, the radiation pulling effect of the two cities on their surrounding areas was relatively weakened, showing a certain "distance–decay effect". At this stage, the proportion of cities at the close to imbalance and minimal coordination levels dropped to 20%, and the coupling coordination between the tourism industry and urbanization in the study region basically reached the ideal state.

According to the subtypes of coupling coordination shown in Table 3, at different levels of coordination, the tourism industry in the study region was mainly obstructed or lagging, which indicates that the development speed of the industry in the region was mismatched, seriously restricting the coordinated and synchronous development of the two systems. In 2010, Nujiang, Baoshan, Dehong, Lincang, and Pu'er were all in the "close to imbalance—tourism industry lagging behind" subtype. At this stage, Nujiang can be taken as a representative city due to the constraints of its location, transportation, and economic level, as well as the fact that its tourism industry started late; therefore, having a poor foundation, the city's coupling and coordination of its tourism industry and urbanization were hindered. Meanwhile, Chuxiong, Honghe, and Dali were in the "minimal coordination—tourism industry lagging behind" subtype. Although the cities represented by Dali were already well known tourist destinations at this stage, there was still some room for its tourism industry to drive its urbanization, while its rapid promotion of urbanization failed to match this. In 2019, Nujiang was in the "close to imbalance—tourism industry lagging behind" subtype. Lincang, Baoshan, Chuxiong, and Honghe were in the "moderate coordination—tourism industry lagging behind" subtype. Lijiang and Xishuangbanna were in the "moderate coordination—urbanization lagging behind" subtype. And Honghe was in the "good coordination—tourism industry lagging behind" subtype. Due to the continuous improvement of infrastructure, the appearance of towns and cities in the mountainous border states of western Yunnan was greatly enhanced over the study period. However, the tourism industry in the region entered a period of transformation and upgrading during this period, and the active role of its tourism industry in the construction of its urbanization needs to be fully realized in the future.

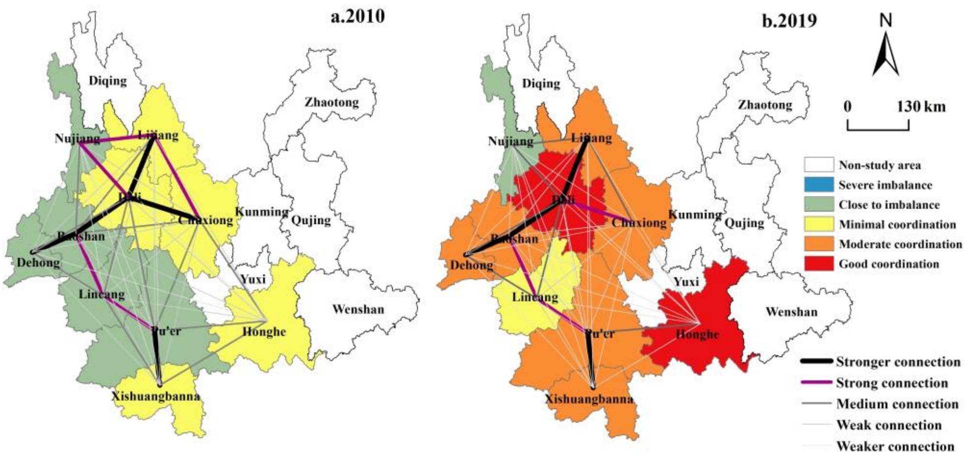

Figure 6. The spatial distribution of coupling coordination degree of tourism industry and urbanization.

According to (7), the spatial linkage values of the coupling coordination degree among the cities were calculated and visualized with ArcGIS10.5 software, and they were divided into five levels (see Figure 6). The results show that a more stable spatial network structure of the coupling coordination degree of the tourism industry and urbanization formed among the cities. In 2010, the spatial connection pattern presented two adjacent triangles, with Lijiang–Dali as the common line, Nujiang–Chuxiong as the triangle points, and Lijiang–Dali–Baoshan–Dehong, Pu'er–Xishuangbanna, and Dali–Chuxiong as three main connected axes. In 2019, the spatial linkages had weakened, with a reduction in general linkages and the degradation of some strong and stronger linkages at different levels observed; for instance, the Nujiang–Baoshan, Dali–Pu'er, and Honghe–Xishuangbanna general linkages had been weakened, and the strong linkage of Dali–Chuxiong and the stronger linkages of Nujiang–Lijiang and Nujiang–Dali had been degraded step by step, in turn. In general, the overall spatial connection in the mountainous border areas of western Yunnan was basically ideal, and the two solid axes of Lijiang–Dali–Baoshan–Dehong and Pu'er–Xishuangbanna had been formed. This indicates that there was a certain synergistic effect of tourism industry and urbanization construction in each state and city, producing spatial spillover and radiation drive.

4.3. Spatial Combination and Evolution Pattern of Coupling Degree and Coupling Coordination Degree of Tourism Industry and Urbanization

4.3.1. Spatial Combination of Coupling Coordination Types

In order to reveal the differences in the spatial combination of the coupling degree and coupling coordination degree within different time periods, the coupling degrees and coupling coordination degrees of two typical years in 10 cities were classified into spatial combinations (see Figure 7). The following can be seen. (1) From the perspective of time, there were seven types of spatial combinations of coupling coordination in the two typical years: in 2010, there were the severe uncoupling–close to imbalance, slight uncoupling–close to imbalance, slight uncoupling–minimal coordination, advanced coupling–close to imbalance, and advanced coupling–minimal coordination types; in 2019, the advanced coupling–moderate coordination and advanced coupling–good coordination types were added. By comparison, it was found that, in 2010, there were four advanced coupling–minimal coordination types, two advanced coupling–close to imbalance types, and two slight uncoupling–close to imbalance types, while in 2019, there were two advanced coupling–good coordination types and six advanced coupling–moderate coordination type, and the combination type had obviously changed to a high level. (2) From a spatial perspective, the combination types of coupling and coupling coordination changed in each city, and the degree of this change showed some variability. For example, the spatial combination type of Nujiang evolved from the severe uncoupling–close to imbalance type to the slight uncoupling–close to imbalance type, Lijiang evolved from the advanced coupling–minimal coordination type to the advanced coupling–moderate coordination type, and Pu'er evolved from the slight uncoupling–close to imbalance to the advanced coupling–moderate coordination type, distinctly reflecting the fact that the coupling coordination was continuously strengthening the coupling of the tourism industry and urbanization, leading to a transformation from quantity to quality.

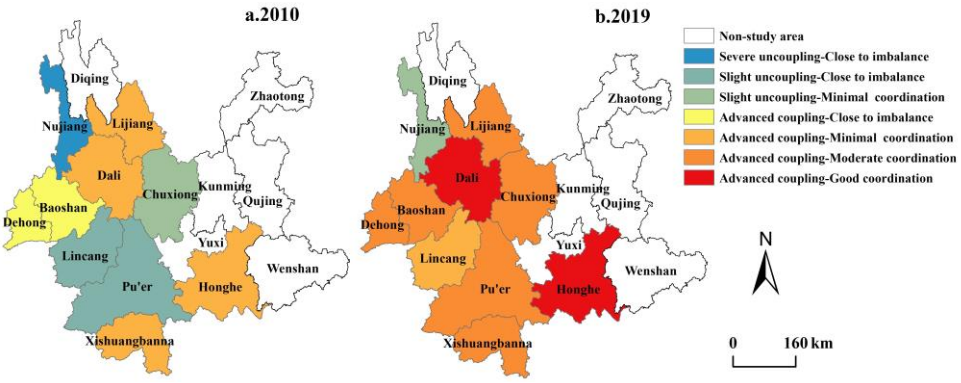

Figure 7. The spatial combination of coupling degree and coupling coordination degree of tourism industry and urbanization.

4.3.2. Evolutionary Model of Coupling Coordination Types

In order to further summarize the evolution pattern of the spatial combination type of the coupling coordination degree, the evolution pattern of the coupling coordination type of the tourism industry and urbanization in the mountainous border areas of western Yunnan can be summarized as the following. (1) A balanced development pattern. This model involved a spatial combination of the tourism industry and urbanization in the study region, with there being increasing levels and small gaps between them. Further, the spatial combination of the coupling and coordination had a high degree of matching, and the overall development level was more balanced. Only Dali belonged to this model. (2) The inertia development model. This model of regional tourism industry and urbanization development continued to be characterized by the original development inertia, with its systems leading or lagging behind the state and thereby remaining the same. Further, the coupling and coordination of spatial combination in this model were more ideal. Lijiang, Honghe, and Baoshan were typical representatives of this model. (3) The inversion development model. In this model, the tourism industry and urbanization development levels reversed, moving from the original development degree to lagging behind, while its coupling and coordination of spatial combination were general. Dehong and Xishuangbanna were the representatives of this model. (4) The leap development model. The spatial combination of the coupling and coordination of the tourism industry and urbanization in this model was not upgraded step by step, but directly crossed certain stages. Pu'er was the most representative of this model, which directly rose from being on the slight uncoupling-close to imbalance to the advanced coupling-moderate coordination, crossing three stages.

4.4. Influencing Factors of the Coupling and Coordination Degree of Tourism Industry and Urbanization

4.4.1. Model Construction and Variable Selection

According to the basic form of the panel Tobit model, and in order to avoid heteroskedasticity and multicollinearity, the explanatory variables were treated logarithmically in order to construct a Tobit model of the factors influencing the coupling and coordination of the tourism industry and urbanization:

$$D_{it} = \beta_0 + \beta_1 \ln is_{it} + \beta_2 \ln ta_{it} + \beta_3 \ln op_{it} + \beta_4 \ln ce_{it} + \beta_5 \ln ca_{it} + \beta_6 \ln ts_{it} + u_i + \varepsilon_{it} \quad (9)$$

In (9), D (coupling coordination degree) is the explanatory variable, β is the parameter to be estimated for each variable, and *is*, *ta*, *op*, *ce*, *ca*, and *ts* are the explanatory variables. Among them, *is* denotes industrial structure, *ta* denotes transportation accessibility, *op* denotes openness to the outside world, *ce* denotes the capital effect, *ca* denotes consumption capacity, and *ts* denotes talent support, which are characterized by the non-agricultural industries' proportion of the GDP, density of graded road networks, actual utilization of foreign direct investment, per capita fixed asset investment, per capita retail sales of social consumer goods, and number of students in general higher education schools, respectively. The data in this section were obtained from the 2011–2020 Yunnan Statistical Yearbook, and some missing data were filled in by linear interpolation.

4.4.2. Regression Model Analysis

In model (1), since the Tobit fixed-effects model cannot account for individual heterogeneity and cannot perform maximum likelihood estimation, a mixed Tobit regression and a random-effects Tobit regression are considered. The likelihood ratio (LR) test rejects the condition of "H0:u = 0" and there is an individual effect, so the random-effects Tobit regression is used (model 1). Tobit regression analysis of the model was performed using Stata software, and the results of the analysis are shown in Table 5.

Table 5. The regression results.

Variate	(1) Random-Effects Tobit Regression	(2) Tobit Regression after Indicator Replacement	(3) Truncated Regression	(4) Random-Effects OLS Regression	(5) Clad Estimate
lnis	0.135 (0.043) ***	0.135 (0.043) ***	0.195 *** (4.00)	0.138 *** (3.86)	0.072 (1.43)
lnta	0.354 (0.088) ***	0.357 (0.091) ***	0.264 *** (3.64)	0.377 *** (5.00)	0.278 *** (4.30)
lnop	−0.025 (0.029)	−0.035 (0.037)	−0.08 (−1.90)	−0.049 ** (−2.03)	−0.087 * (−2.07)
lnce	0.131 (0.058) **	0.148 (0.062) **	0.223 *** (3.30)	0.1567 *** (3.35)	0.342 *** (4.76)
lnca	0.446 (0.091) ***	0.464 (0.089) ***	0.352 *** (3.63)	0.281 *** (3.84)	0.338 *** (4.26)
lnts	0.115 (0.035) ***	0.118 (0.036) ***	0.116 *** (3.43)	0.097 *** (3.21)	0.099 ** (2.83)
Constant	−0.072 (0.033) **	−0.088 (0.022) ***	−0.034 (−1.27)	−0.005 (−0.19)	−0.041 (−1.78)
sigma_u	0.03 (0.014) **	0.031 (0.0138) **			
sigma_e	0.08 (0.007) ***	0.079 (0.007) ***			
LR	$p = 0.048$	$p = 0.041$			

Note: models (1) and (2) have standard deviations in parentheses, models (3), (4), and (5) have Z-values in parentheses, and *, **, and *** indicate significance tests were passed at levels of 10%, 5%, and 1%, respectively.

4.4.3. Analysis of Regression Results

Using model (1) as the benchmark model for analysis, the results showed the following. (1) Regarding industrial structure (*is*), its regression coefficient was 0.135, and this passed the significance test at the 1% level, indicating that the current industrial structure had a significant impact on the coupled and coordinated development of the tourism industry and urbanization in the study region. The tourism industry is influenced by changes in industrial structure [68], and urbanization also requires the boost provided by the optimization of industrial structure [69]. In the context of the long-term positive economic development in the study region during the study period, the region's industrial structure was gradually upgraded, and the supporting role and thrust role were continuously enhanced. (2) Regarding transportation accessibility (*ta*), its regression coefficient was 0.354, and this passed the significance test at the 1% level, indicating that the improvement of traffic accessibility helped promote the coupled and coordinated development of the tourism industry and urbanization. Transportation conditions provide support for the development of the tourism industry and are an important guarantee for the smooth promotion of urbanization. Due to the accelerated construction of transportation infrastructure in the study region during the study period, the region's relatively occluded transportation shortcomings were gradually alleviated, which helped build the construction of the region's regional tourism industry and urbanization. (3) Regarding openness to the outside world (*op*), its regression coefficient was −0.025, and this did not pass the significance test at the 10% level, indicating that the effect of expanding openness to the outside world on the coordinated development of the tourism industry and urbanization in the study region was not yet obvious. Opening up to the outside world can stimulate the economic vitality of towns and cities [70] and drive regional development through technology transfer and spillover effects. However, the total amount of foreign investment actually utilized in the study region was extremely low, and it therefore did not play a significant role in the construction of the region's tourism industry and urbanization. (4) Regarding the capital effect (*ce*), its regression coefficient was 0.131, and this passed the significance test at the 1% level, indicating that the strengthening of the capital effect significantly promoted the coupled and coordinated development of the tourism industry and urbanization. With the implementation of policies, such as Western development, the construction of the Belt and Road Initiative, and the policy of promoting the border and enriching the people, the amount of fixed asset investment in the study region grew rapidly over the study period, and the capital involved in its process of tourism industry development and urbanization construction became effectively guaranteed. (5) Regarding consumption ability (*ca*), this was the indicator with the largest influence factor. Its regression coefficient was 0.446, and this passed the significance test at the 1% level, indicating that the improvement of consumption ability was the key influencing factor for the coupled and coordinated development of the tourism industry and urbanization in the study region. The upgrading of residents' consumption is an important means of promoting the development of the tourism industry and an important factor in the improvement of the economic activity of urban markets. In recent years, the living standards of residents in the mountainous border areas of western Yunnan have improved significantly, and their consumption capacity has been enhanced. Furthermore, the demand for tourism and leisure, as well as for other enjoyment and development-oriented areas, has increased, which has injected vitality into the development of the region's tourism industry and urbanization. (6) Regarding talent support (*ts*), its regression coefficient was 0.115, and this passed the significance test at the 1% level. This indicates that talent support played a significant role in the coupled and coordinated development of the study region's tourism industry and urbanization. Improving the quality of the labor force is a factor important to the promotion of long-term economic growth. Due to the vigorous development of scientific education and the introduction of numerous talent introduction policies in the cities in the mountainous border areas of western Yunnan in recent times, the level of these cities' labor force has been solidly improved, providing a sustainable guarantee for the construction of its tourism industry and urbanization.

4.4.4. Robustness Test

In order to verify the accuracy of the analysis results, some of the explanatory variables were replaced with their characterization indicators, and mixed Tobit regression and random effects panel Tobit regression were performed again. The results of the likelihood ratio (LR) test indicated that random effects panel Tobit regression was still required; the analysis results are shown in model (2) in Table 5. Additionally, to further verify the accuracy of the regression results, broken-tail regression (model 3), ordinary panel random effects (using great likelihood estimation, model 4), and clad estimation (model 5) were used for further analysis. By comparing the results, we found little changes in the coefficients and significance levels of the explanatory variables, indicating that the regression results were robust and credible.

5. Discussion

5.1. Research Findings

In this study, in terms of the development level, the mean values of the tourism industry and urbanization in the mountainous border areas of western Yunnan during the study period were found to have increased by nearly three times and nearly one time, respectively, with the development level having been increased significantly. Further, the standard deviations of the tourism industry and urbanization increased by 68% and 76%, respectively, and the absolute gap in the development levels of the cities was increasing. Further, the coefficients of variation of the tourism industry and urbanization decreased by nearly 1.3 times and nearly 1%, respectively, and the relative gap in the regional tourism industry was gradually decreasing, while the relative gap in urbanization was slowly shrinking. From the viewpoint of spatial layout, the pattern of the tourism industry development level clearly changed, but more than half of the cities studied were still at the low development level, and the intrinsic two-level differentiation was still obvious. Further, the pattern of the urbanization level in each city also showed obvious improvement, but the phenomenon of spatial polarization expanded, and the overall regional development process moved slowly towards being balanced.

In terms of the sequential variation in the coupling coordination degree, the coupling coordination degree of the tourism industry and urbanization in the border mountainous areas of western Yunnan increased by 65.68% during the study period, showing a good development trend of steady growth. At the regional level, the time series of the coupling coordination degree varied, and the average annual growth rate was ranked as the following: West Yunnan > Southwest Yunnan > Northwest Yunnan. In terms of the spatial evolution of the coupling coordination degree, the location differences in the coupling coordination degree expanded during the study period, evolving from two types to four types; in terms of the subtypes of the coupling coordination degree, the cities maintained consistency, with the tourism industry lagging behind (hindered); in terms of the spatial connection of the coupling coordination degree, two solid axes were formed: "Lijiang–Dali–Baoshan–Dehong" and "Pu'er–Xishuangbanna".

From the spatial combination of the coupling coordination types, each city's combination type levels appeared to be elevated to a certain extent, evolving from five types to seven types. Their spatiotemporal patterns were similar to the differentiation characteristics of the tourism industry development level, urbanization level, coupling degree, and coupling coordination degree. Further, the evolution pattern of the coupling coordination types presented a balanced development pattern, represented by Dali, an inertial development pattern, represented by Lijiang, a reversal development pattern, represented by Xishuangbanna, and a leap development pattern, represented by Pu'er.

From the viewpoint of the influencing factors of the coupling coordination degree, industrial structure, transportation accessibility, the capital effect, consumption capacity, and talent support had significant positive effects on the coupling coordination degree of the tourism industry and urbanization in the mountainous border areas of western Yunnan, with the influence degrees of these factors ranked as the following: consumption capacity > transportation accessibility > capital effect > industrial structure > talent support. Meanwhile, the promotion effect of the degree of opening up to the outside world on the coupling coordination degree was not yet obvious.

5.2. Practical Implications

Based on the research results, we propose several recommendations for marginal and less developed regions: First, rely on policies, and find a reasonable orientation based on the background of a given region. By taking advantage of the opportunities brought by the promotion and implementation of regional policies, and by following the principle of "precise positioning, rational exploitation, and development in order", reduce excessive competition and fully explore the development potential of the tourism industry. Further, seize the opportunity provided by the forward position of inland open highlands and practice the urbanization path of scientific development. Second, aim to achieve the effect of "1 + 1 > 2". Guided by the humanistic concept of urbanization and the comprehensive function of tourism, establish a unified mechanism of the "quality improvement" of urbanization and the "transformation and upgrading" of the tourism industry, utilize the interaction and joint effects of the pan-tourism industry, and promote the deep integration and synergistic development of the tourism industry and urbanization. Third, focus on integrated development and the implementation of the "point, line, surface" idea. Take better-developed areas as the essential pivot point, promote the demonstration effect in the process of tourism and urbanization construction, and reduce the cost of monitoring these areas' vicinities. Further, take the circular tour, town belt, etc., as the key axis, promote infrastructure interconnection, co-construction and sharing, and enhance exchange and cooperation between regions. From point to line, interweave surfaces, make good use of the "key point" and "important lines", establish regional cooperation and coordination mechanisms, implement regional cooperation and development strategies, and promote more balanced overall development in marginal and less developed regions. Fourth, strengthen strengths, fill weaknesses, and optimize the power superimposed effect. Given the reality that some marginal and less developed regions are rich in tourism resources but backward in their economic bases, the development of the tourism industry, through industrial structure upgrading, should be promoted in these regions in order to release economic pressure, promote transit construction in order to enhance traffic accessibility, and improve regional residents' income in order to enhance consumption capacity. At the same time, enhance a given region's financial support ability to ensure the source of funds, improve the quality of foreign investment during the broad opening up stage, vigorously develop science and education, and promote rational personnel policy in order to improve labor quality, thereby deepening the coupling and coordination effect of the tourism industry and urbanization.

5.3. Further Discussion: The Complex Relationship between the Tourism Industry, Urbanization and the Ecological Environment

It is necessary to promote urbanization through the development of the tourism industry in marginal and less developed regions, but in this process, the interaction between urbanization and the ecological environment cannot be ignored. On the one hand, the tourism development in marginal and less developed regions mainly occurs in the form of ecotourism, which is dependent on the ecological environment; for example, the mountainous border areas of western Yunnan described in this paper have several national nature reserves, and the existence of these natural resources is the basis for the development of the tourism industry in marginal and less developed regions. On the other hand, urbanization development can negatively affect natural resources and the ecological environment, exacerbate vulnerability, and thus affect the sustainable development of ecotourism. If the urbanization of marginal and less developed regions proceeds into the ecological trap, the chain reaction will be as follows: urbanization destroys the ecological environment, the damage to the ecological environment hinders the development of ecotourism, and ecotourism development affects the urbanization construction, forming a vicious circle, which eventually affects the development of the whole region. Therefore, marginal and less developed regions that are involved in the tourism industry should carefully guide the urbanization process, pay extra attention to the ecological responses, and adopt green routes to urbanization to ensure that urbanization and the development of ecological tourism can interact in a positive fashion.

5.4. Limitations

This study did have several limitations. Firstly, we mainly used ArcGIS and the spatial attraction model to analyze the spatial characteristics of the level of tourism industry development, the level of urbanization, and the coupling coordination degree. However, although we attempted to comprehensively reveal the mechanisms behind these phenomena, further analysis is still needed. Multiple methods can be used to supplement and improve relevant research in the future. Secondly, to ensure the study's completeness, the factors influencing the coupling coordination degree were also analyzed. These factors were selected based on the criterion that they significantly impact tourism and urbanization, and we tried to include all critical factors in the study. However, because tourism and urbanization are complex phenomena, there may have been some factors that we did not include and that therefore should be considered in future studies.

6. Conclusions

Based on the analysis of the mechanism of the coupling and coordinated development of the tourism industry and urbanization, this study measured the development levels and coupling coordination degree of the tourism industry and urbanization in the mountainous border areas of western Yunnan, as well as their spatial–temporal pattern evolutionary characteristics. Furthermore, using the panel Tobit model, the study explored the influencing factors of the coupling and coordinated development of the tourism industry and urbanization in the study region. The important findings of the study were as follows:

(1) The development levels of the tourism industry and urbanization in the mountainous border areas of western Yunnan in the study period showed growth trends, but they were uneven in their spatial distributions.
(2) The coupling coordination degree of the tourism industry and urbanization in the study region also presented a development trend of steady-state growth. However, from the perspective of spatial evolution, the location differences of different cities expanded.
(3) Combining the coupling degree and coupling coordination degree of different cities, four evolutionary patterns were found: balanced development, inertia development, inversion development, and leapfrog development patterns.
(4) The influence degrees of the different factors on the coupling coordination degree were ranked as the following: consumption ability > transportation accessibility > capital effect > industrial structure > talent support > opening up to the outside world.

The research results have reference significance for the development of marginal and less developed regions and can provide insights for the promotion of the effective integration development of the tourism industry and urbanization.

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Notes

1 In this paper: the mountainous border areas of western Yunnan were divided into three major regions, northwest Yunnan, west Yunnan, and southwest Yunnan, of which northwest Yunnan includes Chuxiong, Dali, Lijiang, and Nujiang, west Yunnan includes Baoshan, Dehong, and Lincang, and southwest Yunnan includes Pu'er, Xishuangbanna, and Honghe.

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The Impact Factors and Management Policy of Digital Village Development: A Case Study of Gansu Province, China

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Abstract: (1) Background: Along with the maturity of smart cities, digital villages and smart villages are receiving more attention than ever before as the key to promote sustainable rural development. The Chinese government has made great efforts in promoting the digital development of villages in recent years, as evidenced by policies intensively introduced by the central and local governments, making China a typical representative country in the world. (2) Methods: This paper evaluates the performance and geographic pattern of rural digital development by the Geographic Information System (GIS) in Gansu, a less developed province in western China, and analyzes the driving mechanism of rural digital development using GeoDetector, providing a basis for spatial zoning and differentiated policy design for the construction, planning and management of digital villages based on the GE matrix. (3) Results: First, the development of digital villages shows a prominent geographical imbalance, with 79 counties divided into leader, follower and straggler levels. Second, digital villages show unsynchronized development in different dimensions, with the village facilities digitalization index in the lead and the village economy digitalization index lagging behind. Thirdly, the development of digital villages is characterized by significant spatial correlation and spillover effects, with cold and hot counties distributed in clusters, forming a "center-periphery" structure. Fourth, the factors show significant influence differentiation. They are classified into all-purpose, multifunctional and single-functional factors by their scope of action, and into key, important and auxiliary factors by their intensity of action. Fifth, the interaction and driving mechanism between different factors is quite complex, dominated by nonlinear enhancement and bifactor enhancement, and the synergistic effect of factor pairs helps increase the influence by 1–4 times. (4) Conclusions: It is suggested that the government develop differentiated policies for zoning planning and management based on the level of digital development of villages in combination with the factor influence and its driving mechanism and promote regional linkage and common development and governance through top-level design.

Keywords: rural digitalization; smart village; influence factor; China

1. Introduction

Since the concept of Smart Earth was introduced, the digital development of urban and rural areas has become a new global trend [1,2]. The concept of the Smart Village originated from the Smart City, and just as the Digital City is the fundamental condition for the construction of the Smart City, the Digital Village is the prerequisite for the construction of the Smart Village [3,4]. With the application and popularization of frontier technologies such as big data, cloud computing, artificial intelligence and Internet of Things, especially the maturation of digital cities and smart cities, traditional villages have gained an important opportunity for digital revolution and development, and the construction of digital villages and smart villages is becoming an emerging hot area [5,6]. The digital village is a novel form of modern village construction featuring digital and intelligent production elements with the Internet platform as an operation carrier, and emerging practical technologies such as Internet of Things, cloud computing and big data as the means [7]. To boost the development of rural digitalization, many countries and regions have increased their support in recent years, as evidenced by the "Rural Broadband ReConnect Program" proposed by the U.S. Department of Agriculture [8], the "Smart Countryside Initiative" proposed by the European Commission [9,10], the "Outline of Digital Rural Development Strategy" introduced by the Chinese central government [11] and Russian countryside online projects [12]. The level of rural digitalization varies greatly from country to country due to differences in start-up time, emphasis, investment intensity and driving mechanisms. Therefore, to better promote the construction of the Digital Village or Smart Village, it is of great theoretical significance and practical value to scientifically evaluate and analyze the characteristics of the current situation, determine the development disparities of different regions and reveal their influence factors and driving mechanisms [13].

China is one of the earliest countries to integrate digital technology into rural development, and the government regards digitalization as an important strategy to achieve rural revitalization and sustainable development and make its planning and construction of "digital villages" a typical representative in the world [14]. The Chinese government has long regarded information technology as an important means to promote the development of rural modernization, and as early as 2005 the central government proposed to strengthen the development of agricultural and rural information technology. China is currently in the stage of rapid urbanization, characterized by a massive migration of rural populations to cities and towns and increasingly serious rural shrinkage and decay. To promote rural revitalization, the Chinese central government proposed the "Digital Rural Development Strategy" in 2018. Based on top-level design, the central government of China has successively released national policies such as the *Outline of Digital Rural Development Strategy*, the *Plan for the Development of Digital Agriculture and Rural Areas* (2019–2025) and the *Notice on the Implementation of the National Digital Rural Pilot Project*. To push the all-round construction of digital villages, the central government has further selected 117 counties for pilot projects of digital villages. The pilot counties are in all provincial-level administrative regions (including provinces, autonomous regions and municipalities directly under the central government), including 27 counties removed from the list of national-level poverty-stricken counties. To better implement the central government's macro policies, about 70% of local governments have successively formulated digital village construction plans, practice solutions and other region-specific policies (according to the incomplete statistics by the authors based on policies released on provincial government websites as of 23 October 2022), and some provincial governments (e.g., Guangxi, Yunnan, etc.) have further set provincial digital village pilot counties (cities and districts). The results of the research on China can serve the Chinese government in policy making and can also provide constructive information for the development of digital villages or smart villages in similar countries around the world.

2. Literature Review

Digital villages and smart villages are the physical manifestations of rural information development at different stages with no essential difference. Therefore, this paper integrates the two in the literature analysis. Scholars are currently interested in the following areas.

2.1. Theoretical Research

Scholars have discussed the concept [15], analyzed the necessity and feasibility of rural digitization and intelligent development and proposed different approaches for different regions [16]. They also focus on thematic research on the development of different types of digital villages and smart villages. Most of the papers are dedicated to the analysis of the Smart Tourist Village [17], Taobao Village [18], such as the rural smart tourism service [19] and the development [20] model, which are spontaneous responses of villages to the development of smart tourism and e-commerce. Very few studies deal with the digital preservation and heritage strategies of smart eco-villages [21] and traditional ancient villages [22], such as the construction of traditional village digital archives [23], whose digital development is driven by government ecological or heritage conservation investments. Theoretical research is currently limited to superficial areas such as the definition of the basic connotation of digital villages and smart villages and the deconstruction of the development model of special types of digital and smart villages, while deep academic discussions on the driving mechanisms and evolutionary laws of rural digital development still remain blank (Table 1).

Table 1. Literature review and research gaps analysis.

Objectives	Methodologies	Literatures	Gaps
Concept and definition	Phenomenon observation and logical reasoning	Satola, Budziewicz-Guzlecka [15,16]	Driving mechanism and evolution law
Types and Development mode	Case study and qualitative analysis	Ciolac, Leong, Hu, Li, Huang, etc. [17–23]	
Digital or intelligent application modules		Ogryzek, Mounce, Dai, Francini, etc. [24–31]	Development demand and local supporting capacity
Latest applications of emerging digital and intelligent technologies		Irwansyah, Kaur, Ram, Cvar, etc. [32–38]	
Macro development strategies and policies	Policy analysis and pilot experience promotion	Stojanova, McGuire, etc. [39–41]	Quantitative analysis and evidence-based decision-making
Micro-spatial planning and design schemes analysis	Case study and qualitative analysis	Zavratnik, Wojcik, Bielska, etc. [42–45]	

2.2. Technical Research

Besides the analysis of digital or intelligent application modules, including development paths and solutions for smart rural transportation [24,25], smart land [26], smart grids [27], smart metering [28], smart finance [29], smart governance [30] and scalable architecture for smart villages [31], the scholars focus on the latest applications of emerging digital and intelligent technologies in the development of villages or hamlets [32], including blockchain [33], Internet of Things [34,35], machine learning [36], artificial intelligence [37] and big data technologies [38]. The increasing application of new generation information technology such as the Internet, big data and cloud computing in digital villages and new rural infrastructure in recent years has significantly accelerated digital, networked, intelligent and smart rural development and narrowed the digital divide between urban and rural areas. For example, the use of the Beidou System and artificial intelligence for the scientific management of crops improves management efficiency. Besides, QR code technology enables the full traceability of agricultural products from field to table; e-commerce and live streaming platforms increase the sales of agricultural products and expand the geographical scope of sales. Of note is that the current research is more based on the technology development trend, with less effort focused on the needs and development support capacity of digital village construction.

2.3. Policy and Planning Research

On the one hand, they analyze macro development strategies and policies, including Stojanova's analysis of the policy evolution of the EU Smart Village [39], and the introduction of rural smart policy in Australia and the 'smart' rural development program in Northern Ireland by Randell-Moon [40] and McGuire [41]. On the other hand, they conduct micro-spatial planning and design schemes analysis; for example, Zavratnik [42] analyzed the case of smart village initiatives and practices in Slovenia, Wojcik [43] and Bielska [44] assessed the spatial model and planning digitization of smart village development in

Poland and Li [45] analyzed the digital village spatial design schemes in Youzhaqiao Village, Guangshui, China. Notably, these practices are innovative, but unfortunately, they are based more on empirical and exploratory work and at odds with trends and requirements for quantitative analysis and evidence-based decision-making.

2.4. Research Gaps Analysis

In summary, a series of valuable papers are available on digital and smart village development, mostly focusing on the concepts, types, functional modules and technological applications, development policies and spatial planning of smart and digital villages [46]. All the conclusions provide a valuable reference for this study. However, there are some limitations in existing studies. First, there is still insufficient scholarly research on how to evaluate the level of digital and intelligent development of villages and measure inter-regional differences and correlations though it is a key basis for government management. Although Venkatesh [47], Gerli [48], Erdiaw-Kwasie [49], Chen [50] and Labrianidis [51] analyzed the digital divide in Indian, British, Australian, Chinese and European villages, they failed to give satisfactory answers to the questions above (on the degree of development and its spatial effects). As Maja [52] stated, despite the good results of digital and smart village research and practice, research on indicators and criteria that can be used to evaluate them is still deficient as of now. Second, the construction of digital and smart villages is influenced by many factors, and there are no papers specifically analyzing the driving factors and their mechanisms of action. As with digital and smart cities, revealing the deep-seated driving mechanisms of digital and smart development in rural areas is a prerequisite for the proactive government intervention and management of digital and smart village construction and also a basis for setting development goals, policies and plans in different regions according to local conditions [53]. Therefore, it is very necessary to study the influence factors and their mechanisms for the theoretical construction and practice of digital and smart villages.

3. Materials and Methods

3.1. Study Area: Gansu Province

Gansu Province is in northwestern China and is a less developed region (Figure 1). The study area covers 79 county-level administrative districts in Gansu Province, excluding Chengguan, Qilihe, Xigu and Anning districts in Lanzhou City, Jiayuguan City (which has no subordinate districts or counties), Jinchuan District in Jinchang City, Baiyin District in Baiyin City and Subei County in Jiuquan City (Figure 2). Eight units are excluded from the study area because of the data deficiencies. In the *Index of Digital Rural Counties, 2020*, data are only available for counties where the ratio of agricultural value added to GDP was less than 3% in 2019, excluding data for prefecture-level cities.

We chose Gansu as the study area mainly for the reasons of policy support and development status. Policy support comes from both central government and local government. According to the *Notice on Announcing the List of National Digital Rural Pilot Areas*, Gaolan County of Lanzhou City, Yumen City of Jiuquan City and Gaotai County of Zhangye City are in the first batch of national pilot areas for digital villages. Driven by the national pilot and supported by the central government, Gansu has carried out provincial pilot construction in 5 cities, 10 counties, 50 towns and 500 villages. In the *Outline of the Fourteenth Five-Year Plan for National Economic and Social Development of Gansu Province and the Visionary Goals for 2035*, the provincial government clearly put forward "the digital rural development strategy". The city and county governments also attach great importance to the construction of digital villages. For example, Gaotai, a national pilot county, has released the *Development Plan of Digital Villages in Gaotai County (2020–2024)* and the *Implementation Plan of the National Pilot Construction of Digital Villages in Gaotai County*. With the support of government investment, Gansu has witnessed faster construction of digital villages than its counterparts, quite typical across the country. According to the *County Digital Village Index Report* released by the New Rural Development Institute of Peking

University in conjunction with Ali Research Institute, 91 of the 100 fastest growing counties in the county digital village index in 2020 are from western China. Gansu ranks among the top five provinces with the fastest development of digital villages: Inner Mongolia (11%), Tibet (10%), Ningxia (10%), Gansu (9%) and Hebei (7%) by growth rate [54].

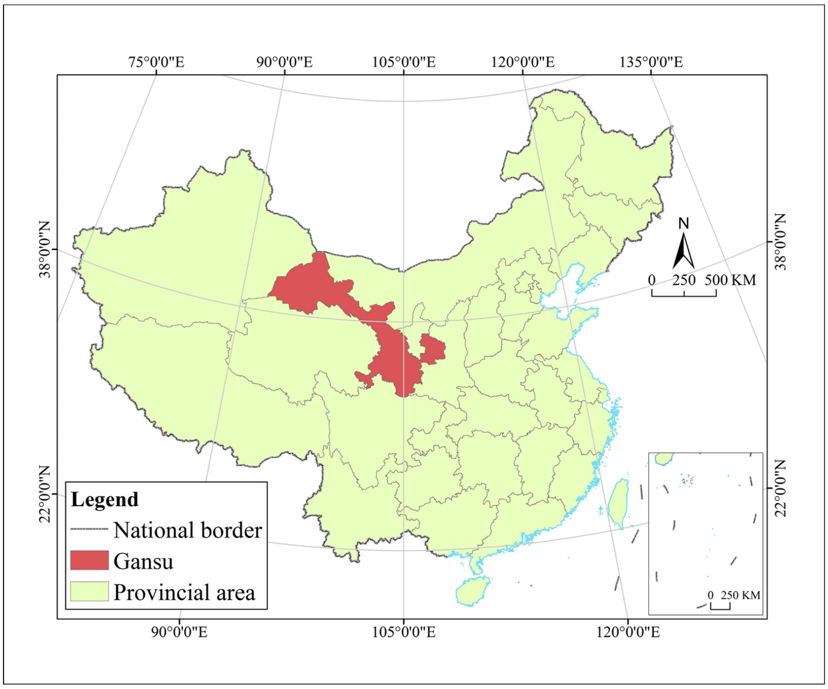

Figure 1. Location of the Study Area.

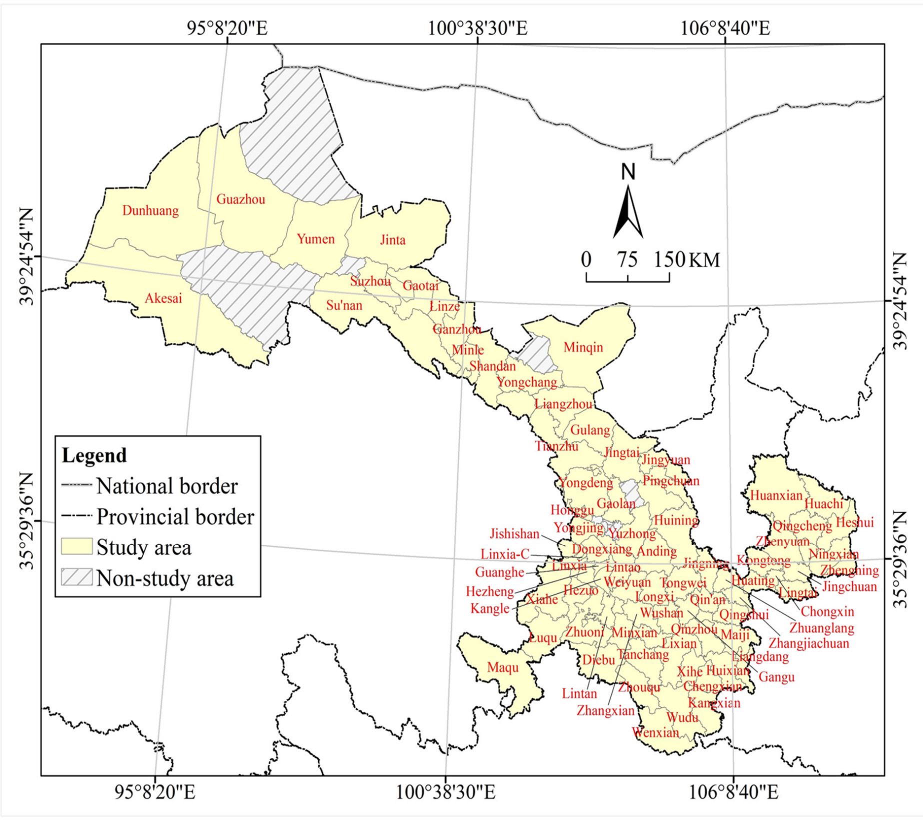

Figure 2. Study Area.

3.2. Research Question, Steps and Methods

The digital village strategy has achieved much after years of implementation, but it also faces great challenges. To accommodate the new development situation, there is an urgent need to optimize the digital village policy. However, there is still a lack of basic and critical knowledge on the level of digital village construction, regional differences and impact mechanisms to provide an adequate basis for the government. Using the Geographic Information System (GIS) and GeoDetector, this paper is dedicated to an empirical study on 79 counties in Gansu, China (including all national digital village pilots in the province) to analyze the level of digital development of villages and the characteristics of regional differences, reveal the influence factors and their mechanisms of action and provide references for the construction of digital or smart villages in China and similar countries around the world. After data collection and preprocessing (as detailed in Section 2.3), the study consists of three processes and five steps (Figure 3).

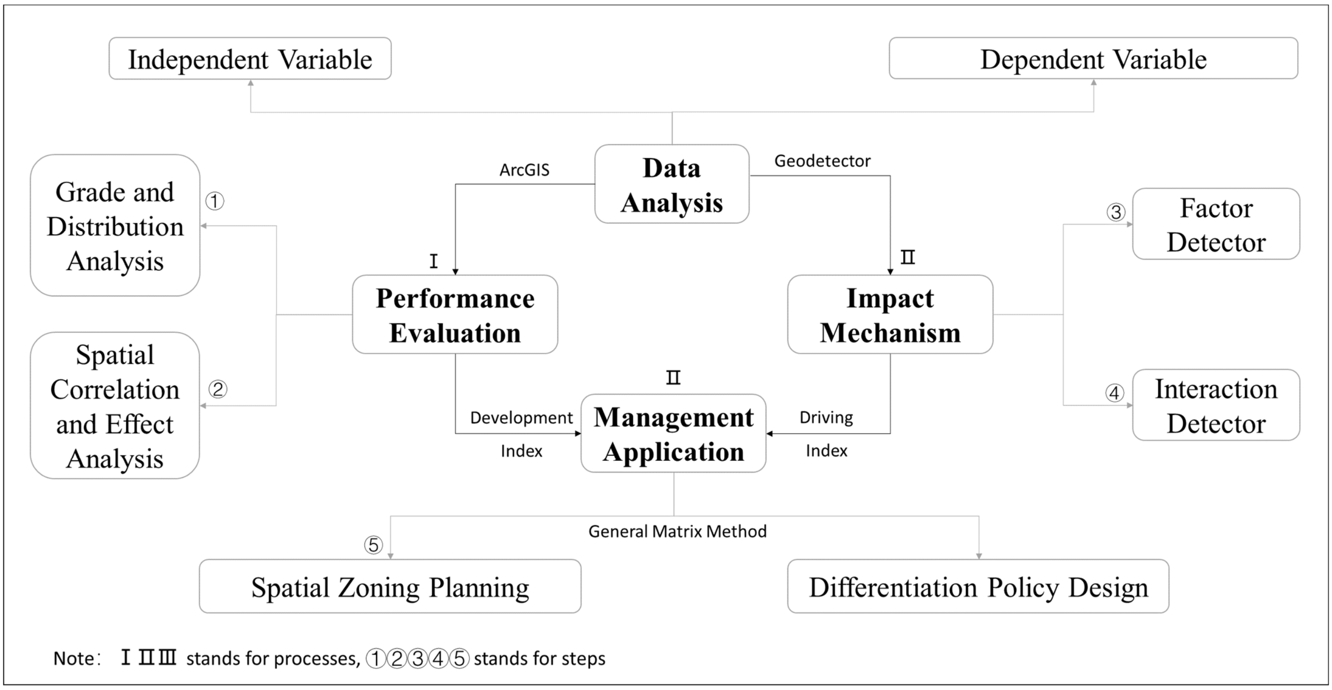

Figure 3. Research steps.

3.2.1. Performance Evaluation and Spatial Characteristics of Digital Village Development

The first process is to analyze the performance and spatial characteristics of digital countryside development in Gansu Province using GIS tools. What are the characteristics of the development and discrepancy of digital villages in different regions? By the spatial analysis method of GIS, we try to evaluate the development level and reveal the spatial differentiation and correlation characteristics of the rural digitalization level and lay the foundation for driving mechanism analysis and policy design.

The first step is to analyze the geographical distribution pattern of the digital rural development index using the spatial clustering analysis tool, which is the most used method for spatial analysis and a nonparametric method that combines statistical principles with graphical means [55]. There are some natural turning points, characteristic points in any statistical series, with which the object of study can be divided into groups of similar nature, so the break points themselves are good boundaries for classification. In the analysis based on GIS, we group the data using the natural breakpoints, and emphasize that the data themselves “speak”, minimizing a priori assumption in rule detection and model construction to better fit the actuality. Compared with other classification methods such as quantile, equal interval and standard deviation, the natural breakpoint method maximizes the difference between different classes and better visualizes the spatial heterogeneity of the digital rural development index.

The second step is to analyze the local aggregation and correlation characteristics of the digital rural development index in space using the spatial hotspot analysis tool to reveal where the clustering of high or low value areas occurs in geographic space [56]. In this paper, we classify the study area into four types of hot, sub-hot, cold and sub-cold areas by Hotspot Analysis Tool, based on the index Getis-Ord G_i^*. The statistical significance of G_i^* is tested using the standardized parameter Z [57,58]. $Z > 2.58$ indicates a hot area, representing the high-value cluster area. That is to say, the high values do not exist in isolation, but that they, as well as the digital rural development indexes of adjacent regions, are in the high value region and can be considered as leaders in the digital development of the villages in the study area. $Z < -2.58$ indicates a cold area, which represents the low-value cluster area. That is, the high values do not exist in isolation, but they, as well as the digital rural development indexes of adjacent regions, are in the low value region and can be considered as laggards in the digital development. The areas with $1.96 < Z < 2.58$ or $-1.96 < Z < 1.96$ are sub-hot or sub-cold areas, indicating that the high and low values are isolated, i.e., the central region has completely opposite attribute values to its surrounding neighbors, and shows central polarization (high in the center and low in the periphery) or collapse (low in the center and high in the periphery). A larger absolute value of the index G_i^* indicates that it is more statistically significant and it is less likely to be randomly distributed. With n representing the number of counties, Y_i and Y_j as the values of the digital rural development index in counties i and j, respectively, $\overline{Y}$ as the mean value of the digital rural development index, W_{ij} as the spatial weight matrix in global spatial autocorrelation, S_0 as the sum of spatial weight matrices and S as the standardization of the digital rural development index, the index G_i^* is calculated as follows [59]:

$$G_i^* = \frac{\sum_{j=1}^{n} W_{ij} Y_j - \overline{X} \sum_{j=1}^{n} W_{ij}}{S \sqrt{\frac{n \sum_{j=1}^{n} W_{ij}^2 - \left(\sum_{j=1}^{n} W_{ij}\right)^2}{n-1}}} \tag{1}$$

$$\overline{Y} = \frac{\sum_{j=1}^{n} Y_j}{n} \tag{2}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} Y_j^2}{n} - \left(\overline{Y}\right)^2} \tag{3}$$

3.2.2. Influencing Factors and Impact Mechanism of Digital Village Development

The second process is to analyze the mechanisms driving the development of digital villages based on the GeoDetector. What factors have influenced the process of the digital and intelligent development of the countryside? GeoDetector is used to quantify the influence of different factors on rural digitization and reveal the interaction and effect between different factors. The analysis of the driving mechanism can be conducted based on GeoDetector [60], Geographically Weighted Regression [61], the Spatial Durbin Model [62] and other methods. GeoDetector is used in this paper, as it allows simultaneous analysis of the direct and interactive effects of the influence factors and fits the needs of this study better than other methods. GeoDetector is a collection of open-source research applications developed by Prof. Wang Jinfeng for measuring spatial heterogeneity, detecting explanatory factors and analyzing interactions between variables (including two versions in Excel and R languages, free to download at http://www.geodetector.cn/, accessed on 12 October 2022) that has been applied in many fields of natural and social sciences. The basic principle of GeoDetector is based on the second law of geography (the Law of Spatial Heterogeneity). It divides the study area into geographic subdivisions in calculation and defines the variance of the digital rural development index within a subdivision smaller than that between subdivisions as spatial stratified heterogeneity.

The third step is to analyze the direct influence of different factors on the development of digital villages by the factor detection tool. The key to digital rural development index factor detection and interaction detection using GeoDetector is to calculate the index q, which represents the heterogeneity of the dependent variable and the influence of the independent variable. The index q represents the direct influence of different factors (such as X_i and X_j) on the digital rural development index in factor detection, which is expressed as $q\ (X_i)$ and $q\ (X_j)$) in this paper. By comparing the similarity in spatial patterns between the influence factors (independent variable, X_i) and the digital rural development index (dependent variable, Y_i), GeoDetector calculates and outputs index q [63] (Figure 4). The maximum value of index q is 1 and the minimum value is zero. A larger index indicates that the factor has a greater influence on the digital rural development index. With h representing the number of zonings of the influence factors in the study area (2–10 in this paper), N_h and N being the number of counties in the area h and the study area, respectively, σ_h^2 and σ^2 as variances of the digital rural development indexes in the area h and the study area, respectively, and SSW being the sum of the variance of the zonings (Within Sum of Squares) and SST being the total variance of the study area (Total Sum of Squares), q is calculated as follows [64]:

$$q = 1 - \frac{\sum_{h=1}^{l} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST} \tag{4}$$

$$SSW = \sum_{h=1}^{l} N_h \sigma_h^2 \tag{5}$$

$$SST = N\sigma^2 \tag{6}$$

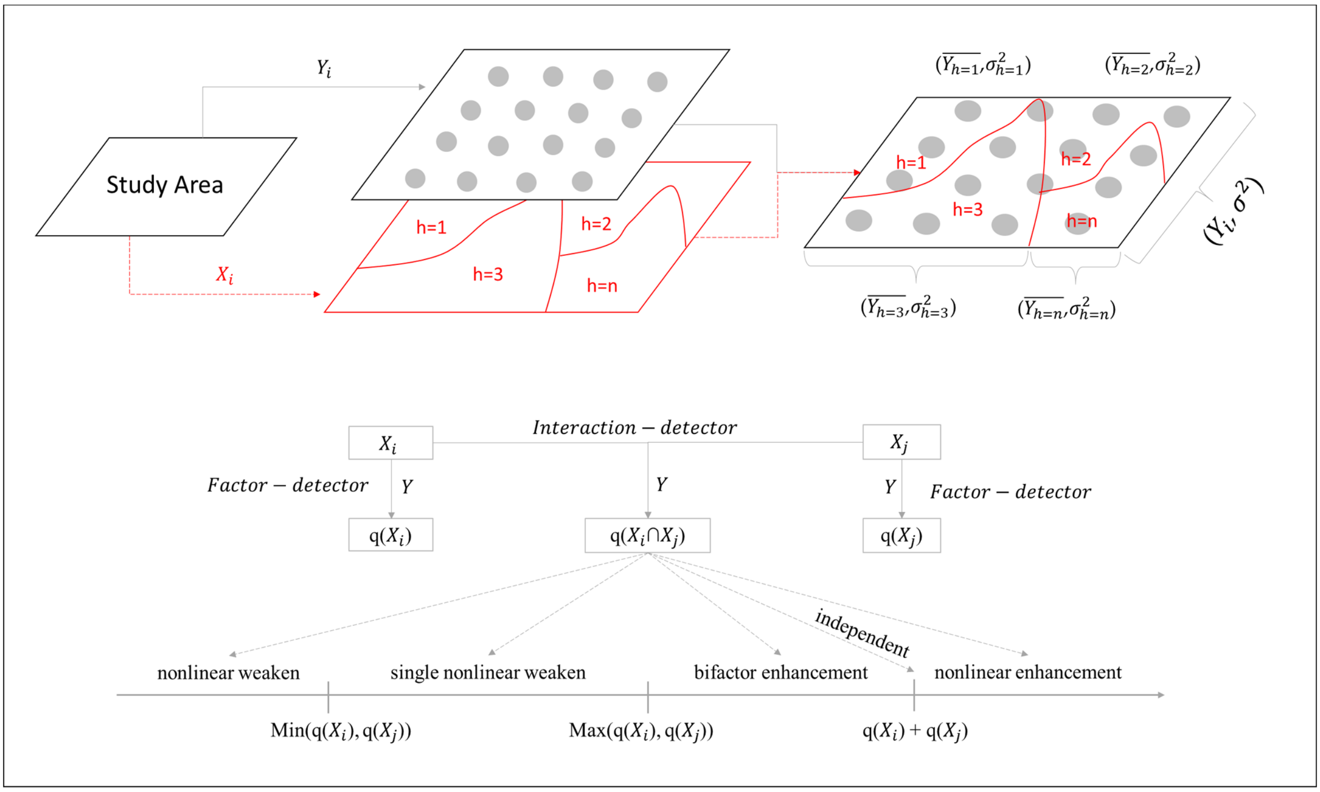

Figure 4. Factor and interaction detector of GeoDetector.

The fourth step is to analyze the combined influence of different factors acting together on the development of digital villages using the interaction detection tool to reveal the interaction relationship between factors. In the interaction detection the index q represents the combined influence of i and j factors when acting together on the digital rural development index, which is expressed in this paper as $q\ (X_i \cap X_j)$. According to the relationship of $q\ (X_i \cap X_j)$ with the minimum direct influence value (Min ($q\ (X_i)$, $q\ (X_j)$), the maximum value (Max ($q\ (X_i)$), $q\ (X_j)$) and the sum value ($q\ (X_i) + q\ (X_j)$)), the interactive influence is divided into five classes [65]. Depending on the type of factor-pair interaction, it is possible to determine whether the two factors increase or decrease the influence when they act together. Both nonlinear weaken and single nonlinear weaken represent the presence of an antagonistic effect between different factors, indicating that the driving forces of i and j cancel each other with influence weakened or even disappearing when they act together on Y. The pairing of the two factors should be avoided in policy design. Both bifactor enhancement and nonlinear enhancement represent a synergy effect between different factors, suggesting that the driving forces of i and j reinforce each other with enhanced or even significantly amplified influence when they act together on Y. It is important to induce the pairing of the two in policy design [66,67] (Figure 4).

3.2.3. Management Zoning and Policy Design of Digital Village Development

The third process is to divide the study area into multiple spatial zones and design differentiated management policies by using the general matrix method. How to apply the analysis results to the design process of digital rural development policy? The results of the analysis of the first two problems are coupled using the GE matrix to provide ideas and suggestions for policy design from the perspective of spatial zoning and differentiated management. The last step is to divide the study area into a variety of space partitions by the general matrix method and design targeted and adaptive management policies for each partition. The general matrix method, also known as the nine-quadrant evaluation method, is a portfolio analysis method designed by the General Electric Company in the United States. It evaluates the competitiveness and attractiveness of companies separately based on weighted indices to establish nine combinations and three strategy types. In the study of village digitalization, the development index is chosen to represent the competitive power as the horizontal coordinate, and the driving index is chosen to represent the attractiveness power as the vertical coordinate. The two indices are divided into three levels by the quantile method, thus contributing to nine combinations and three types of policy areas. Targeted and appropriate investment strategies and management policies are designed for each type based on the actual construction and development needs of the digital villages in the policy area (Figure 5).

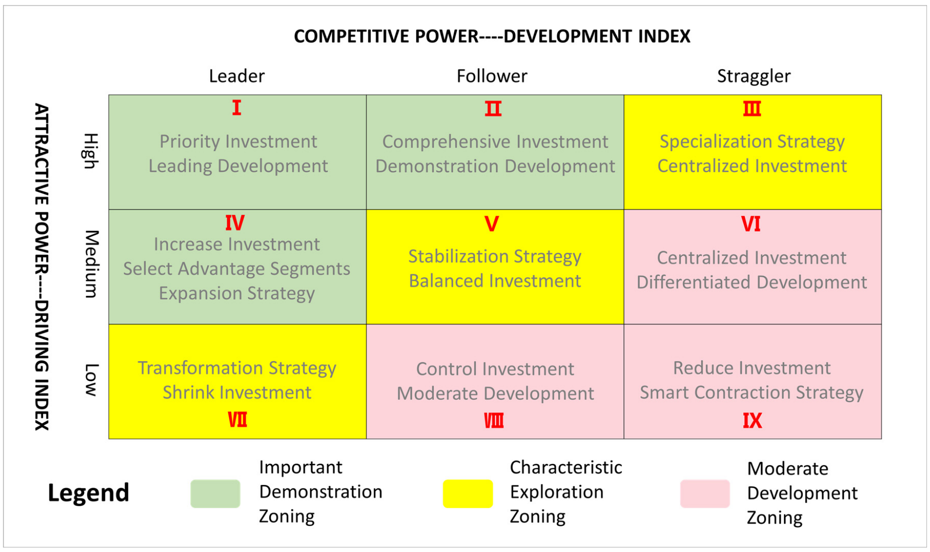

Figure 5. General matrix method.

3.3. Indicator Selection and Data Sources

The Chinese government has not issued an official scheme for measuring the development level of digital villages and constructing an index system [68], although there are two schemes available. The first is that Zhang [69] constructed a provincial digital rural development index and creatively proposed the concept of Digital Rural Development Readiness. It refers to the degree of preparation for the construction of digital villages and puts forward five first-level indexes: macro environment support, general infrastructure support, information environment support, government service environment and application service. The second is China's county-level digital rural development index published by the Institute of New Rural Development of Peking University and the Ali Research Institute. Annual reports for 2018 and 2020 have now been released. The reports focus on evaluation at a county scale, and the report for 2020 provides sample data of 2481 counties (districts or cities), a large proportion of county-level regions in China. The digital countryside index for counties sums up the digital content and specific representations of China's rural infrastructure, rural economy and rural management, and includes specific representational indexes from the perspectives of both producers and consumers, with full consideration of the emerging digital phenomena in current rural development [70]. Moreover, the report represents an aggregate of national macro statistical data, industrial data and Internet big data to measure actual digital rural development more accurately, which has had a great social influence [71].

Therefore, based on the comprehensive consideration of spatial scale, data quality and spatial demand, the indexes in the second scheme are used as research data in this paper. The level of digital village development is represented by the village digitalization index, which is further divided into three key sub-indexes: the village facilities digitalization index, village economy digitalization index and village management digitalization index. All indexes have a value in the range of (1, 100) and a larger value represents a higher level of development [72]. Since the Chinese government has been vigorously promoting the development of "new infrastructure", digital economy and digital government in recent years [73], all four indexes are set as dependent variables.

As there is no specific research on the factors influencing the construction of digital villages at present, it is impossible to draw directly on the research experience of other scholars. We can extract the possible set of influence factors by analyzing the key procedures of digital village construction practice. First of all, both the central government and local governments in China have incorporated the construction of digital villages into the development plans of new urbanization and rural revitalization, and factors related may affect the development of digital villages [74]. Given that urbanization and rural revitalization are complex processes, this paper chooses rural population, urbanization rate, rural consumption, rural resident and per capita income to characterize them, based on the research approach of Xie [75] and Zhang [76]. Secondly, rural digitalization is a new product of the integration of traditional rural development to a certain stage and emerging information technology, so the county's economic development stage and industrial structure will inevitably have a great impact on the rural digitalization process. Following the research approach of Ouyang [77], Li [78] and Zhao [79] et al., this paper chooses to represent the impact of economic and industrial structure and the level of industrialization with Gross Domestic Product (GDP), Secondary Industry Added Value, Tertiary Industry Added Value and GDP Per Capita. Thirdly, the construction of digital villages is still in its early stages, and the government plays a significant role in the process of digitizing villages. Based on the findings of Shen [80] and Chang [81], this paper uses Government Revenue and Fixed Asset Investment to represent the state or potential of government investment in the development of the digital countryside. In summary, this paper constructs a system of indexes applied to driving mechanism analysis from the perspective of urbanization, industrialization and government support using 10 independent variables and 4 dependent variables (Table 2).

Table 2. Variable composition analysis.

Variable	Code	Indicator	Data Source
Dependent	Y_1	Village Digitalization Index	*Index of Digital Rural County, 2020*
	Y_2	Village Facilities Digitalization Index	
	Y_3	Village Economy Digitalization Index	
	Y_4	Village Management Digitalization Index	
Independent	X_1	Rural Population	*Gansu Development Yearbook, 2021* *County Statistical Bulletin, 2020* *Work Report of County Government, 2021*
	X_2	Urbanization Rate	
	X_3	Rural Consumption	
	X_4	Rural Resident Per Capita Income	
	X_5	Fixed Asset Investment	
	X_6	Gross Domestic Product (GDP)	
	X_7	Secondary Industry Added Value	
	X_8	Tertiary Industry Added Value	
	X_9	GDP Per Capita	
	X_{10}	Government Revenue	

Spatial statistical analysis of the dependent variable data using GIS tools was conducted to evaluate the development performance of digital villages in Gansu, and to pro-vide a basis for method selection for driving mechanism analysis by spatial effect detection. The dependent variable data came from the Peking University Open Research Data Platform developed by Prof. Huang Jikun, Director of the Institute for New Rural Development, Peking University, and Mr. Gao Hongbing, Director of AliResearch. By importing the dependent and independent variables into GeoDetector, we explained the driving mechanism of rural digitalization, including the direct influence and indirect interaction effects of factors, and coupled the Development Index (the result of spatial clustering analysis of the dependent variable) and Driving Index (the independent variable based on the weighted sum of driving forces) through the GE matrix to spatially partition the rural digitalization in Gansu and provide a basis for differentiated policy design. Most of the independent variables are from the *Gansu Development Yearbook, 2021*, and those missing are from the *County Statistical Bulletin, 2020* and the *Work Report of County Government, 2021*.

4. Results

4.1. Performance Evaluation and Spatial Effect

This section is mainly to answer the first question (what are the characteristics of the development and discrepancy of digital villages in different regions?) and provide the basis for the selection of driving mechanism analysis methods through spatial effect de-tection. Based on the independent variables (village digitalization index, village facilities digitalization index, village economy digitalization index and village management digitalization index), the study area is classified into leader, follower and straggler types us-ing the spatial clustering analysis tool to evaluate the development level of rural digitali-zation. In addition, the spatial hotspot analysis tool is adopted to detect spatial autocorrelation. If the independent variables are spatially heterogeneous and correlated, the spatial econometric model rather than statistical regression methods should be chosen to analyze the driving mechanisms.

4.1.1. Village Digitalization Index

Linxia had the largest village digitalization index, up to 68.14, while Luqu had the smallest value of 32.72, less than half of the maximum. The average was 47.83, with 50.63% of counties above the average. Linxia, Liangzhou, Yongdeng, Dunhuang, Yuzhong, Jingtai, Kangxian, Xifeng, Suzhou, Kongtong are leaders in the rural digitalization in Gansu Province, dispersed in geographical distribution. It should be noted that the three national pilots, Gaolan in Lanzhou City, Yumen in Jiuquan City and Gaotai in Zhangye

City, are not leaders in digital countryside construction, so they need to leverage national investment in future to accelerate development. Yongjing, Huixian, Weiyuan, Jingyuan, Huating, Huining, Liangdang, Qinzhou, Hezuo, Xihe, Ningxian, Ganzhou, Jingning and Gaotai are followers in the digital development of rural areas in Gansu Province, mostly concentrated along the Yellow River and on both sides of the traffic arteries. Kangle, Wenxian, Jishishan, Yumen, Zhangjiachuan, Zhuoni, Sunan, Diebu, Dongxiang, Akesai, Minqin, Xiahe, Maqu and Luqu are stragglers in rural digitalization in Gansu Province, and most of them are autonomous counties of ethnic minorities. The counties lagging behind in the construction of digital villages are all concentrated in the provincial boundary of Gansu Province, especially in the southwestern mountainous areas (Figure 6).

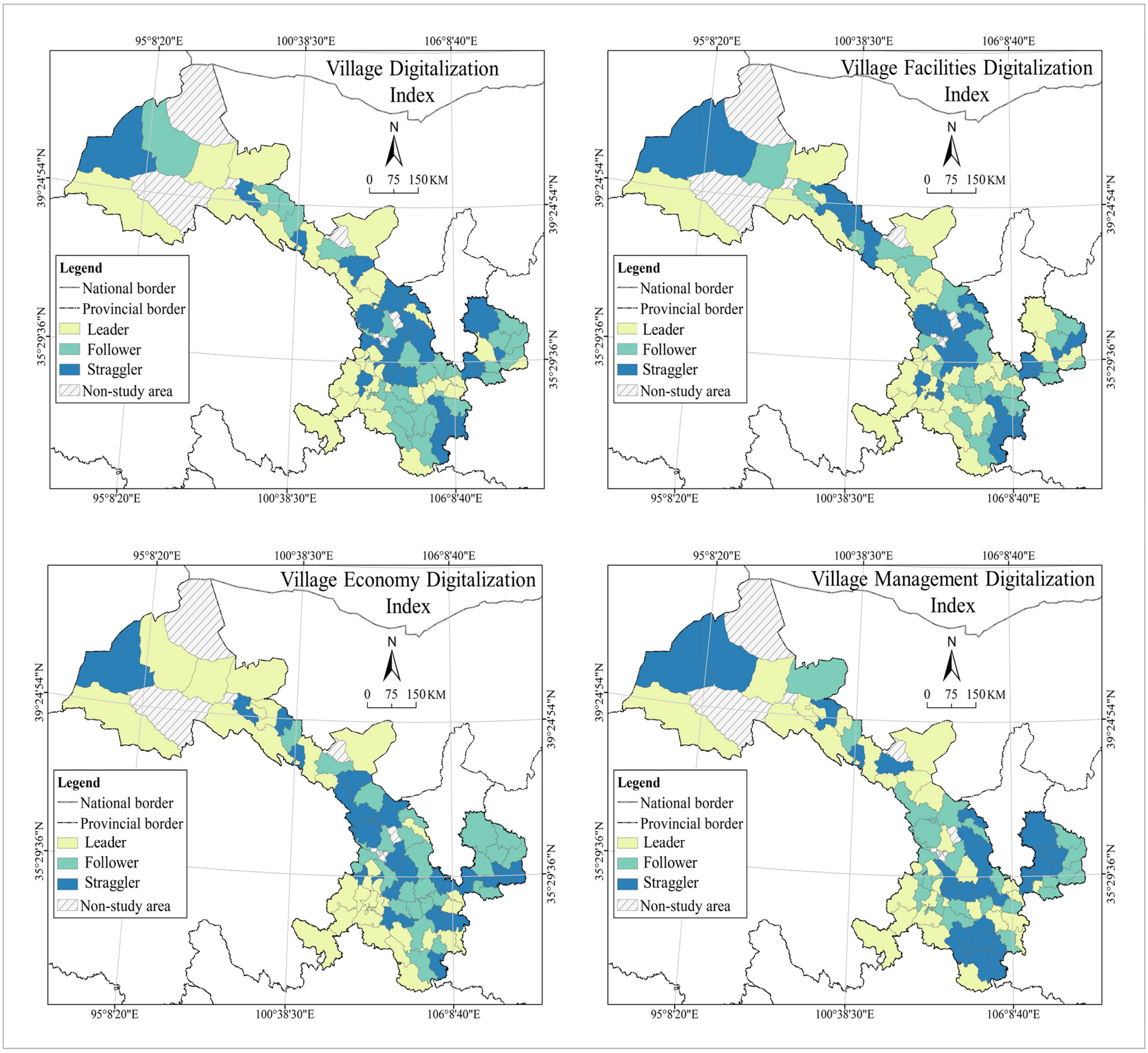

Figure 6. Analysis on development and geographic pattern of village digitalization in Gansu.

By use of the spatial hotspot analysis tool, it can be seen that rural digitalization in Gansu Province shows significant spatial agglomeration and correlation, and the geographical distribution of hot and cold counties shows a "center—periphery" spatial pattern. Guazhou, Shandan, Tianzhu, Jintai, Pingchuan and Yuzhong are hot spot areas, mostly clustered in the provincial capital metropolitan area. Most of the counties of the sub-hot type are concentrated in the periphery of the hot area and extend along the Yellow River to the east and south of Gansu Province. Maqu, Luqu, Zhuoni, Diebu and Xiahe are cold spot areas, all concentrated in the autonomous region of ethnic minorities in the southwest of Gansu Province. About half of the counties of the sub-cold type are distributed in the eastern periphery of the cold spot areas, and the other half are in the Hexi Corridor in northern Gansu Province (Figure 7).

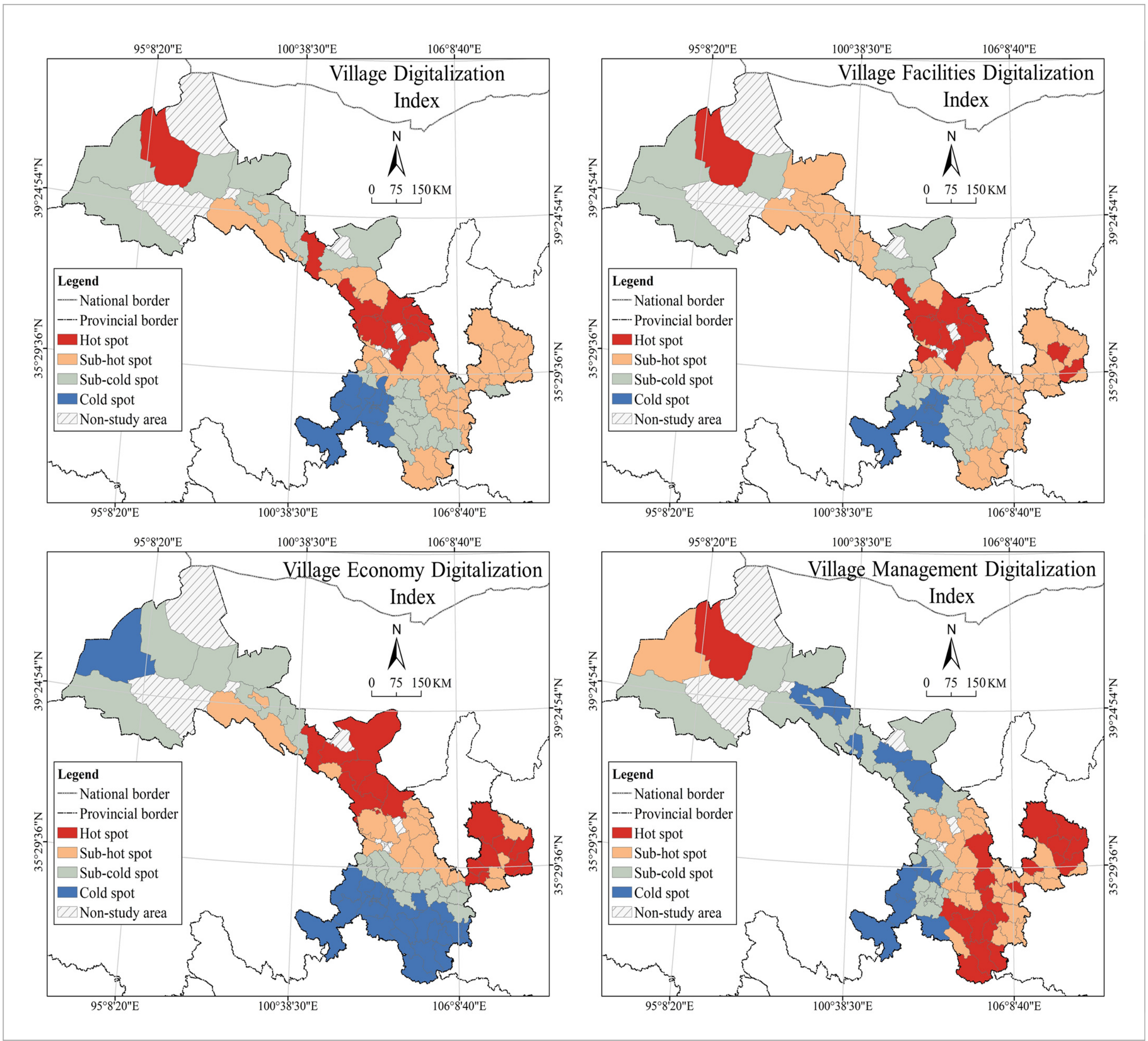

Figure 7. Analysis on spatial effect of village digitalization in Gansu.

4.1.2. Village Facilities Digitalization Index

Linxia had the largest village facilities digitalization index, up to 96.06, while Maqu had the smallest value, only 34.65, differing from the minimum by 2.77 times. The mean value was 67.31, much higher than the village digitalization index, and 51.90% of counties were above the mean. Linxia, Yongdeng, Chongxin, Dunhuang, Gaolan, Yuzhong, Lintao, Liangdang and Honggu are leaders in the digital development of rural facilities in Gansu Province, mostly clustered in the Lanzhou metropolitan area, Tianshui–Longnan metropolitan area and the Hexi Corridor town belt in clusters. Suzhou, Xihe, Jingtai, Longxi, Huining, Jingchuan, Qingcheng, Lingtai, Yumen, Liangzhou, Guanghe, Zhuanglang, Zhengning, Yongchang, Gangu and Qingshui are followers in the digital development of rural facilities, forming four clusters in Dingxi, Jiayuguan, Qingyang and Wuwei. Zhangjiachuan, Minqin, Linxia, Xiahe, Diebu, Dongxiang, Akesai, Luqu and Maqu are stragglers in the digital development of rural facilities, mostly concentrated in the Gannan Tibetan Autonomous Prefecture (Figure 6). In the national pilot project, Gaolan of Lanzhou City and Gaotai of Zhangye City are leaders. In particular, Gaolan ranks fifth and has played a good demonstration role. Yumen of Jiuquan City is a follower, ranking 42nd, and its village facilities digitalization index is only 67.20, still below the average, with a big gap with the predetermined target of the central and provincial governments.

The spatial pattern of cold and hot spots in the village facilities digitalization index in Gansu Province is largely similar to that of the village digitalization index, differing only in some local areas. Most of the hot counties are clustered in the Lanzhou metropolitan area, largely the same as the village digitalization index, and the sub-hot counties are further expanded in Tianshui and the Hexi Corridor. The cold counties are still clustered in the Gannan Tibetan Autonomous Prefecture, but their geographical scope is shrinking, and the counties in the northwest are now sub-cold counties.

4.1.3. Village Economy Digitalization Index

Liangzhou had the largest village economy digitalization index, up to 77.02, while Zhuoni had the smallest value, only 27.29, differing from the minimum by 2.82 times. The average was 36.21, and only 36.71% of counties were above the average. Only Liangzhou, Linxia and Suzhou are leaders in the digital development of the rural economy, and all national pilot counties are not included. Yuzhong, Jingtai, Weiyuan, Kongtong, Guanghe and Yongdeng are followers in the digital development of the rural economy. They are scattered in geographical distribution, mostly in Longnan and Longxi. Dongxiang, Hezheng, Minqin, Zhangjiachuan, Guazhou, Sunan, Gaotai, Tanchang, Akesai, Maqu, Lintan, Diebu, Zhouqu, Shandan, Yumen, Xiahe, Jinta, Wenxian and Zhuoni are stragglers, covering most of Gansu Province.

Unlike the village digitalization index and the village facilities digitalization index, the village economy digitalization index forms two hot and cold spot centers, respectively. The big hot spot center is located in the Jinchang–Wuwei metropolitan area, with sub-hot counties expanding to Lanzhou. The small hot spot center is in the Qingyang–Pingliang metropolitan area. The small and large hot spot centers are connected through the sub-hot spot area. The large cold spot is located in the Gannan–Longnan region, while the sub-cold spots are distributed in a band on its north side. The small cold spot center is located in the Jiuquan–Zhangye region, distributed in a ring-like cluster.

4.1.4. Village Management Digitalization Index

Huanxian had the largest village management digitalization index up to 79.26, while Luqu had the smallest at only 19.48, differing from the minimum by 4.07 times. The average was 50.25, with less than half of the counties exceeding the average. Huanxian, Lintao, Kangxian, Lixian, Huining, Guazhou, Dunhuang, Kongtong, Jingyuan, Tongwei, Longxi, Yongchang and Qinan are leaders in the digital development of rural management in Gansu Province, distributed in clusters in Longnan and in a finger cluster in the Dingxi-Tianshui–Pingliang–Qingyang region. Pingchuan, Guanghe, Jingchuan, Minxian, Lintan, Jingtai, Linxia, Yongdeng, Hezheng, Ningxian, Huixian, Yuzhong, Tianzhu, Zhangxian, Huachi, Yongjing, Heshui and Gangu are followers in the digital development of rural management in Gansu Province, distributed in clusters in the periphery of the leaders and expanding to the Lanzhou–Baiyin integrated development area and the town belt of the Hexi Corridor. Zhangjiachuan, Liangdang, Diebu, Zhuoni, Maqu, Yumen, Akesai, Linze, Gaolan, Shandan, Sunan, Xiahe, Minqin, Kangle and Luqu are stragglers in the digital development of rural management in Gansu Province, clustered in the Gannan Tibetan Autonomous Prefecture and the town belt of the Hexi Corridor (Figure 8). Gaotai of Zhangye City in the national pilot project ranks 14th (61.74), leading the digitalization process of rural management in Gansu Province; however, Yumen of Jiuquan City, ranking 70th (34.69) and Gaolan of Lanzhou City, ranking 73rd (29.16), are both within the top 10 of the bottoms, with insufficient demonstration and leading power for the region.

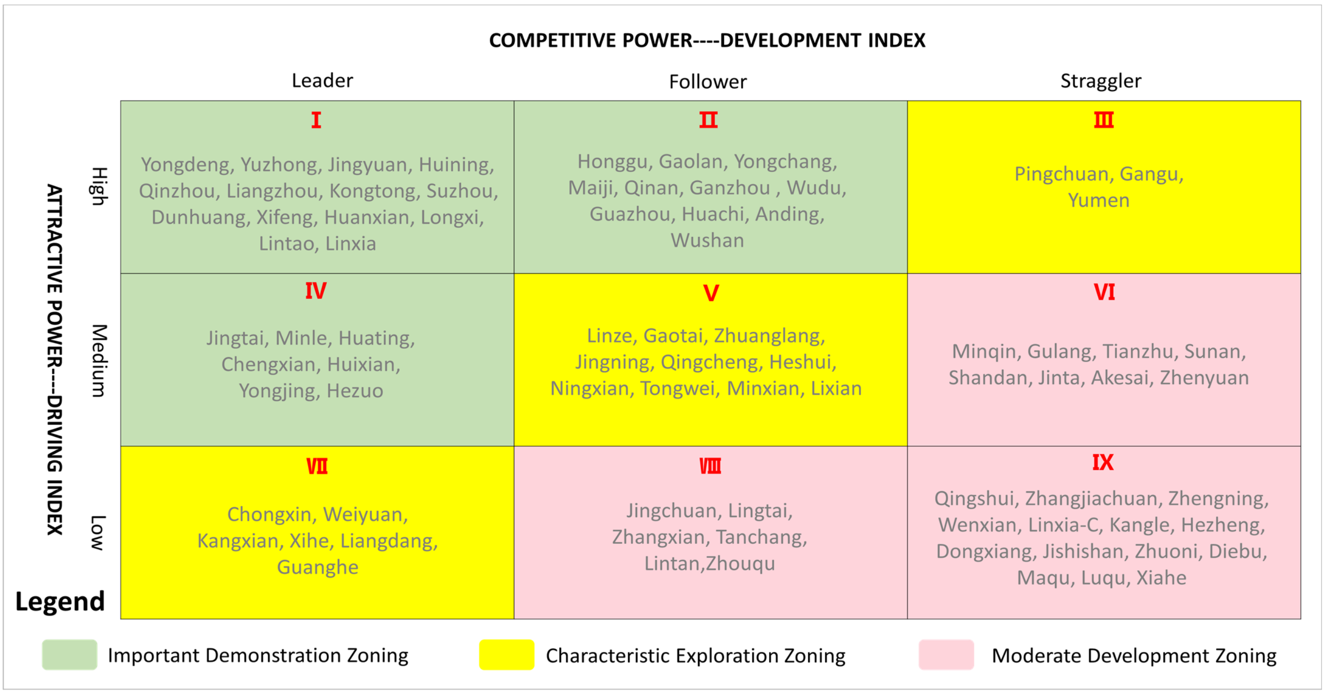

Figure 8. Analysis on spatial zoning of village digitalization in Gansu.

The hot and sub-hot counties are concentrated in the Longnan–Tianshui–Pingliang–Qingyang urban dense area in southeastern Gansu Province, forming a "center-periphery" structure. With Gaotai, Linze, Suzhou, Yongchang, Liangzhou and Gulang counties as the center and Minqin, Jinta, Yumen, Minle, Shanda, and Jingtai counties as the periphery, a cold and sub-cold belt-like agglomeration area is formed in the Hexi Corridor. A cluster agglomeration area of cold and sub-cold counties is formed in Sunan with Maqu, Luqu, Xiahe and Diebu counties as the center and Zhuni, Hezuo, Kangle and Jishishan counties as the periphery.

4.2. Influencing Factors and Impact Mechanism

This section addresses the second question (what factors have influenced the process of digital and the intelligent development of the countryside?) by means of GeoDetector. With the dependent and independent variables imported, the software outputs the q (X_i) and q $(X_i \cap X_j)$ index values to represent the direct and indirect influence of the factor, respectively. In addition, the software also outputs factor interaction types, including nonlinear weaken, single nonlinear weaken, bifactor enhancement and nonlinear enhancement, which are used to determine whether the factor interaction effect is antagonistic or synergistic.

4.2.1. Influence of Factors: Factor Detector

The mean value of the direct influence of the factors is 0.23 and the driving forces of tertiary industry added value, government revenue, fixed asset investment, gross domestic product and secondary industry added value are above the mean. The tertiary industry added value is the most influential, followed by government revenue, far ahead of other factors. Notably, the influence of Rural Resident Per Capita Income is very weak, the direct influence of GDP Per Capita is insignificant (not statistically significant) and the direct influence of Rural Population is only moderately statistically significant. The mean value of the direct influence of the factors is 0.24, and the driving forces of government revenue, tertiary industry added value, secondary industry added value, gross domestic product and fixed asset investment are above the mean. The largest direct influence is found in government revenue while the smallest is found in GDP per capita and is not statistically significant; rural population has a large influence but it is only moderately statistically significant (Table 3).

Table 3. Factor detector of village digitalization in Gansu.

Indicator	Code	Y_1		Y_2		Y_3		Y_4	
		q	p	q	p	q	p	q	p
Rural Population	X_1	0.21	0.08	0.21	0.09	0.10	0.03	0.24	0.04
Urbanization Rate	X_2	0.11	0.05	0.21	0.04	0.05	0.05	0.00	0.60
Rural Consumption	X_3	0.20	0.03	0.23	0.05	0.18	0.04	0.08	0.02
Rural Resident Per Capita Income	X_4	0.05	0.05	0.11	0.02	0.05	0.05	0.05	0.35
Fixed Asset Investment	X_5	0.28	0.02	0.27	0.02	0.25	0.05	0.29	0.02
Gross Domestic Product	X_6	0.27	0.03	0.30	0.02	0.27	0.01	0.32	0.01
Secondary Industry Added Value	X_7	0.25	0.01	0.33	0.00	0.14	0.05	0.02	0.19
Tertiary Industry Added Value	X_8	0.45	0.00	0.35	0.00	0.35	0.00	0.35	0.00
GDP Per Capita	X_9	0.13	0.38	0.02	0.19	0.10	0.37	0.10	0.03
Government Revenue	X_{10}	0.39	0.00	0.37	0.00	0.33	0.01	0.07	0.07

The mean value of the direct influence of the factors is 0.18, and the driving forces of tertiary industry added value, government revenue, gross domestic product, fixed asset investment and rural consumption are above the mean. Both tertiary industry added value and government revenue are far ahead in direct influence, while rural residents' per capita income and urbanization rate rank last. Note that the direct impact of GDP per capita is weak and is not statistically significant. The mean value of the direct influence of the factors is 0.15, and the driving forces of tertiary industry added value, gross domestic product, fixed asset investment and rural population are above the mean. The direct influence of tertiary industry added value is far ahead, while that of rural consumption is very weak and nearly negligible. It is worth noting that government revenue is only moderately statistically significant, while rural resident per capita income, secondary industry added value and urbanization rate are not statistically significant with small direct influence (less than 0.1).

4.2.2. Interaction of Factors: Interaction Detector

There is a significant synergy effect when different factors act together, manifested as bifactor enhancement and nonlinear enhancement. The mean of the interaction effect is 0.59 and 60.00% of the factor pairs are above the mean. In the interaction relationship, 82.22% of the 45 factor pairs show nonlinear enhancement, rural population, urbanization rate, rural consumption, rural resident per capita income, GDP per capita and government revenue as super interaction factors. It is important to note that the factor pairs of gross domestic product ∩ GDP per capita, rural population ∩ government revenue, tertiary industry added value ∩ GDP per capita, tertiary industry added value ∩ rural population and tertiary industry added value ∩ fixed asset investment rank in the top five for the interaction effect (Table 4).

Table 4. Interaction detector of village digitalization index.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	0.21									
X_2	*0.50*	0.11								
X_3	*0.66*	*0.58*	0.20							
X_4	*0.41*	0.13	*0.27*	0.05						

Table 4. *Cont.*

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_5	*0.74*	*0.58*	*0.59*	*0.41*	0.28					
X_6	*0.73*	*0.49*	*0.69*	*0.38*	*0.66*	0.27				
X_7	*0.60*	*0.51*	*0.56*	0.32	*0.67*	0.53	0.25			
X_8	***0.78***	0.55	*0.68*	*0.60*	**0.74**	0.60	0.64	0.45		
X_9	*0.60*	*0.44*	*0.61*	*0.29*	*0.68*	***0.82***	*0.67*	***0.78***	0.13	
X_{10}	***0.80***	*0.51*	*0.66*	*0.47*	*0.69*	*0.70*	*0.68*	0.64	*0.68*	0.39

Note: Italics represent non-linear enhancement of interaction effect, and bold represents the top five in all factor pairs. Tables 5–7 have the same meaning.

The interaction relationships between different factors, super interaction factors and the village digitalization index are largely the same, but there are some differences in factor pair composition and their interaction effects. The mean of the interaction effect is 0.60 and 57.78% of the factor pairs are above the mean. Of the 45 factor pairs, 84.44% show an interaction relationship of nonlinear enhancement, including urbanization rate ∩ rural consumption, rural population ∩ rural consumption, rural consumption ∩ fixed asset investment, rural population ∩ government revenue, rural population ∩ fixed asset investment ranking the top five (Table 5).

Table 5. Interaction detector of village facilities digitalization index.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	0.21									
X_2	*0.68*	0.21								
X_3	***0.79***	***0.80***	0.23							
X_4	*0.46*	0.28	*0.54*	0.11						
X_5	***0.75***	*0.75*	***0.78***	*0.56*	0.27					
X_6	*0.73*	*0.73*	*0.71*	*0.55*	*0.62*	0.30				
X_7	*0.61*	*0.67*	*0.68*	*0.47*	*0.68*	0.57	0.33			
X_8	*0.72*	*0.71*	*0.74*	*0.59*	*0.68*	0.55	0.64	0.35		
X_9	*0.39*	*0.34*	*0.42*	0.13	*0.40*	*0.40*	*0.44*	*0.50*	0.02	
X_{10}	***0.77***	*0.66*	*0.70*	*0.57*	*0.68*	0.67	0.63	0.64	*0.50*	0.37

The interaction between factor pairs is manifested as bifactor enhancement and non-linear enhancement, while the latter decreases to 66.67%. The mean of the interaction effect is 0.42 and 51.11% of the factor pairs are above the mean. Notably, rural population, rural consumption, gross domestic product, tertiary industry added value and GDP per capita are super interaction factors; fixed asset investment ∩ tertiary industry added value, tertiary industry added value ∩ GDP per capita, fixed asset investment ∩ government revenue, GDP per capita ∩ government revenue, fixed asset investment ∩ gross domestic product is among the top five in interaction force (Table 6).

Table 6. Interaction detector of village economy digitalization index.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	0.10									
X_2	*0.25*	0.05								
X_3	*0.37*	*0.27*	0.18							
X_4	*0.22*	0.08	0.24	0.05						
X_5	*0.47*	0.29	*0.55*	0.30	0.25					
X_6	*0.44*	0.31	*0.53*	*0.35*	***0.61***	0.27				
X_7	*0.36*	0.18	*0.42*	0.16	0.40	*0.45*	0.14			
X_8	*0.47*	0.40	*0.55*	*0.46*	***0.66***	0.50	*0.51*	0.35		
X_9	*0.29*	*0.23*	*0.53*	*0.23*	*0.58*	*0.60*	*0.40*	***0.65***	0.10	
X_{10}	*0.48*	0.38	0.53	0.36	***0.63***	0.50	*0.55*	0.57	***0.62***	0.33

The interaction relationships between different factors, super interaction factors, the village digitalization index and village facilities digitalization index are largely the same, but there are some differences in factor pair composition and their interaction effects. The mean of the interaction effect is 0.38 and 57.78% of the factor pairs are above the mean. A total of 86.67% of the factor pairs show nonlinear enhancement in the interaction, where fixed asset investment ∩ tertiary industry added value, rural population ∩ tertiary industry added value, rural population ∩ fixed asset investment, rural population ∩ gross domestic product, fixed asset investment ∩ gross domestic product rank in the top five in terms of interaction power (Table 7).

Table 7. Interaction detector of village management digitalization index.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	0.24									
X_2	*0.40*	0.00								
X_3	*0.37*	*0.12*	0.08							
X_4	*0.50*	*0.17*	*0.18*	0.05						
X_5	***0.74***	*0.32*	*0.43*	*0.54*	0.29					
X_6	***0.71***	*0.40*	*0.45*	*0.53*	**0.62**	0.32				
X_7	*0.35*	*0.09*	0.09	*0.14*	*0.35*	*0.39*	0.02			
X_8	***0.74***	*0.40*	*0.45*	*0.52*	***0.76***	0.59	*0.40*	0.35		
X_9	*0.43*	*0.16*	*0.23*	*0.23*	*0.55*	*0.51*	*0.23*	*0.50*	0.10	
X_{10}	*0.40*	*0.17*	0.14	*0.23*	*0.44*	*0.44*	0.10	0.44	*0.27*	0.07

The indirect influence minus the direct influence allows for analysis of the net interaction effect of factor pairs. The mean value of the net effect of all factors on the interaction effect calculated represents the degree of synergistic enhancement of the factors. For example, Rural Population has a direct influence of 0.21 on the village digitalization index, and has an interactive influence of 0.50, 0.66, 0.41, 0.74, 0.73, 0.60, 0.78, 0.60 and 0.80 with Urbanization Rate, Rural Consumption, Rural Resident Per Capita Income . . . , Government Revenue, respectively, and the net interaction effects are 0.29, 0.45, 0.2, 0.53, 0.52, 0.39, 0.57, 0.39 and 0.59, with a mean of 0.43 (Table 8). For the Village Digitalization Index and the Village Facilities Digitalization Index, there are significant differences in enhancement of the interactive influence of factors, with GDP Per Capita, Rural Population, Rural Consumption, Rural Population and Urbanization Rate stronger for the former, while Rural Consumption, Rural Population and Urbanization Rate are stronger for the latter. For the Village Economy Digitalization Index and Village Management Digitalization Index the enhancement of all factors is relatively balanced.

Table 8. Average value of factor interaction effect net value.

Indicator	Code	Y_1	Y_2	Y_3	Y_4
Rural Population	X_1	0.43	0.45	0.27	0.28
Urbanization Rate	X_2	0.37	0.41	0.21	0.24
Rural Consumption	X_3	0.39	0.45	0.26	0.20
Rural Resident Per Capita Income	X_4	0.31	0.35	0.21	0.29
Fixed Asset Investment	X_5	0.36	0.38	0.25	0.24
Gross Domestic Product	X_6	0.35	0.31	0.20	0.19
Secondary Industry Added Value	X_7	0.32	0.27	0.24	0.22
Tertiary Industry Added Value	X_8	0.22	0.30	0.18	0.18
GDP Per Capita	X_9	0.49	0.37	0.36	0.25
Government Revenue	X_{10}	0.26	0.28	0.18	0.22

4.3. Management Zoning and Policy Design

This section deals with the third question (how to apply the analysis results to the design process of digital rural development policy) using the GE matrix. To provide a quantitative basis for spatial planning zoning, the 79 counties in the province are classified into nine sub-categories (combinations) and three categories by hierarchical classification (quantile clustering) in the GE matrix, using the development index and the driving index as the horizontal and vertical axes, respectively. According to the national and Gansu digital village construction policies, differentiated policies are designed for the three categories of planning zones based on the rural digital development needs of the study area.

4.3.1. Spatial Zoning Planning

As a backward and underdeveloped region with limited government and social resources, Gansu should adopt an unbalanced development strategy in the initial stage of rural digitalization. In addition, the analysis in Sections 3.1 and 3.2 shows that there are significant spatial heterogeneity and correlation characteristics in the construction of digital villages in the province. Therefore, spatial zoning should be delineated and differentiated management policies should be designed to improve policy adaptability and regional linkage. Gansu should, according to the development base, location conditions and resource endowment of its counties, make scientific planning and the reasonable arrangement of key tasks and projects of digital village construction by zoning and classification to promote the process. Information technology facilities and services should be built according to the development needs of rural areas, farmers and agriculture, while taking measures to prevent image projects and wastefulness.

In this study, the policy partitions are delineated by the general matrix method, where the horizontal coordinates are directly based on the analysis results in Figure 6, while the vertical coordinates are weighted to calculate the driving index. The direct influence (set to zero when not statistically significant) and the interactive influence are given the same weight in the calculation. Tables 2 and 7 are summed up, and then the proportion of each factor is calculated as the weight. Taking the village digitalization index as an example, the direct and interactive influences of X_1~X_{10} are shown in the first column of Tables 2 and 7, corresponding to the total influences of 0.64 (0.21 + 0.43), 0.48 (0.11 + 0.37), . . . , 0.49 (0 + 0.49), 0.65 (0.39 + 0.26), with a sum of 5.72, corresponding to weights of 0.11 (0.64/5.72), 0.08 (0.48/5.72), . . . , 0.09 (0.49/5.72) and 0.11 (0.65/5.72), respectively. For each county, the weighted sum of all impact factors is calculated as the driving index, and quantile clustering is performed for all counties in the study area. By interacting the horizontal and vertical coordinates, all counties in the study area are classified into nine subcategories (combinations) and three categories.

For the village digitalization index, the policy zoning is as follows: 14 counties are in the leader-high (I) combination, i.e., Yongdeng, Yuzhong, Jingyuan, Huining, Qinzhou, Liangzhou, Kongtong, Suzhou, Dunhuang, Xifeng, Huanxian, Longxi, Lintao, Linxia; 10 counties are in the high (II) combination, i.e., Honggu, Gaolan, Yongchang, Maiji, Qinan, Ganzhou, Guazhou, Huachi, Anding, Wushan and Wudu; 3 counties are in the straggler-high (III) combination, i.e., Pingchuan, Gangu and Yumen; 7 counties are in the leader-medium (IV) combination, i.e., Jingtai, Minle, Huating, Chengxian, Huixian, Yongjing and Hezuo; 10 counties are in the follower-medium (V) combination, i.e., Linze, Gaotai, Zhuanglang, Jingning, Qingcheng, Heshui, Ningxian, Tongwei, Minxian and Lixian; 9 counties are in the straggler-medium (VI) combination, i.e., Minqin, Gulang, Tianzhu, Sunan, Shandan, Jinta, Akesai and Zhenyuan; 6 counties are in the leader-low (VII) combination, i.e., Chongxin, Weiyuan, Kangxian, Xihe, Liangdang and Guanghe; 6 counties are in the follower-low (VIII) combination, i.e., Jingchuan, Lingtai, Zhangxian, Tanchang, Lintan and Zhouqu; 14 counties are in the straggler-low (IX) combination, i.e., Qingshui, Zhangjiachuan, Zhengning, Wenxian, Linxia-C, Kangle, Hezheng, Dongxiang, Jishishan, Zhuoni, Diebu, Maqu, Luqu and Xiahe (Figure 8).

The analysis results of the village facilities digitalization index, village economy digitalization index and village management digitalization index are shown in Figures 9–11 (where the images are self-explanatory, and they are not described in detail here so as to control space), which are important references for the planning, design, policy, programming and implementation of digital village construction.

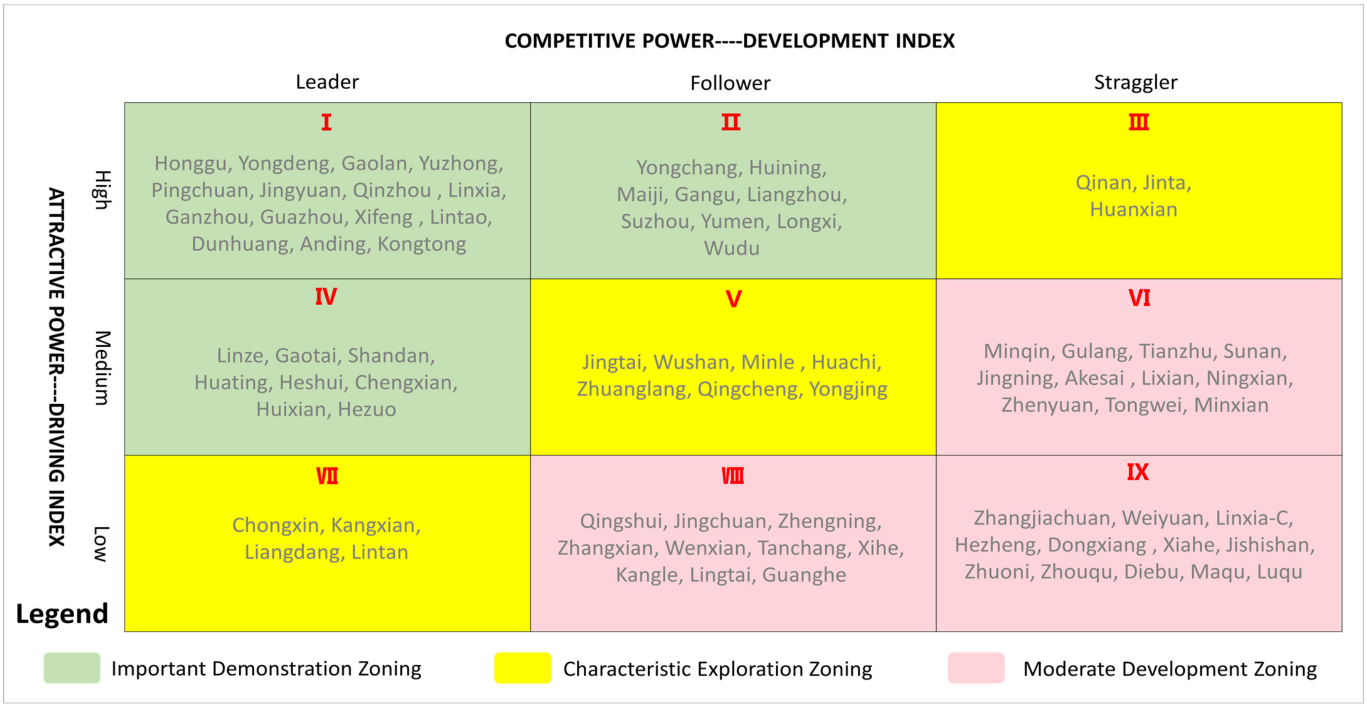

Figure 9. Analysis on spatial zoning of village facilities digitalization in Gansu.

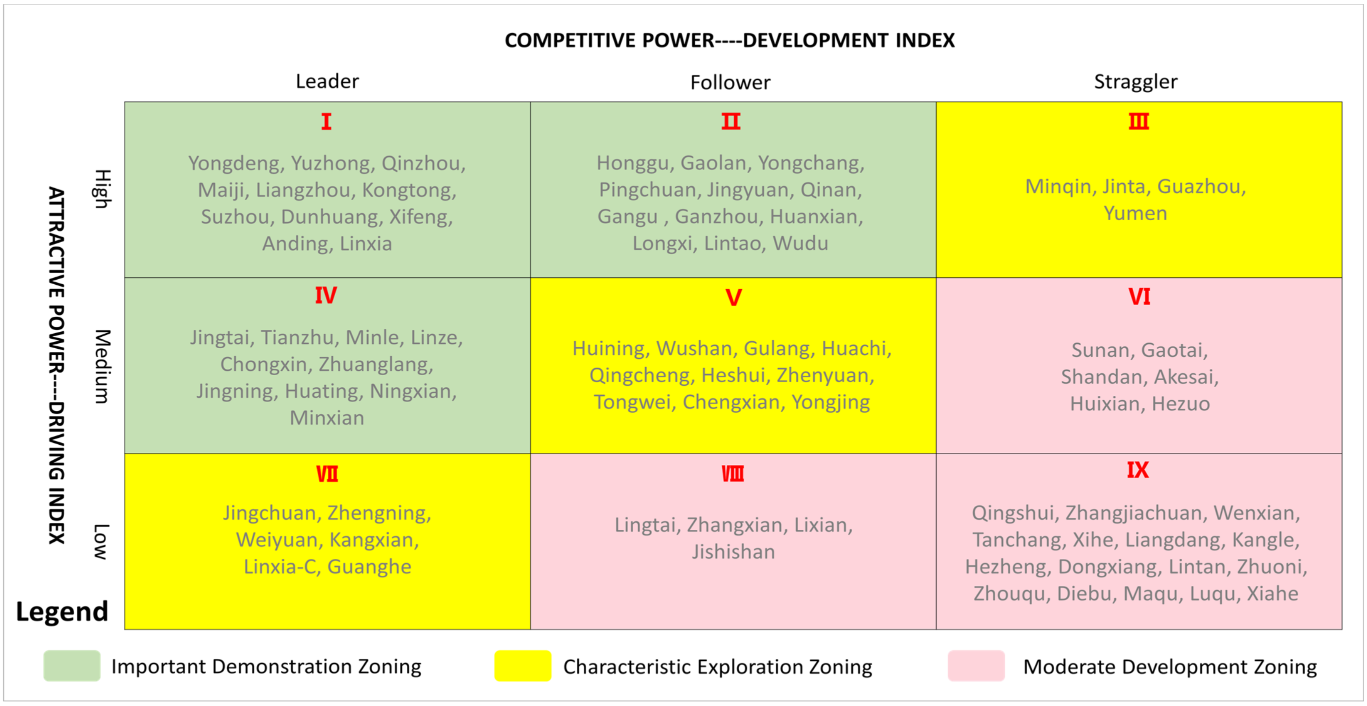

Figure 10. Analysis on spatial zoning of village economy digitalization in Gansu.

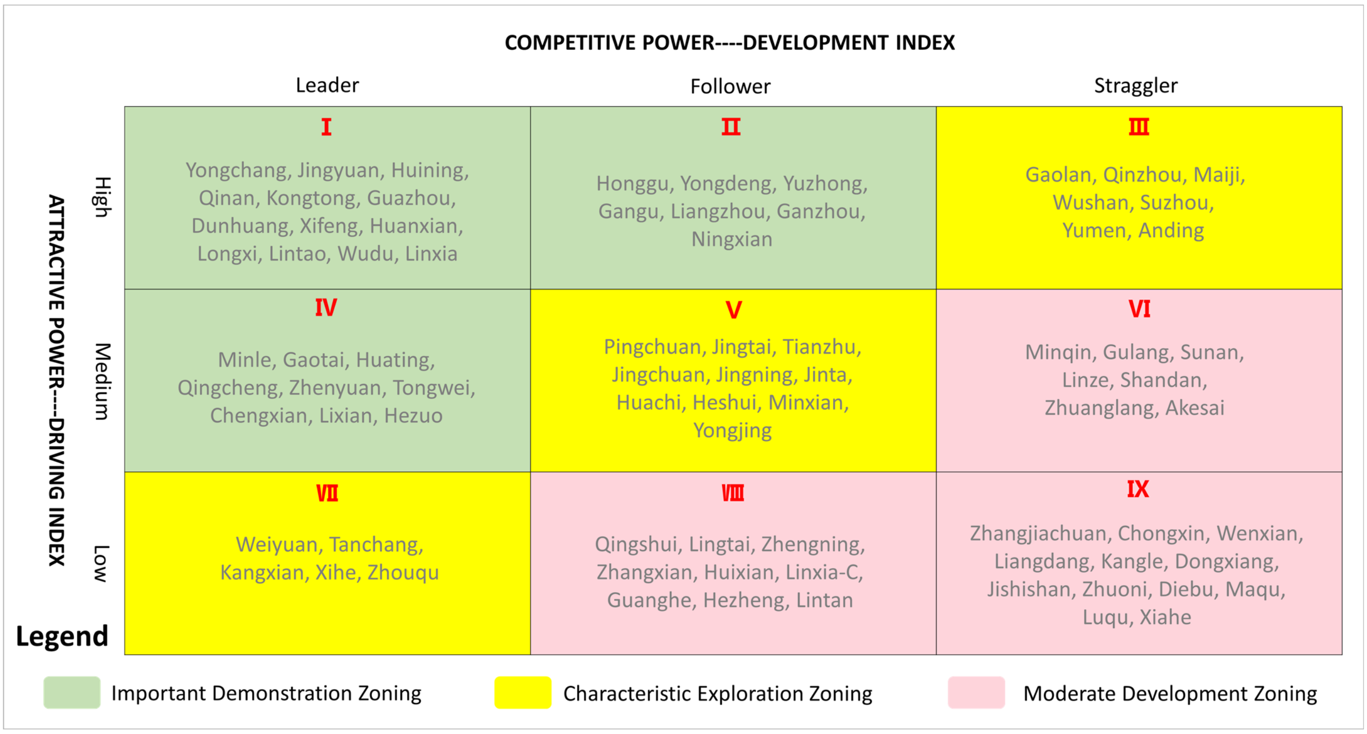

Figure 11. Analysis on spatial zoning of village management digitalization in Gansu.

4.3.2. Differentiation Policy Design

1. Important Demonstration Zoning: Shaping Leadership

The development index and the driving index of rural digitalization in this type of policy area are both high with strong competitive power and attractive power in Gansu. With a promising development and high regional status, they are the priority and focus regions for investment. They should adopt an expansion strategy in the future and try to grow into the leaders of rural digitalization in the province. First, the Gansu provincial government and municipal governments should give more preference to the counties within the policy area in allocating funds, capital and resources for rural digitalization. Second, all counties in this policy area should, in accordance with the people-oriented and bold innovation idea, give full play to the main role of farmers to stimulate the enthusiasm, initiative and creativity of farmers, so that the majority of farmers become participants and beneficiaries of the construction of the digital countryside. They should further boost the passion for digital development of agricultural enterprises in terms of the goal of agricultural and rural modernization, help and encourage farmers and agricultural enterprises to apply the new generation of information technology, cultivate new business forms and new models of the rural digital economy and drive the overall innovation of the rural development system, mechanism and model. Third, the counties within this policy area should have a sense of responsibility and mission to develop standards for the construction of digital villages in Gansu. It is necessary to develop guidelines or norms for digital rural construction in Gansu based on its own development stage and actual conditions as well as the experience of other provinces. Fourth, it is necessary to guide Gansu to establish early a dynamic monitoring mechanism for the development of digital villages, strengthen the management and supervision of the implementation process and carry out evaluation and guidance for the construction of digital villages.

Of note is that in the process of implementing the expansion strategy, the strategic focus of digital village construction is not exactly the same for counties in the three combinations of I, II and IV. The counties in Combination I should adopt an overall leading development strategy and enjoy priority in capital and resource allocation to promote their long-term leadership in the rural digitalization of Gansu. The counties in Combination II should adopt a model development strategy and increase overall investment to prompt them to become specialized or all-round emerging leaders in the rural digitalization of Gansu. For counties in Combination IV, a strategy of expansion in a dominant segment should be adopted, and according to the results of the analysis in Figures 9–11, increased investment should be made in a certain dominant segment to maintain the position. In general, a digital countryside development model that matches the knowledge structure of the rural population should be established for the three combinations to promote information construction in fields such as rural economy, politics, culture, society, ecological civilization and party construction as a whole, to help revitalize the countryside and move forward the construction of "digital Gansu" by creating a digital countryside brand and image of Gansu as an endorsement pilot.

2. Characteristic Exploration Zoning: Highlight Specialty

Since the development index and driving index of rural digitalization in this policy area are at a midpoint, limited funds, capital and resources should be invested in specialized and characteristic fields for the needs of rural areas, farmers and agricultural development in the future. First, Figures 8–11 are overlaid for analysis to determine the areas of strength for each county in the policy area. Second, a development strategy suitable for specialization, stabilization and transformation is determined based on their resources and conditions. It should be noted that transformation can be considered as a special type of specialized development strategy. Specialization requires establishing strengths and further focusing on their advantages, while transformation requires making up for weaknesses and overcoming the shackles and constraints of weaknesses on the development of strengths.

Gangu and Kangxian should adopt a stabilization strategy because they have the same combination of facilities, economy and management digitalization index and a very balanced development in all areas. Pingchuan, Yumen, Linze, Gaotai, Zhuanglang, Jingning, Qingcheng, Heshui, Ningxian, Tongwei, Minxian, Lixian and Chongxin should adopt a specialization strategy. For example, for Zhuanglang and Jingning, their village digitalization indexes are in Combination V, their facilities digitalization indexes are in Combinations V and VI, their economy digitalization indexes are in Combination IV and their management digitalization indexes are in Combinations VI and V, respectively. Obviously, they have significant advantages in the field of rural economy digitalization and a specialization strategy should be adopted for them to further highlight their advantages and shape their own characteristics in the future. Weiyuan, Xihe, Liangdang and Guanghe should adopt a transformation strategy as they have significant lagging areas and no prominent areas of strength. In Liangdang, for example, there is no prominent strength with the village digitalization index and facilities digitalization index in Combination VII, and a serous lag with the economy and management digitalization index in Combination IX. Therefore, if additional investments are made in infrastructure informationization in the future, it is probable that the returns will hardly achieve the expected goals, and it is recommended to shift future investments of funds, capital and resources to the areas of economic and managerial digitization that are seriously lagging behind to eliminate their constraints on the development of facilities and overall digitization.

For specialization and transformation development, targeted strategies should be adopted to rapidly expand the strengths or make up for the weaknesses. For example, in the development of the digital economy relying on the agricultural products of Taobao Village, live streaming village and Internet celebrity, it is necessary to deepen e-commerce into the countryside, unblock the channel of industrial products to the countryside and promote the online purchase of daily necessities, agricultural materials and tools, the production and operation services of rural residents, besides efforts to promote the sale of agricultural products online and accelerate the construction of logistics facilities for processing, packaging, cold chain transport, storage and delivery to cities of agricultural products. For example, when relying on the digital platform for village self-governance, it is required to carry forward the practice of villagers' online deliberations and online supervision, promote more village high-frequency government affairs and villagers' services to be performed online and by cell phone, and establish electronic ledgers for village assets and finances.

3. Moderate Development Zoning: Enhancing Foundation

Since the policy area has a low competitive power and attractive power of rural digital development, a smart contraction strategy should be adopted to improve the efficiency of capital and resource utilization. For Qingshui, Zhangjiachuan, Zhengning, Wenxian and other counties in Combination IX, it is difficult to change their current status in the short term due to their low level of development and weak power. They should make good use of policy and transfer funds from higher level governments in the future according to the basic needs of national and local (provincial and municipal) governments to accelerate the pace of the digital transformation of rural infrastructure and enhance the foundation and capacity of digital rural construction. For example, they should improve the survey and statistics of the basic data of rural roads and update electronic maps regularly to raise the level of informationization of comprehensive supervision of rural roads. Moreover, they should accelerate the digital transformation of rural power grids and implement rural power grid consolidation and upgrading projects to make up for and strengthen the weaknesses of rural power grids.

Wushan, Minqin, Gulang, Tianzhu, Shandan and other counties in Combination VI should implement differentiated development strategies and concentrate their limited resources. For example, Tianzhu has a very low index of facilities and management digitalization (the former in Combination VI and the latter in Combination V), but it has a high economy digitalization index (in Combination IV) with a high potential and strong driving force for digital economy development, so it should concentrate its limited resources into digital economy development in the future. For example, it should accelerate the development of e-commerce for agricultural products and agricultural supplies and its supporting system, preferably by planning and creating a number of Taobao Villages, live-streaming villages and Internet celebrity agricultural products. Jingchuan, Lingtai, Zhangxian, Tanchang, Lintan and Zhouqu, counties in Combination VIII, should implement an appropriate development strategy. For example, Zhouqu, located in an autonomous region of ethnic minorities and a high mountain valley area, has a complex topography, frequent natural disasters and lagging economic development. Zhouqu currently has a very low index of facilities (in Combination IX), economy (in Combination IX) and management (in Combination VII) digitalization. Zhouqu should control the quantity and distribution of digital countryside investments around national policies and local characteristics in the future and make clever use of limited resources to ensure that it does not fall behind in the wave of rural digitalization in Gansu. For example, it should respond to national policy requirements to overcome school networking difficulties, optimize the construction of education information technology infrastructure, achieve full broadband network coverage in rural elementary schools and township primary and secondary boarding schools and promote the full popularization of online teaching in all schools across the county. Moreover, it should explore the regional and humanistic characteristics of Zhouqu, organize the census of Tibetan cultural resources, the protection and utilization of traditional villages and historical and cultural towns, the digitalization of intangible cultural heritage and explore the construction of a "digital cultural relics resource library", "digital exhibition hall", "intelligent cultural station" and "digital bookstore".

5. Discussion

5.1. Development Characteristics

The development of the digital countryside in Gansu Province is characterized by prominent inequalities, with significant clustering and correlation features. Geographically, the level of digital development in rural Gansu Province varies widely in space and shows significant imbalance. The digital development of rural villages in ethnic minority autonomous regions is seriously lagging behind, and the leading and demonstration role of the national pilot counties remains to be enhanced. From the perspective of fields, the construction of the digital countryside in Gansu Province is not synchronized in different dimensions. For example, the digital infrastructure is in a leading position, while the development of the digital economy is lagging behind. In terms of spatial effects, cold and hot spots are distributed in bands or clusters, forming a “center-periphery” spatial structure and pattern geographically.

The development of digital villages and smart villages is currently on the rise, and multi-scale studies at national, provincial and county levels are constantly emerging. Although it lags behind the development of digital cities and smart cities [82,83], it has become a new hot spot in academia, government and society [84,85]. The unequal development process of rural digitalization is a universal phenomenon due to the large differences in development environment, resource conditions, investment and support, start-up time and construction mode in different regions [86,87]. As more new generation information technologies such as Internet, big data and cloud computing have been applied to the construction of digital villages and new rural infrastructure in recent years, digital, networked, intelligent and smart rural development has accelerated significantly, narrowing the digital divide between urban and rural areas. For example, the use of the Beidou System and artificial intelligence for the scientific management of crops can improve management efficiency; furthermore, with the help of two-dimensional code technology, we can achieve the full traceability of agricultural products from the field to the table, and with the help of e-commerce and live broadcast platforms we can improve the sales numbers of agricultural products and enlarge geographical sales scope.

Some of the findings of this paper corroborate the study conclusions available. At the national scale, Rey-Alvite [88] found through an empirical study of 28 EU countries that there are large differences in smart village development goals, needs, current progress and characteristics, and that there is still a long way to go for a balanced development of digital and smart villages. Li [89] analyzed the opportunities and challenges facing the digital development of infrastructure and public services in rural America and proposed strategies for narrowing the smart divide in rural areas. At the provincial scale, Adamowicz [90] found through the empirical study of the provinces of Poland that there are large inter-provincial differences in the development of smart villages and that some provinces are already at risk of being marginalized. Zhu [91] conducted an empirical test on the level of digital rural development in China’s provinces and found that there are very large regional differences and spatial autocorrelations, forming a decreasing spatial pattern of “east-middle-west”.

Although this study is based on the county scale, its conclusions are generally consistent with their analysis results. Besides the difference in research scales, this paper further decomposes the village digitalization index into a village facilities digitalization index, village economy digitalization index and village management digitalization index. It also grades and partitions the level of digital development of villages, which significantly improves the fineness and accuracy of the study and is more valuable for the theoretical evolution and practical development of digital villages and smart villages.

5.2. Dynamic Analysis

In terms of the range of direct influence of the factors, rural consumption, fixed asset investment, gross domestic product and tertiary industry added value are all-purpose factors, and they have significant influence on the digital rural development index in all dimensions. Rural population and government revenue are also all-purpose factors, but the former has only moderate statistical significance on the village digitalization index and village facilities digitalization index, and the latter has only moderate statistical significance on the village management digitalization index. Urbanization rate, rural resident per capita income and secondary industry added value are multifunctional factors, which have significant influence on the village digitalization index, village facilities digitalization index and village economy digitalization index, but not on the village management digitalization index. Gross domestic product per capita is a single function factor and has no significant influence on all dependent variables except for the village management digitalization index.

As for the intensity of the direct influence of the factors, the factors can be classified into three categories by overlay analysis of multiple dimensions. With index q that is not statistically significant set to zero, the average of multiple dimensions of the digital rural development index is calculated and ranked according to their direct impact. Tertiary industry added value, gross domestic product and government revenue all have a direct influence close to or above 0.3, and they are key factors. Urbanization rate, rural resident per capita income and GDP per capita all have a direct influence less than 0.1, mostly negligible, and they are auxiliary factors. Fixed asset investment, rural population, secondary industry added value and rural consumption have a direct influence between the key factor and the secondary factor, and they are important factors.

The interaction of factor pairs is dominated by nonlinear enhancement and supplemented by bifactor enhancement. The synergistic effects of the factor driving mechanism are very complex. In addition to the auxiliary factors such as urbanization rate, rural resident per capita income and GDP per capita, which mainly rely on interaction effects to exert indirect influence, the interaction effects of key and important factors such as tertiary industry added value and secondary industry added value should also not be ignored. The factors such as tertiary industry added value, rural population, urbanization rate, rural consumption, rural resident per capita income, GDP per capita and government revenue play the role of super-interaction factors in different dimensions of rural digitalization. The interactive influence between factors cannot be ignored, even for factors with weak direct influence, because it reaches 1–4 times the direct influence in combination with the interactive influence of synergistic factor pairs. Therefore, to achieve the best results in policy implementation, different resources and measures should be matched and combined according to the interaction of factor pairs in the future policy design.

This paper is original in its study of the factors influencing rural digital development and their interactive effects, and some of the aforementioned views are supported by some scholarly papers. According to the global samples (non-China), Chinn [92] argued that per capita income, international trade, urbanization rate, infrastructure, regulatory quality and other economic and social indicators are the determinants of national digital development differences. Park [93] analyzed the characteristics of digital inequality in rural Australia and argued that factors such as population, education level and employment status exacerbate the digital divide in rural development. They found that farmers' income, urbanization rate and rural population have a great influence on the construction of digital villages, which is largely similar to the findings of this paper. However, their study is at the national scale and does not match the needs of local government policy design. Moreover, there is no sufficient discussion on whether the forces of these factors are influenced by scale effects and whether it also applies to the county scale prior to this study.

In the empirical study of China, Ma [94] and Leng [95], at the national scale, concluded that government credit support and farmers' income growth have a significant positive impact on the adoption of digital technologies for rural development. Li [96] found significant spatial heterogeneity, agglomeration and correlation in digital rural development at the provincial scale in China, with population density, industrial structure and economic development having a significant influence on them. Zhao [97] argued that the development of digital villages in Chinese counties significantly contributes to farmers' household consumption. Su [98], based on micro-survey data from national digital village pilot counties in Sichuan, Chongqing and Ningxia, found that farmers in less economically developed and poverty-stricken areas have a low willingness to build digital villages, with lagged participation rates in rural digitalization. Zhang [99] found a significant positive mediating effect of farmers' income on digital village development based on a survey of 164 administrative villages in Zhejiang Province. Despite the differences in research scale and sample geography, government support, farmers' income, economic base, industrial structure and demographic characteristics are found to have a general influence on the construction of digital villages in China.

5.3. Governance Enlightenment

In the context of the current new wave of technological revolution, rural areas should not be left behind in digitalization, urbanization, industrialization and agricultural modernization [100]. Given that it has become a consensus that digitalization and intelligence are the key ways to achieve sustainable development in rural areas [101], the government should strengthen top-level design and planning guidance by developing proper work programs and action plans. In terms of government management and policy design, Gansu's experience has reference value for other provinces in China and other countries in the world. The national digital village development strategy requires the government of Gansu to develop a digital village construction work plan for the province, and the city and county governments to develop digital village construction action plans at the county level according to demand. The provincial government should set provincial digital village pilot counties in all prefecture-level cities according to the level of digital development of villages in the work program and action plan. Depending on the resource base and development needs, each prefecture-level city should have two to five counties. In addition, each county should select two to three towns or three to five villages in the administrative region as county-level pilot areas for the fine implementation of the work. In addition, efforts should be made to formulate differentiated policies for different types of villages such as those clustered and upgraded, integrated with suburban areas, under characteristic protection and relocated and merged, in strict accordance with the rural revitalization strategy and the development support strategy for ethnic minority areas in the pilot selection, with full consideration of the influence and interaction of different factors to accelerate the overall development of rural digitalization in Gansu Province.

It is important to note that the digital development capacity and potential of different regions vary widely [102], so zoning plans should be developed and implemented according to the level of development and its driving mechanisms to effectively improve policy precision and effectiveness [103]. First, the important demonstration zoning counties should maintain their current development trend and promote the interactive construction of digital villages, digital cities and smart cities [104]. Second, the characteristic exploration zoning counties should find the bottleneck of digital rural development, develop special measures to drive digital facilities, digital economy, digital management and digital life, and try to improve the quality of digital development. There are also many problems for the better developed areas of economic and managerial digitization. For example, the county government tends to implement a unified digital platform in all villages, while the villages are passively "involved" or "participate" in the process, with a variety of the platform functions contrary to the actual needs of rural development [105]. Therefore, it is necessary to investigate and analyze villagers' demands and interest gambling in the future and comprehensively optimize and enhance the functions of rural digital platforms accordingly to improve the speed and quality of rural digital governance and digital economy development [106,107]. Third, the moderate development zoning counties are priority areas for government intervention, especially the minority autonomous regions. Undeveloped infrastructure, insufficient human resources and the lack of diverse industrial structures pose great challenges the construction of digital villages in ethnic minority agglomerations, requiring both the central and local governments to increase investment and support to minority communities and autonomous regions in the future [108]. More economically underdeveloped places have slower rural digitalization processes, and lower levels of digitalization will lead to further marginalization. Digital villages and economic development may form a vicious circle [109]. Therefore, for these counties with weak self-generating capacity, especially poverty alleviation or poverty return prevention, the construction of digital villages should be combined with economic development and a focus on the digitalization of infrastructure, industry and consumption to put the development of villages in a virtuous cycle [110].

6. Conclusions

With the development of urbanization, global rural construction is faced with severe challenges such as population loss, economic depression, facility and building decay, ecological and environmental pollution. Rural digitalization is a new means to deal with these problems and is also the key to rural transformation and sustainable development [109]. In this paper, based on the case study of 79 counties in the Gansu Province of China, we analyze the level of digital development of rural areas in less developed regions of the country and its driving mechanism based on a combination of GIS tools and GeoDetector. The conclusions are presented as below:

(1) In view of the uneven development of rural digitalization, differentiated policies should be developed in accordance with zoning planning and spatial governance. By regional heterogeneity, the 79 counties are divided into leader, follower and straggler levels according to the gap of the digital rural development index among different counties. By domain heterogeneity, the development of digital applications in different dimensions is out of sync, with the village facilities digitalization index in the leading position, the village management digitalization index in the middle and the village economy digitalization index lagging behind.

(2) Due to the significant spatial agglomeration in the development of digital villages, the government should strengthen top-level design while insisting on regional linkage and joint governance. Rural digitalization shows characteristics of spatial correlation and spillover to the periphery. The hot, sub-hot, cold and sub-cold regions are distributed in bands or clusters, forming a spatial pattern of "center-periphery".

(3) The direct influence of different factors varies greatly, and the factor pair driving mechanism is complex. From the perspective of the scope of action, they can be divided into all-purpose factors (e.g., gross domestic product), multifunction factors (e.g., secondary industry added value) and single-function factors (e.g., GDP per capita); from the perspective of intensity of action, they can be divided into key factors (e.g., tertiary industry added value), important factors (e.g., rural population) and auxiliary factors (e.g., urbanization rate). The factor pair interactions are dominated by nonlinear enhancement and supplemented by bifactor enhancement, with very complex synergistic effects and driving mechanisms. Therefore, efforts should be made to drive the rational combination of different resources and measures in future policy design based on the direct influence and interaction of factors.

The biggest innovation in this paper is the systematic analysis of the factors influencing rural digitization and reveals the interaction between different factors. This study focuses on the county scale and further decomposes the village digitalization index into three sub-indexes to provide more granular analysis. The digitalization of villages is a new trend in global development, and the research methods and analysis results of this paper are applicable not only to China but also to similar countries around the world. As mentioned above, the United States, the United Kingdom, Romania, India, Australia and the European Union all face challenges similar to China's in rural development, such as stagnant or regressive rural development and population loss. These countries and regions are now working to explore and experiment with a variety of solutions using digital tools to leverage sustainable rural development, and this paper will provide a valuable reference for them.

This paper also has some limitations, such as the use of cross-sectional data in the study. Although Peking University released data for both 2018 and 2020, differences in the index system for calculating the index in different years as well as significant missing data for the study area in 2018 (excluding data for municipal districts) resulted in the inability to conduct panel analysis, which may affect the accuracy of the analysis results. Regardless, this paper has taken the first step to explore the driving mechanism of rural digitalization, which will be of great benefit to the future emergence of high-quality theoretical research and practical solutions.

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Article

Space Accessibility and Equity of Urban Green Space

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Abstract: Urban green space is an essential form of infrastructure for cities, providing a significant spatial guarantee for sustainable urban development, an essential ecological, social, and cultural function, and an important symbol of urban modernisation and civilisation. However, with the development of cities, urban problems are becoming more serious, such as the increase in impervious surfaces and urban heat islands and the decrease in urban green space and liveability. Therefore, this study integrates the theories and methods of landscape ecology and spatial syntax with GIS technology to construct a comprehensive model for examining the spatial accessibility of green spaces based on remote images and landscape pattern indices, using Fuzhou City as the study area. The study then incorporates demographic variables to explore the characteristics of an equitable distribution of urban green space at the street scale. The results show that the accessibility of green space in the urban areas of Fuzhou decreases from the centre to the periphery. From north to south, there is a trend of 'low-high-low', with the northern region exhibiting the lowest accessibility, followed by the southeastern region, and then the western region. In terms of spatial equity in green space, Fuzhou has a more significant share of surplus green space provision, both in terms of the number of streets and area. This shows that the surplus of green space in Fuzhou is greater than the deficit and that the distribution of space is fair. We hope this study will not only help people gain a deeper understanding of green space but also provide a reference for their rational planning and management, thereby improving the accessibility and equity of urban green space as well as their quality and configuration. We also expect it to provide valuable theoretical and technical support for the planning of ecological functions and sustainable development.

Keywords: green space; accessibility; equity; landscape pattern; remote sensing

1. Introduction

Urban green space is open space in cities used as parks or other green spaces [1] and defined by the World Health Organization as 'urban land with any vegetation cover' [2], which may be accompanied by artificial features such as playgrounds, blue spaces (water), or natural landscapes [3]. Urban green spaces are sometimes used as private or institutional land for university campuses, community gardens, etc., but are generally open to the public. State parks and national parks located outside urban areas do not belong to urban green spaces. The concept of "rus in urbe" (country in the city), which refers to the integration of green spaces into urban planning, dates back to ancient Rome in the first century [4,5]. Modern urban green spaces can be traced back to the urban squares of London in the 17th and 18th centuries [6]. Urban green spaces can reduce surface runoff and the heat island effect [7], reduce air pollution, and positively impact the physiological and psychological well-being of residents in surrounding communities [8,9]. Urban green space guarantees human survival and ecological balance and allows urban residents to enjoy the services of their natural ecosystems. Historically, neighborhoods dominated by disadvantaged groups have tended to lack green spaces, due to policies (such as the redlining policy in past US housing policies) and economic inequalities [10]. In recent years, green space planning has begun to emphasize environmental justice and community participation [11]. Clearing pollution and adding green spaces can increase the value of surrounding homes, known as environmental gentrification [12], but this process may also have negative impacts by forcing disadvantaged groups to relocate due to being unable to afford the rising housing prices [13,14]. Among the seventeen Sustainable Development Goals designated by the United Nations [15], goals eight, nine, and eleven refer to "promoting inclusive and sustainable economic growth, a good job for everyone, resilient infrastructure, and inclusive and sustainable cities and human settlements". Sustainable development, however, can only be achieved if cities provide ecosystem services through 'green public space' and coexist in ecological harmony. Furthermore, Section 11.7 states that "by 2030, the provision of safe, inclusive, and accessible green and public space should be universal, especially for women, children, the elderly and people with disabilities". The World Health Organization's Healthy Cities Programme, launched in 1986, includes green coverage and green space accessibility among the 32 quantifiable indicators developed in collaboration with European metropolises to assess the effectiveness of promoting healthy cities [2,16]. With the intensification of urban environmental problems, improving the urban environment by introducing green space has become an effective and standard measure [17,18]. However, the distribution of urban green space is often uneven because of design concepts, historical reasons, and other factors [19,20]. Numerous studies have confirmed the importance of urban green space for the health of residents. Chen (2017) analysed 42 urban green space studies, and they concluded that urban green space affects the health of urban residents by improving environmental conditions (air quality, noise, and visual aesthetics), promoting outdoor activities (fitness and social activities), and enhancing social cohesion (neighbourhood satisfaction, sense of security, and sense of belonging or psychological well-being). Studies have also shown that the more parks and green spaces near homes and the more frequently people use them, the better their self-rated health status [21].

The concept of accessibility first emerged in the transportation field. Hansen [22] proposed that accessibility refers to the ease of travel from an origin to a destination using a specific mode of transportation. Accessibility has been studied and applied in various fields, such as behavioral research, resource allocation, and economics. It has also been introduced to urban planning, geographic information systems, and public administration disciplines. There is no accepted definition of accessibility, as scholars have defined the concept using various research fields and perspectives. Some scholars believe that accessibility is the cost individuals incur when participating in social activities, such as traffic congestion and environmental pollution. Others perceive accessibility as the expected quantity of arriving at a destination for activities such as leisure, consumption, and exercise, explaining the relationship between land use and the ease or difficulty of reaching a destination. Other scholars define accessibility as the degree of difficulty in reaching a particular land use in a city. Kongjian Yu [23] believes that accessibility is the relative ease of reaching a landscape destination from a spatial point and uses indicators such as time, distance, and cost to calculate this. Accessibility of green space refers to the ease of reaching a park or green space from a residential area by overcoming spatial barriers while considering the cost, time, and distance of transportation. Mullick argues that the progressively increasing numbers of elderly and disabled people place an increased demand on the accessibility of green space in the U.S. The article argues for several important aspects related to equitable access and the impact of human interference on wilderness, highlighting the need for more effective government policies to maintain the integrity of the natural environment [24]. Oh and Jeong conducted a study on the walkability of streets to urban parks and the suitability of parks with the help of GIS technology, using Seoul as an example [25]. Alexis Comber et al. used the network analysis function of GIS to study green space in the British city of Leicester and concluded that the accessibility of different religious and ethnic groups can be used as part of the criteria and reference for the provision of green space services by the British government in the future [26].

The concept of equity originated in the western social sciences. It was later applied in urban planning to consider the optimal state of public social services and resource allocation, and this concept has been developed and revised. For example, Kabisch used the Lorenz curve and Gini coefficient to compare the equity of public green space for all residents, immigrants, and adults over 65 years old in Berlin, Germany, and found that the equity of green space for immigrants was the lowest [27]. Jin Y. applied the Lorenz curve to study the equity of green space in terms of quantity but not the equity of green space per capita [28]. The Lorenz curve and Gini coefficient were eventually established as the UN standard to quantify the equity of green space per capita and to judge the equity of green space distribution by the UN standard based on the Gini coefficient of per capita income. Currently, the distinction between the concepts of accessibility and equity is not clear, and evaluations of urban parks and green spaces often focus on accessibility, with less research on equity. Equity in park and green space distribution is a concept derived from accessibility, incorporating the needs of green space users to determine whether the distribution of green space satisfies the needs of residents in a fair manner. It has strong socioeconomic characteristics and is closely related to the spatial distribution and demographic structure of the population. Research on park and green space equity in foreign countries has focused on exploring fairness and justice among different social groups. This study aims to address the limitations of research on green space equity that only considers single social factors, as well as the limited research on green space equity. We develop a supply-demand model of green space accessibility relative to population composition, gender, age, and ethnicity to explore the equity of urban green space distribution.

In recent years, China has experienced rapid socioeconomic development. However, urban problems have also become increasingly severe, with an increase in impervious areas and urban heat islands and a decrease in urban green space and liveabilityUrban green space positively impacts the urban environment, can alleviate ecological and environmental problems brought on by urban development, and is a public urban space that cannot be ignored in urban construction. Considering the historical pattern of urban development, high population diversity, and explosive urbanisation rate, the accessibility of green space has also become a vital issue for environmental equity in Chinese cities [29,30]. Especially in recent years, China has proposed the construction of "Beautiful Mainland China, Ecological Cities", and the liveability of the urban environment has gradually become a topic of concern for government departments, scholars, and the general public.

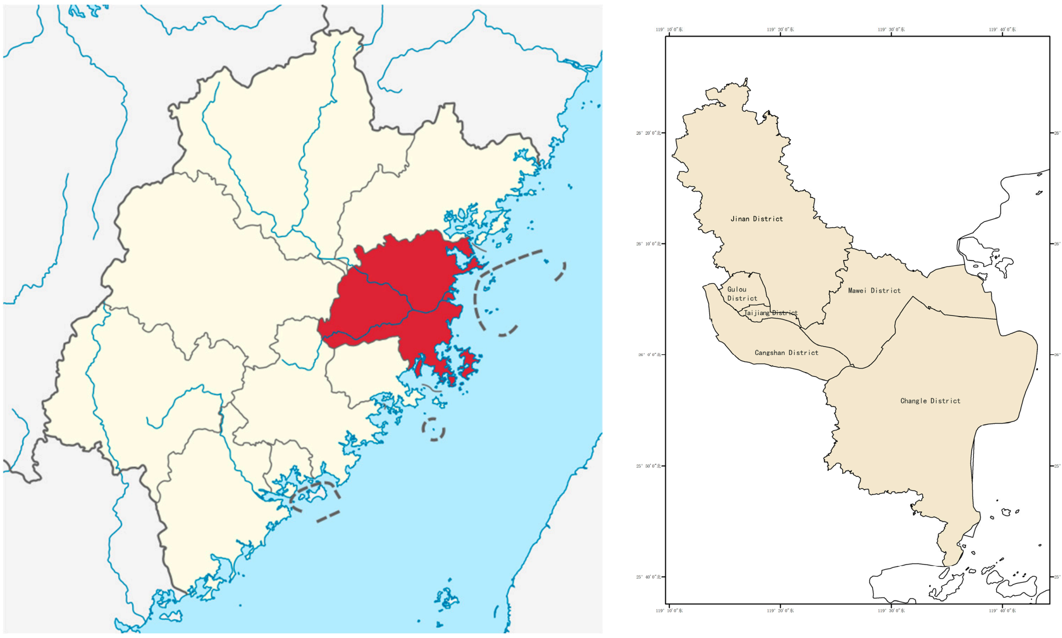
In summary, this study examines the problems of urban green space and people's demand for green space. By using spatial and statistical analysis, we establish a framework for assessing the equity and accessibility of green space in urban areas and analyse the distribution of accessibility and equity in Fuzhou City, which can be applied to future spatial planning and design.

2. Materials and Methods

2.1. Study Area

2.1.1. Geographical Location

Fuzhou City is located on the southeast edge of the Eurasian continent, on the southeast coast of China and at the mouth of the Min River in the east-central part of Fujian Province. It is located between latitudes 25°15′ and 26°29′ north and longitudes 118°08′ and 120°31′ east, bordered by Nanping and Sanming to the west, Ningde to the north, Putian to the south, and the East China Sea to the east. In this study, Fuzhou City was chosen as the target, including six districts: Gulou, Taijiang, Cangshan, Jinan, Mawei, and Changle, with 65 streets. The area is 1754.62 km^2, and the household population is 3,095,000 (Figure 1).



(**a**) (**b**)

Figure 1. Geographic location of Fuzhou City and study area: (**a**) Fuzhou City location map; (**b**) Fuzhou City study area.

2.1.2. Natural Environment

Fuzhou City is on the southeast edge of the Eurasian continent and faces the Pacific Ocean to the east. It has a typical subtropical monsoon climate. In this city, there have been many meteorological disasters closely related to the construction of green space systems in Fuzhou's urban climate, including typhoons, heavy rain and floods, cold waves, late frosts, and strong convective weather. Fuzhou City is susceptible to typhoons between May and November each year; heavy winds and rain often cause garden trees to fall or break, causing significant damage to the urban green spaces. Fuzhou City has established several protective forest belts in coastal areas; however, effective protective forest belts have not yet been built around the central city. Heavy rain and flooding have greatly damaged the riverside green space on both banks of the Minjiang and Wulong rivers. In addition, landslides associated with typhoons damage suburban forests, and long-term waterlogging can lead to the suffocation and death of some garden trees. Cold waves also threaten tropical and subtropical ornamental trees in Fuzhou's urban green space. Late frosts and strong convective weather can also significantly impact garden plants.

2.1.3. Vegetation Status

Fuzhou belongs to two vegetation zones: the South Asian tropical rainforest and the Central Asian subtropical evergreen broad-leaved forest. Influenced by various natural conditions, the vegetation types are complex, and there are many plant species. According to the plan, by 2020, the main indicators for urban landscaping in Fuzhou will be a green coverage rate of 42.25%, a greening coverage rate of 45.41%, a per capita park green space of 15.4 square meters, and a significant improvement in the ranking of per capita park green space. All construction indicators will meet the requirements for the creation of a "National Ecological Garden City".

2.2. Research Framework

This study focuses on Fuzhou City as the research subject, using data from remote sensing images, OpenStreetMap (OSM), and demographic variables. GIS and space syntax methods were used to investigate the distribution of green space accessibility and equity in Fuzhou City. The study has roughly four parts (Figure 2).

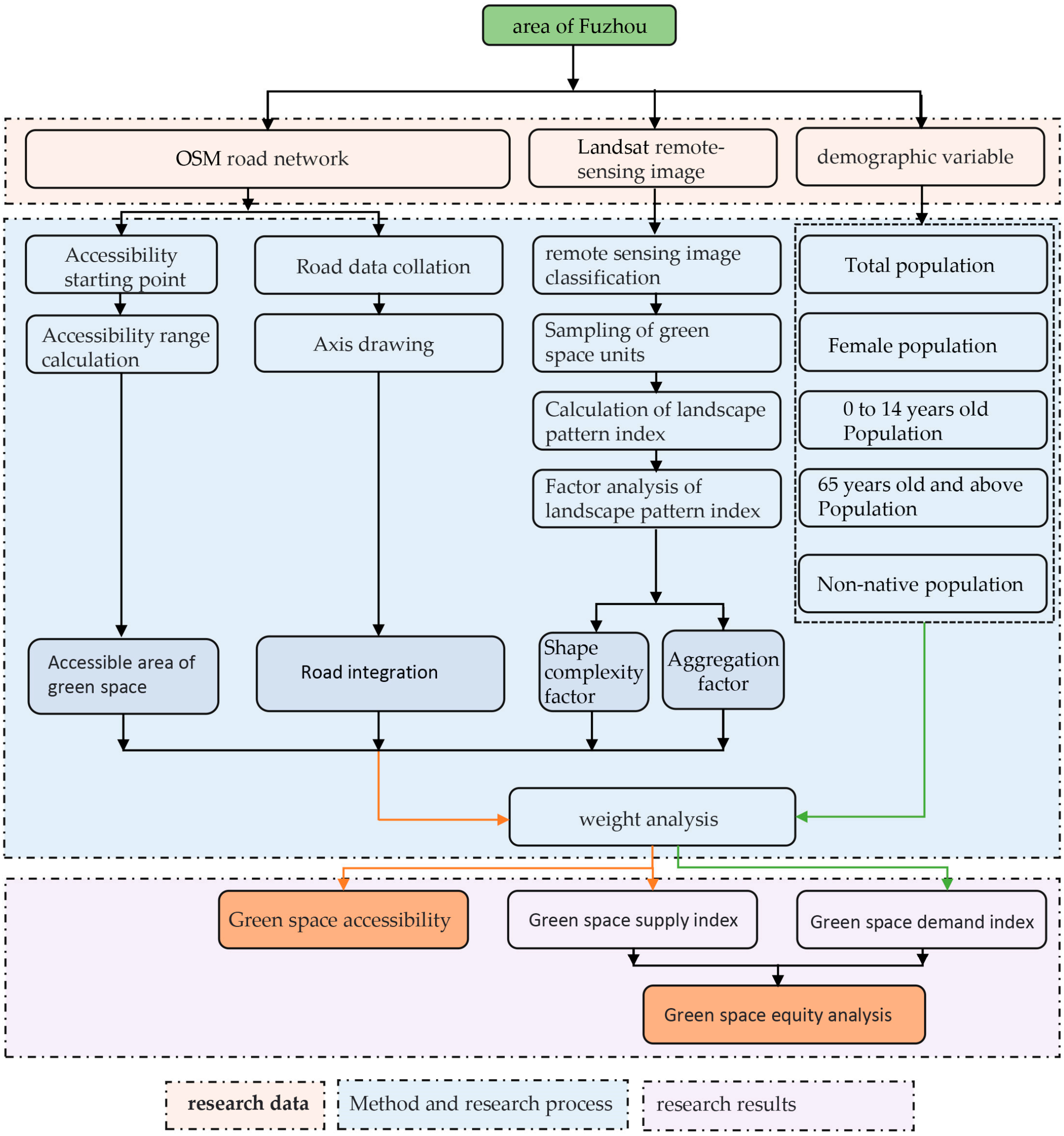


Figure 2. Research Framework.

The first part is based on road data, which is the starting point for analysing the integration and accessibility of urban areas in Fuzhou City and their range of accessibility.

The second part is based on remote sensing images, calculating the green space landscape pattern index, and extracting the landscape pattern index factors through factor analysis.

The third part examines the spatial accessibility of green space in urban areas of Fuzhou City based on integration, the landscape pattern index, and the green space accessibility area.

The fourth part examines the spatial equity of green space in the urban areas of Fuzhou City based on demographic variables.

2.3. Data Sources

2.3.1. Remote Sensing Images

The remote sensing image data for this study were mainly obtained from the Landsat series of telemetry satellites, which provide a large amount of image data that can be used in various fields, such as natural resource exploitation, natural disaster prevention, environmental pollution monitoring, and natural plant growth observation. In addition to the spatial resolution band of 30 m, the panchromatic band with a spatial resolution of 15 m is added to the Operational Lan Imager (OLI) images. The Hue, Saturation, Value (HSV) transform fusion method in the transform domain substitution method is adopted to select the band combinations of the near-infrared, red, and blue bands that are convenient for highlighting vegetation information and fusing with the panchromatic band. After completing the image fusion, a mask is created to crop out the extent of the study area based on the administrative division vector information of the study area. Then, the pre-processing results of the study area images are obtained, as shown in Figure 3.

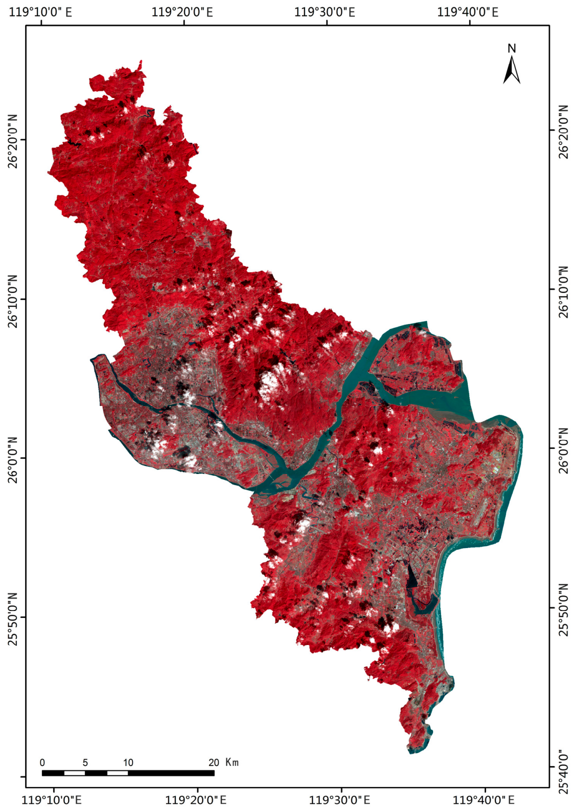


Figure 3. Remote sensing images of Fuzhou city in 2022.

2.3.2. Road Network Data

The road network data used for spatial equity modelling of green spaces were obtained through the official OSM website in November 2022. The downloaded data were cropped and reprojected to obtain the road network corresponding to the study area. In addition, isolated roads and cut-off roads that have an impact on the accessibility analysis are manually identified, and vector modifications are performed (Figure 4).

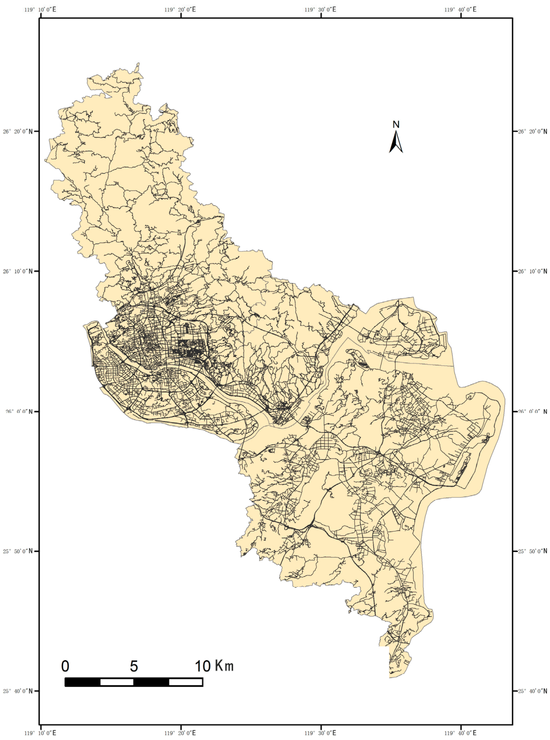


Figure 4. Road network data of Fuzhou City in 2022.

2.3.3. Demographic Variables

The socio-demographic data used to study the spatial equity of green spaces were obtained from the sixth census of China in 2010 (the seventh census in 2020 still needs to be completed, so only the sixth census data were used). The "Fuzhou 2010 Census Data—Township and Street Volume" census data mainly reflect the basic situation of the population, covering the total resident population, female population, population aged 0–14, population aged 65 and above, and foreign population (Appendix A, Table A1).

2.4. Methodology and Research Process

2.4.1. Space Syntax Integration

Space syntax is a mathematical method proposed by British scholar Bill Hillier in the 1970s for describing and analysing spatial relationships. The basic principle involves dividing the space into scales and spatial partitions to describe the quantitative topological relationships between spaces and determine the connection between human behaviour and spatial morphology [31,32]. Integration in space syntax refers to the agglomeration or dispersion between an element of a spatial system and other elements. It measures the ability of a space to attract arrival traffic as a destination, reflecting the centrality of the space in the whole system. The higher the integration, the higher the accessibility, the stronger the centrality, and the easier it is to gather people. Previous studies have utilized spatial syntax theory to study urban green space, such as the use of depth map software to establish a regional spatial model of the urban road network and the analysis of the carrying capacity, penetration, and connectivity of the urban road network. These studies accurately reflect the coupling relationship between urban structure, transportation networks, and human activities [33]. In addition, by analyzing the integration degree of urban roads and park green spaces, researchers can determine the variability of costs, such as time and distance, consumed by citizens to reach the park green space, the permeability of the park green space, and the connectivity of the surrounding environment. This can further determine the ease of use of the park green space within a certain range and judge the accessibility level of this park green space [34,35]. The spatial syntax method studies and analyzes the relationship between urban spatial structure and urban park green space layout from the perspective of the interactive relationship between people and space. Its advantage is that it not only considers the influence and connection of park green space to the surrounding elements, but also incorporates people's subjective perception of space in the analysis of permeability and accessibility [36]. Therefore, the spatial syntax method enables researchers to make reasonable and effective adjustments to their planning after learning about the current state of the urban structure and issues related to human social activities [37].

To quickly and efficiently facilitate the analysis of samples, this study uses depth map software, which was developed based on the theory of spatial syntax, to analyse the urban street network by axis analysis and line segment analysis. This study mainly adopts line segment analysis. The core work of line segment analysis is the acquisition of the axis map, which can be drawn in two ways, automatically generated by the Axial Map command in the software, or drawn by hand. This study adopts the manual drawing method to obtain the axis map. The basic principle of drawing an axis map is "longest and least" [38]. When expressing a curved street, the axis should be tangent to the boundary as much as possible to ensure the longest and the least number of axes (Figure 5).

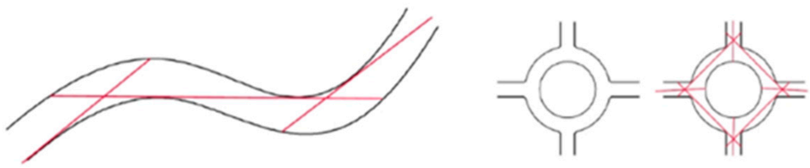


Figure 5. Basic principles of axis drawing.

Using the space syntax method, the OSM data was employed as the base and combined with the actual urban image map to draw the axis model of the study area in Auto-CAD. The completed spatial syntax model was imported into Depthmap10 in DXF format and then checked for model calibration. The Map-Convert Drawing Map function was applied to convert it into the axial map required for this study. Finally, the spatial syntax-related variables were calculated using Depthmap10, SDNA, and other related software. Thus, Fuzhou City's final road integration was mapped (Figure 6).

The average length of the study (Table 1) is 265.10 m, for a total of 10,409 lane segments in the urban area of Fuzhou, and the integration ranges from 79.36 to 709.54, with an average value of 514.28. The road integration in the urban area of Fuzhou is higher in Taijiang and Gulou districts, at 641.48 and 620.04, respectively, which shows that these two districts have the lowest number of roads but the highest integration. In contrast, Jinan and Changle districts have the highest number of roads and the lowest road integration, with 415.51 and 482.83, respectively. These two districts are relatively large, so the road construction is relatively complex.

2.4.2. Remote Sensing Image Classification

Remote sensing images reveal the differences between features using the difference between high and low brightness values or image element values (representing the spectral information of features) and spatial variations (representing the spatial information of features), which is the physical basis used to distinguish different image features. Remote sensing image classification is achieved using the computer to analyse the spectral and spatial information of various features in remote sensing images, select features, classify each image element into different categories according to some rules or algorithms, and then obtain the corresponding information between images and basic features. The classifier used in this study is the maximum likelihood supervised classifier [39,40]. The maximum likelihood classification is a method of image classification in which a nonlinear set of discriminative functions is statistically established based on the maximum likelihood method (Bayesian judgement criterion method) in two or more classes of judgements, assuming that the distribution functions of each class are normally distributed. The training area is selected to calculate the attribution probability of each sample area for classification [41].

According to the research requirements and the spectral resolution capability of Landsat images, four categories of target features were identified in this study (Table 2): cultivated land, vegetation, construction land, and water (Figure 7).

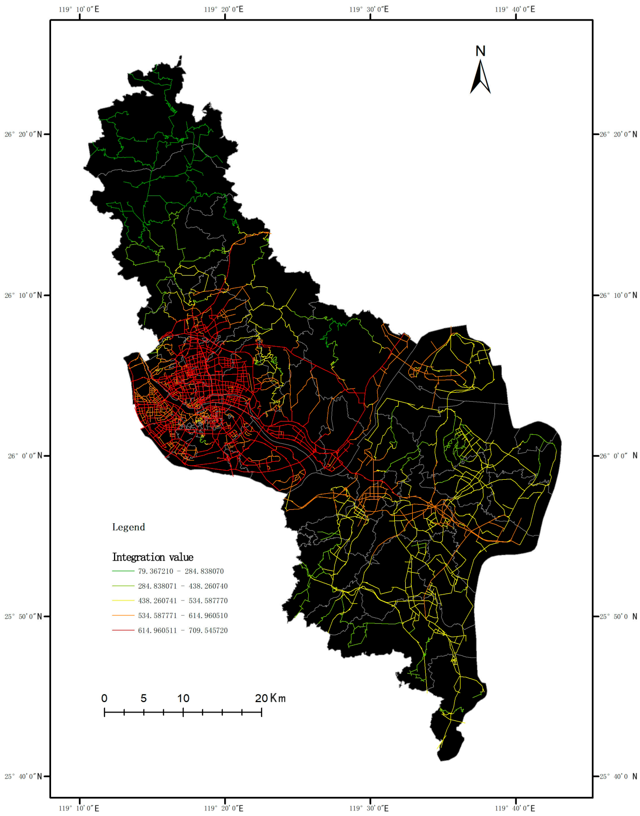


Figure 6. Road integration in Fuzhou city.

Table 1. Fuzhou city road integration statistics table.

	Gulou District	Taijiang District	Cang Shan District	Jinan District	Mawei District	Changle District	Total
Average value	620.04	641.48	619.93	415.51	531.69	482.83	514.28
Standard deviation	58.71	30.15	41.01	203.79	138.83	64.75	150.87
Number of segments	944	541	2017	2983	977	2947	10,409

Table 2. Land classification systems in the study area.

Type Code	Type Name	Description of Land Type
1	vegetation	Urban woodland, park green space, protective green space, subsidiary green space, road green belts, residential area greenery, and green belts around the city.
2	construction land	Includes commercial building land, transportation land, residential land, industrial land, unvegetated bare land, industrial and mining land, special land, etc.
3	cultivated land	Includes land occupied by crop cultivation, including paddy fields, dry land, etc.
4	water	Including rivers, lakes, reservoirs, coastal waters, etc. (excluding paddy fields and mudflats).

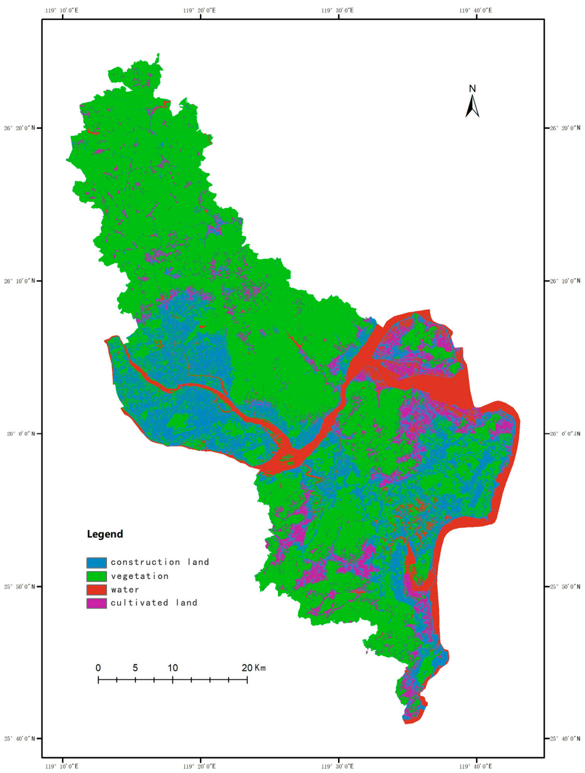


Figure 7. Land type of Fuzhou City.

2.4.3. Green Space Landscape Unit

From the remote sensing images, the green space (vegetation category) in the urban areas of Fuzhou is unevenly distributed, the number of green spaces within the urban area is minimal, and the area of green spaces in the northern and northwestern parts of Fuzhou is large and widely distributed. If the landscape units are randomly selected, the pattern of green space within each is likely similar. Moreover, the proportion of green space area is similar, resulting in insufficient independent variables for landscape analysis. Specifically, we divided the study area into a 1 km $\times$ 1 km grid and used a stratified sampling method to extract green space landscape units. The stratification was based on the percentage of green space area within the grid [42,43]. According to the previous research results, the number of stratification layers was determined to be six [44]. The stratum boundary was determined by the square root method of cumulative equivalent frequency proposed by Dalenius and Hodges [42]. The sampling rate was determined using the stratified fixed ratio method, i.e., the sampling rate of each stratum was determined to be a fixed value of 20%, whereby the overall number of samples was determined to be 485 and the overall sampling rate was determined to be 20.6%. Figure 8 shows the final extracted green space landscape unit of the study area, and the vector unit was used to crop the classification data of the study area. Thus, the classification data within the landscape unit was obtained (Figure 8).

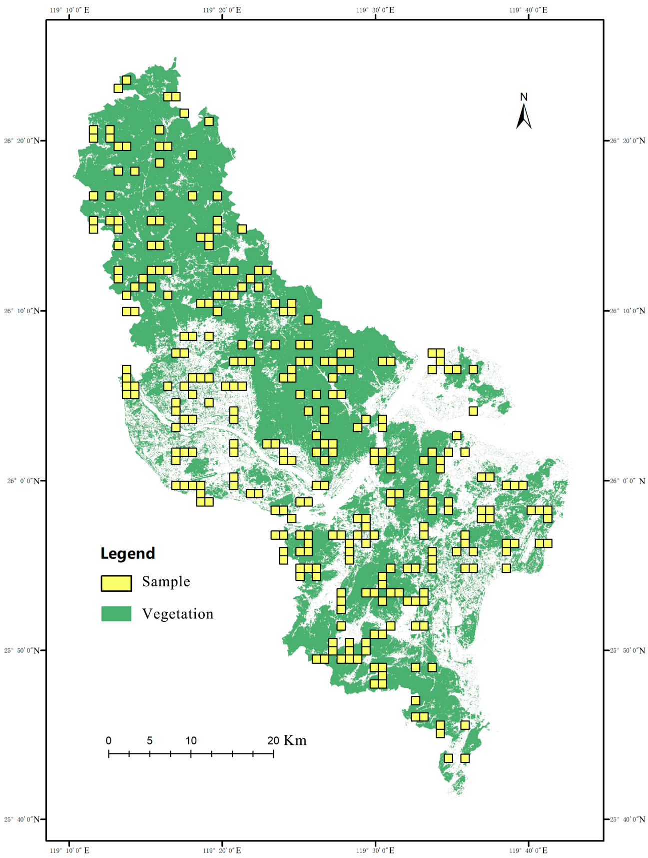


Figure 8. Green space landscape unit sample of Fuzhou City.

2.4.4. Landscape Pattern Analysis

Modern landscape ecology includes various methods for landscape pattern analysis [45], such as textual, graphical [46,47], and landscape pattern indices [48]. According to Turmer [49], studying the causes of landscape spatial heterogeneity and its ecological implications requires quantification of landscape patterns [50]. The landscape pattern index is a simple quantitative index that represents the landscape's structural composition and spatial configuration characteristics, which can meet this need. In addition, the landscape pattern index can be used to conduct comparative studies of landscape spatial patterns in different places, simultaneously or over time. A significant number of scholars have conducted applied research on urban green areas in landscape ecology, using various quantitative indicators to analyze the spatial distribution patterns of urban green areas. They emphasize the importance of maintaining and restoring the continuity and integrity of landscape ecological processes and patterns [51,52]. Zhang Liquan et al. applied GIS-based landscape pattern analysis combined with an artificial neural network (ANN) to quantitatively analyze the urban landscape pattern and its change in Shanghai. They established an artificial neural network that better simulates the response of Shanghai's landscape pattern to natural, social, and economic factors, such as residential land use, road diversity, population diversity, urban development history, and the Huangpu River [53]. Based on previous studies, we selected 16 landscape pattern indices: Percent of Landscape (PLAND), Largest Patch Index (LPI), Edge Density (ED), Average Patch Area (AREA_MN), Area-Weighted Mean Patch Area (AREA_AM), Standard Deviation of Patch Area (AREA_SD), Density of Patches (PD), Landscape Shape Index (LSI), Average Shape Index (SHAPE_MN), Area-Weighted Mean Shape Index (SHAPE_AM), Standard Deviation of Patch Shape Index (SHAPE_SD), Area-Weighted Patch Fractal Dimension (FRAC_AM), Mean Euclidean Nearest Neighbor Index (ENN_MN), Isolation Index (SPLIT), Aggregation

Index (AI), and COHESION Index (COHESION). The formula and ecological significance of the indices are shown in Appendix A, Table A2.

Each index's basic descriptive statistics (maximum value, minimum value, mean value, and standard deviation) were evaluated to determine whether the landscape index exhibited any abnormal behaviour. If the standard deviation was too large, the index was excluded. Spearman's correlation coefficient was introduced to analyse the correlation among landscape indices. A two-tailed test was used to verify the significance of the correlation between landscape indices [54]. The formula is as follows:

$$r_i = 1 - \frac{6\sum d_i^2}{n(n^2-1)},$$

where n is the number of rank pairs for the two variables in the correlation analysis, i.e., the sample content, and d_i is the difference between the ranks of the same pair (i = l, 2, 3 . . . , n). If the absolute value of the correlation coefficient is greater than 0.90 and significant for $p \leq 0.01$, there is a significant correlation between the indices. If the absolute value of the correlation coefficient is less than 0.90 but significant for $p \leq 0.01$, this correlation coefficient can only indicate the trend of the change in the indices, i.e., the change in one index predicts the trend in the other index. If the absolute value of the correlation coefficient is less than 0.90 and $p \leq 0.01$, then there is no meaningful correlation between the indices.

After statistical analysis, the average nearest distance index (ENN_MN) had invalid values in several landscape calculation units (Appendix A, Table A2), which were not representative and were excluded. Table 3 shows the descriptive statistics of each of the remaining landscape indices. The statistics of each index are within a reasonable range, do not appear to be significantly too large or too small, and do not need to be rejected.

Table 3. Statistical analysis results of the Landscape Pattern Index.

Landscape Pattern Index	N	Min Value	Max Value	Mean Value	Standard Deviation
PLAND	485	1.2920	99.9322	54.159960	30.7942202
PD	485	0.2475	36.4759	6.299242	7.2109512
LPI	485	0.4233	99.9322	48.134889	34.9398279
ED	485	0.8292	170.0588	61.415113	38.1500532
LSI	485	1.0376	16.1528	5.739334	3.6041949
AREA_MN	485	0.3033	401.4000	72.245199	112.2738604
AREA_AM	485	0.8055	401.4000	182.873622	144.6140559
AREA_SD	485	0.0000	196.1550	50.391546	60.5577562
SHAPE_MN	485	1.0376	3.5625	1.533616	0.3809547
SHAPE_AM	485	1.0376	9.4691	3.128739	1.2533318
SHAPE_SD	485	0.0000	2.2131	0.629029	0.4028415
FRAC_AM	485	1.0049	1.3056	1.152776	0.0531038
COHESION	485	59.6835	99.9995	95.890443	5.9247636
SPLIT	485	1.0014	14,072.0119	190.473403	1012.3020546
AI	485	45.9649	99.9426	86.301793	13.0960904

According to the results of Spearman's correlation analysis for each index (Appendix A, Table A3), within the area-boundary-diversity class indices, the correlation coefficients of indices ED, Area_SD, and other values were less than 0.90 and significant at $p \leq 0.01$, so these two indices were retained, and the rest were excluded. Similarly, within the shape class index and spread index, the indices that did not match were excluded, and SHAPE_MN, SHAPE_SD, FRAC_AM, and COHESION are retained.

In summary, the final indices selected to describe the spatial landscape pattern of the green space were ED, AREA_SD, SHAPE_MN, SHAPE_SD, FRAC_AM, and COHESION.

2.4.5. Factor Analysis

Factor analysis, an extension of principal component analysis, condenses numerous original variables into a few factor variables with minimal information loss and makes factor variables highly interpretable as a multivariate statistical method [55]. Factor analysis groups variables according to the magnitude of the correlation, revealing the level of correlation between variables within the same group and variables in different groups, with each group representing a basic structure, which is called the common factor. For the problem under study, the original variables can be described as the sum of a linear function of the fewest common and unique factors. The factor analysis modelling process can rotate and transform the loading matrix to help interpret the meaning of each factor [56,57]. Factor analysis can both reduce the dimensionality and achieve the purpose of classification. Factor analysis of the six screened landscape pattern indices resulted in the following factor loading matrix (Table 4).

Table 4. Results of the Landscape Pattern Index Factor Analysis.

Landscape Pattern Index	**Main Components**	
	1	**2**
Eigenvalue	2.435	1.856
Variance contribution ratio (%)	40.576	30.932
Cumulative variance contribution ratio (%)	40.576	71.508
ED	0.866	−0.322
AREA_SD	0.072	0.811
SHAPE_MN	−0.213	0.526
SHAPE_SD	0.870	0.359
FRAC_AM	0.934	0.089
COHESION	−0.076	0.825

As shown in Table 4, the two extracted principal components explain 71.508% of the total variance of the original variables, with individual contribution rates of 40.576% and 30.932%. SHAPE_SD, ED, and FRAC_AM have the highest correlation with the first principal component, and COHESION and AREA_SD have a higher correlation with the second principal component. Furthermore, SHAPE_MN has a weak correlation with both principal components; thus, this index was excluded. The remaining five indices were re-run for factor analysis, and the analysis results are shown in Table 5.

Table 5. Results of the Landscape Pattern Index Factor Analysis.

Landscape Pattern Index	**Main Components**	
	1	**2**
Eigenvalue	2.411	1.699
Variance contribution ratio (%)	48.223	33.978
Cumulative variance contribution ratio (%)	48.223	82.201
ED	0.834	−0.417
AREA_SD	0.134	0.878
SHAPE_SD	0.894	0.304
FRAC_AM	0.948	−0.048
COHESION	0.004	0.812

From Table 5, the first principal component has a strong positive correlation with FRAC_AM (the higher the number of sub-dimensions, the more complex the landscape geometry); ED (the more significant the edge diversity, the greater the fragmentation); and SHAPE_SD (the more significant, the greater the landscape patch diversity), indicating that this principal component is mainly related to the diversity of the green space, and the more complex the shape of the green space patch and the greater the boundary length, the greater the value of the first principal component.

The second principal component has high loadings on COHESION (the higher the degree of patch fragmentation, the lower the degree of fragmentation) and AREA_SD (the more significant the standard deviation of the patch area, the greater the diversity of landscape patch sizes), indicating that this principal component is related to the degree and connectivity of green space patches, and the more aggregated the patch areas, the higher the value of the second principal component. Therefore, the first principal component can be defined as the green space shape complexity factor, and the second principal component is the green space aggregation factor.

The coefficients corresponding to each index in the two principal components were calculated using the main component loading matrix, and the coefficient matrix of the index was obtained as follows (Table 6).

Table 6. Score matrix for each Landscape Pattern Index Factor.

Landscape Pattern Index	Main Components	
	1	2
ED	0.362	−0.221
AREA_SD	0.019	0.519
SHAPE_SD	0.357	0.205
FRAC_AM	0.394	−0.001
COHESION	−0.032	0.477

The equations of the two principal component factors and the selected landscape pattern index are expressed as follows:

$$F1 = 0.362 \times ED + 0.019 \times AREA\_SD + 0.357 \times SHAPE\_SD + 0.394 \times FRAC\_AM - 0.032 \times COHESION,$$

$$F2 = -0.221 \times ED + 0.519 \times AREA\_SD + 0.205 \times SHAPE\_SD - 0.001 \times FRAC\_AM - 0.477 \times COHESION.$$

F1 and F2 are the shape complexity and aggregation factor of landscape unit *i*, respectively, ED, AREA_SD, SHAPE_SD, FRAC_AM, and COHESION are the edge diversity index, patch area standard deviation, patch shape standard deviation, area-weighted average patch sub-dimension, and patch cohesion index of landscape unit *i*, respectively.

2.4.6. Green Space Accessibility Model Construction

1. Green space accessibility calculation points

Since it is challenging to obtain high-precision building distribution images and to extract buildings from remote sensing images with 30 m resolution, using buildings as target units to calculate their accessibility is not feasible. If the accessibility is calculated using impervious surface image elements as the target unit, the calculation volume is too large, and multiple impervious surface images belong to the same feature. In this study, the accessibility was calculated using a regular grid as the target unit, which is a simple and standard calculation method used in the literature that is feasible and efficient. First, the impervious surface in the study area was divided into 1 km × 1 km grid cells. When applying the grid method, the geometric centre of the grid cells is used as the starting point for calculating the accessibility. Thus, the number of green areas within a specific range was retrieved (Figure 9).

2. Green space accessibility calculation range

Next, we defined the accessible area and accessible green space in the study area. The "accessible area" is the area enclosed by the target points that can be reached within 2 km of the road network from the centre of the grid. The "accessible green space" is the green space within the reachable area. In this way, each closed area constitutes a spatial unit [58]. The accessibility area, green space shape complexity factor, green space aggregation factor, and road integration of green space within this spatial unit can be calculated.

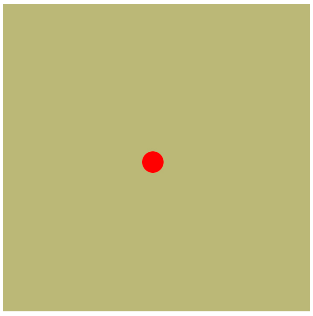


Figure 9. Schematic diagram of accessibility calculation points.

The results are shown in Figure 10. The average accessible area of Fuzhou City is 1.07 km^2. The accessible area of Fuzhou City is 1.31 km^2 in Taijiang District, 1.28 km^2 in Gulou District, 1.09 km^2 in Cangshan District, 0.99 km^2 in Mawei District, and 0.89 km^2 in Jinan District. The size of the accessible area depends on the development of the transportation network, which can be used as an indicator of the accessibility of the regional transportation network.

3. Choice of accessibility factors

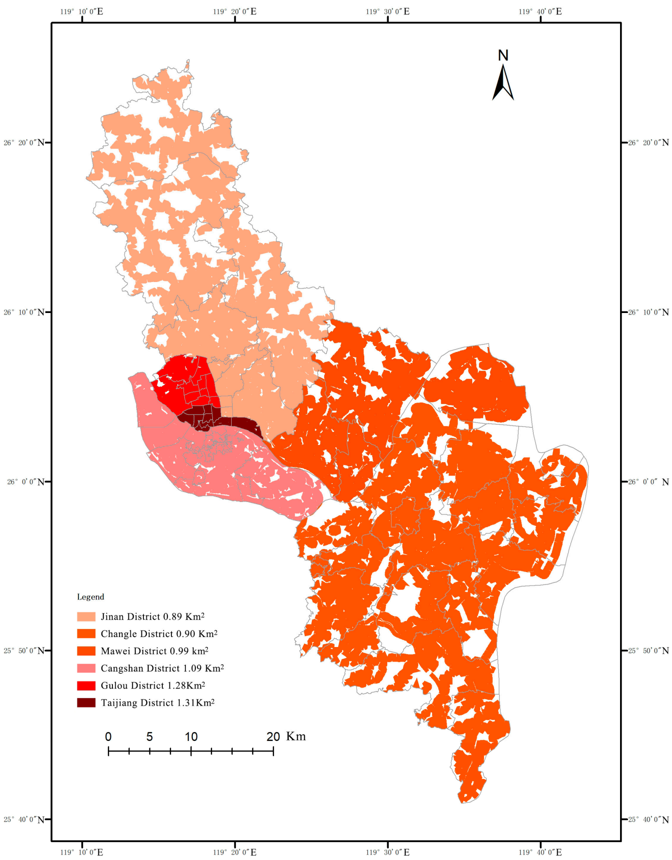


Figure 10. Accessible area in Fuzhou city.

Green space area:

Green space area is the most widely used representative attribute in green space accessibility and equity studies [59,60]. The green space area is associated with the probability that residents can access urban green space in the study area. Urban residents have a higher probability of being exposed to urban green space when the area of green space around the city is significant. In this study, the green space area was the most fundamental indicator of green space accessibility, which was calculated based on the ranges of the available area.

Road integration:

Within the urban space, the higher the integration index value, the higher the road carrying capacity, and the higher the traffic flow. The core expression is the urban spatial structure, which is built along several axes with high integration. Many reports have used the spatial syntax theory to show that the high integration area has high population diversity and high traffic flow. This also indicates that, in this spatial system, the core area of integration with relatively dense axes is usually the area with high activity in the city, where prosperous commercial trade and large populations are gathered. Hence, it is also a central node of a city, and the accessibility is relatively high.

Green space shape complexity factors and aggregation factors:

The landscape pattern index can help concentrate landscape pattern information and represent the structural composition and spatial configuration characteristics of quantitative indicators. It is an essential technical means for assessing landscape patterns, and helps describe the structural characteristics and spatial distribution of urban green space and ecological networks. However, in recent years, different landscape pattern indices have reflected different aspects of the pattern. A single landscape index often requires more work to fully and accurately explain the ecological process. The joint application of the landscape index is an effective way to analyse landscape spatial patterns and examine the explanatory ability of the landscape index when set for the ecological process. Therefore, we selected two representative factors to measure green space landscape structure from complex and redundant landscape indices.

4. Weight analysis

The analytic hierarchy process is used in a multi-objective, comprehensive evaluation. The analytic hierarchy process is used to simulate the human decision-making process. It decomposes and classifies complex target systems and quantifies non-quantitative events with the help of mathematical analysis to provide a reliable quantitative basis for analysing and predicting the development of a system [61].

First, it is necessary to clarify the hierarchy of green space accessibility measurements. According to the purpose of the study, the spatial accessibility of green space was taken as the target layer. The three factors, namely quantity, landscape structure, and road accessibility, were taken as the criteria layer. Then, two indicators of shape complexity and aggregation were included under the criteria layer of landscape structure. Based on these indicators, the Green space accessibility model hierarchy is established in Figure 11. After calculation, the final weight distribution of each indicator was determined, as shown in Table 7.

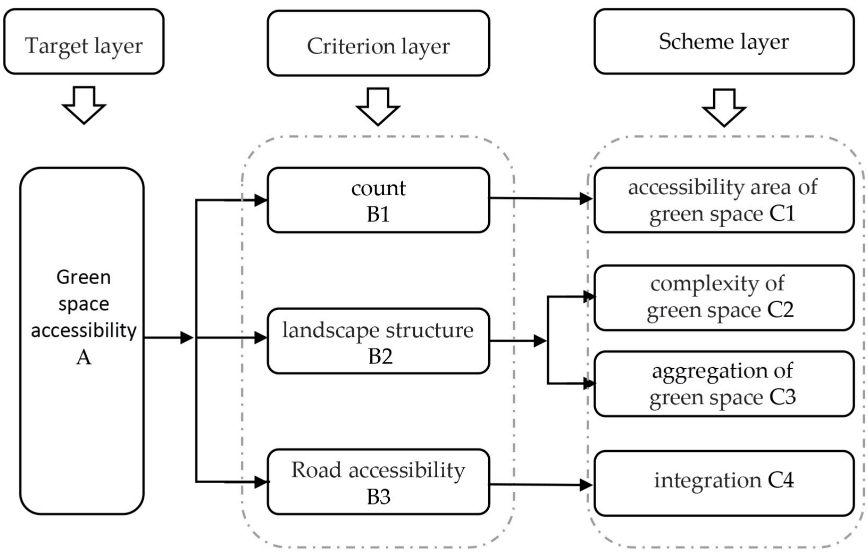


Figure 11. Green space accessibility model hierarchy.

Table 7. Weight value of factors.

Accessibility Area of Green Space Factor	Complexity of Green Space Factor	Aggregation of Green Space Factor	Integration
0.38	0.18	0.18	0.26

3. Results

3.1. Green Space Accessibility Metric Results

We calculated the area of accessible green space, shape complexity, aggregation factor, and integration value for each grid cell separately (Figure 12). Moreover, the factors were weighted according to the weights determined in Table 7 to obtain the final green space accessibility metric results (Figure 13). The accessibility of green space in urban areas of Fuzhou decreases from the centre of the city to the edge. From north to south, the urban area of Fuzhou shows a trend of "low-high-low"; the northern part of the urban area of Fuzhou is the lowest, followed by the southeastern part, and then the western part. Administrative districts refined the accessibility of Fuzhou's urban areas, and Fuzhou's districts were divided into three classes according to their mean values of green space accessibility.

The statistics are shown in Table 8. Gulou District and Taijiang District, classified as the first class, have the highest mean values of 189.49 and 194.95 for green space accessibility in Fuzhou City, respectively. As older urban areas, Gulou District and Taijiang District have the lowest mean areas of accessible green space. The clustering of green areas is also low. However, the complexity of their green area shapes and road integration is relatively high, so their green area accessibility averages are also the highest.

The average values of green space accessibility are also higher in Cangshan District and Mawei District, at 170.06 and 139.94, respectively, classified as the second class. The complexity of the green space shape is relatively high in Cangshan District. Road integration is also high, so the accessibility of green space is relatively high in the whole district. In contrast, the average value of green space accessibility is higher in the part of Mawei District near the city centre and lower in the part far from the city centre, especially in the part adjacent to Jinan District.

Jinan District and Changle District are classified as the third class, with mean green space accessibility values of 112.53 and 120.47, respectively. These values are relatively higher at the border between Jinan District and Gulou District and then decrease as they move away from the city centre. The mean green space accessibility values are higher in the central part of the Mawei District because of its green space area, green space shape complexity, and road integration. However, the values outside the Mawei District are relatively low.

The frequency histogram of green space accessibility in each administrative district of Fuzhou City was drawn based on the statistical data (Figure 14). The maximum frequencies occurred at relatively similar intervals in the six administrative districts. The maximum frequencies of 3.7%, 2.3%, and 1.6% occurred in Taijiang, Gulou, and Cangshan, respectively (180,210). The maximum frequencies of the Mawei and Jinan districts were close to each other, 0.6% and 0.5%, respectively (180,190). The maximum frequency of the Changle District is 1.5%, appearing in the interval (140,160).

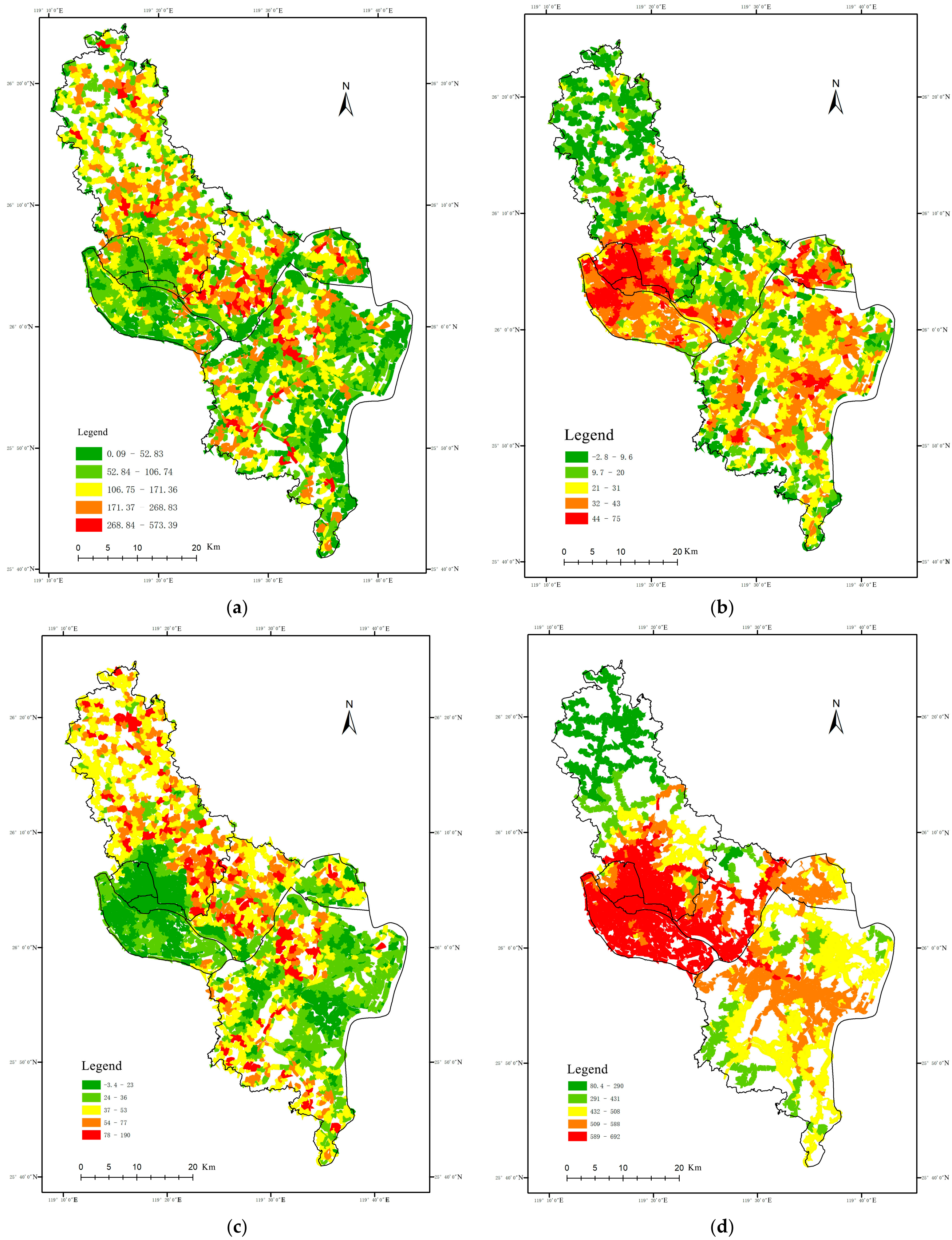


Figure 12. Distribution of green space accessibility factors in urban areas of Fuzhou: (**a**) green space accessibility area; (**b**) green space shape complexity factor; (**c**) green space aggregation factor; and (**d**) road integration.

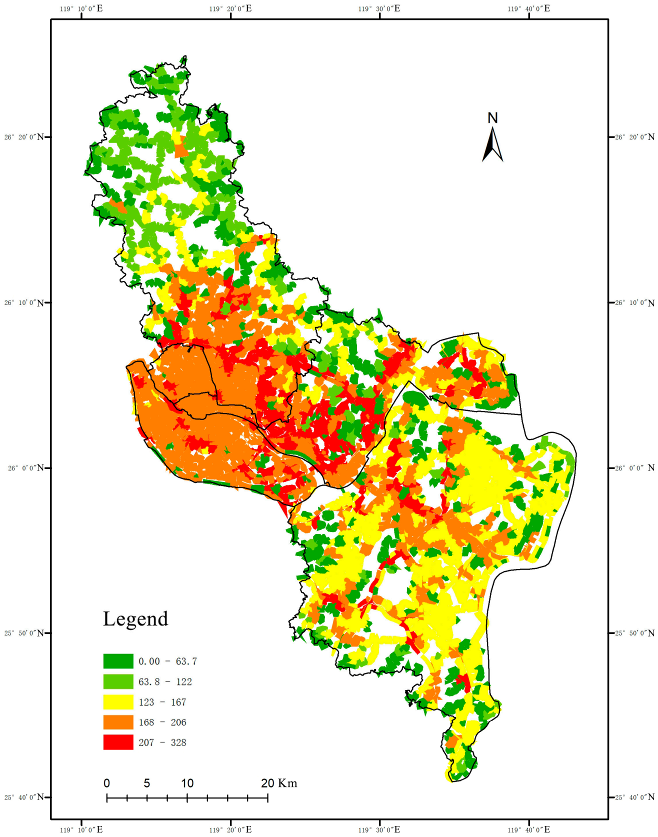


Figure 13. Distribution of accessible green spaces in Fuzhou City.

Table 8. Statistical descriptions of green space accessibility in urban areas of Fuzhou.

Statistical Values / Administrative District	Gulou District	Taijiang District	Cangshan District	Jinan District	Mawei District	Changle District
Average value	189.49	194.95	170.06	112.53	140.38	120.47
Standard deviation	29.25	11.34	54.45	66.55	75.81	61.66
Grid number	48	32	171	617	319	806

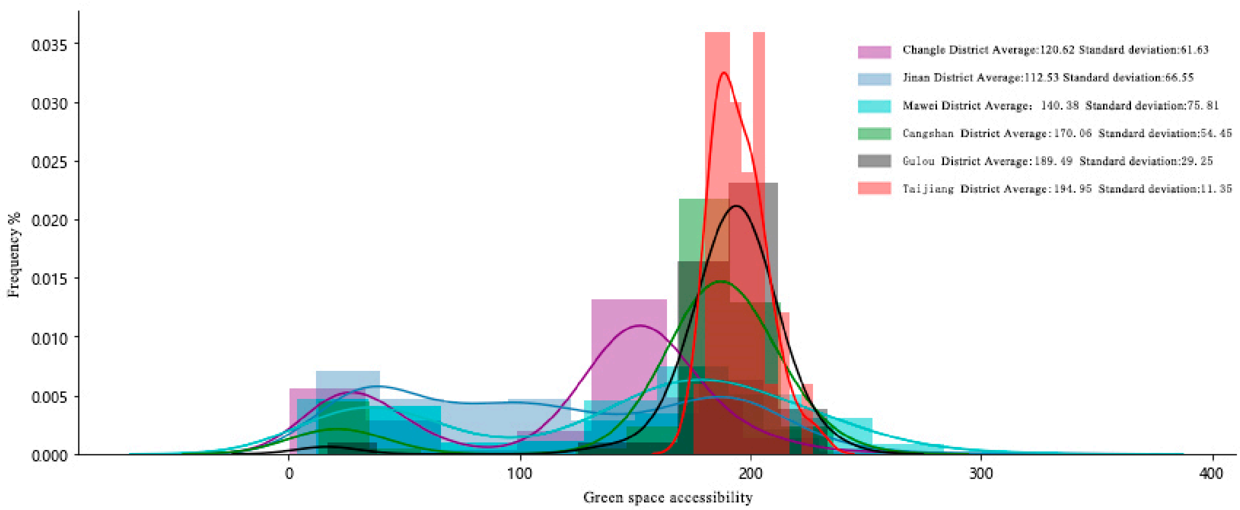


Figure 14. Frequency distribution of green space accessibility in urban areas of Fuzhou.

3.2. Fairness of Green Space Based on Supply and Demand Index

3.2.1. Green Space Supply Index in Fuzhou City

Based on the research results on green space accessibility, we selected four indicators for the supply index of green space, namely the green space accessibility area index CA, the green space shape complexity index (F1), the green space aggregation index (F2), and the road integration index (IN). Taking streets as the calculation unit, each index was normalised using the extreme difference standardization method, and then each street's corresponding value was analysed using ArcGIS. Moreover, the ArcGIS natural breakpoint classification method was used to classify the values into five levels: higher, high, moderate, low, and lower (Figure 15).

The statistics are shown in Table 9. The majority of streets have low or lower values of the green space accessibility area index, as observed for 30 streets, accounting for 46.15% of the total number. Among them, 17 are classified as low and 13 are classified as lower, which have mean values of 0.274 and 0.098, respectively. There are 10 streets with higher values, 11 streets with high values, and 14 streets with moderate values, which are 0.843, 0.598, and 0.398, respectively.

The statistics of the green space shape complexity index show that 26 streets have low or lower values, accounting for 40% of the total number of streets. The number of streets with low values is 21, with a mean value of 0.332, and the number of streets with lower values is 5, with a mean value of 0.109. Then there are 16 streets with higher values, 10 streets with high values, and 13 streets with moderate values, which are 0.912, 0.754, and 0.543, respectively.

Fuzhou City's low green space aggregation index accounts for 43.08% of the total streets, with 28 streets. The number of streets with low and lower values is 14 and 13, with mean values of 0.083 and 0.193, respectively. There are 10 streets with high mean values, 13 streets with high values, and 15 streets with moderate values, which are 0.899, 0.598, and 0.398, respectively.

In the distribution of green space, the green space accessibility area index, green space shape complexity index, and green space aggregation index are dominated by low values, accounting for 46.15%, 40%, and 43.08% of the total streets, respectively. The performance of the integration index is the opposite. The number of streets with low or lower values is 11, accounting for 16.92% of the total streets, with mean values of 0.152 and 0.587, respectively. At the same time, 63.08% of the total streets exhibit high (20 streets) or higher values (21 streets), which have mean values of 0.973 and 0.908, respectively. There are 13 streets with moderate values, with a mean value of 0.717.

In summary, the four indices of green space supply in urban areas of Fuzhou City have an overall low percentage at the street level. The number of streets with higher values accounted for 15.38% (the green space accessibility area indicator), 24.62% (the green space spatial complexity indicator), 15.38% (the green space aggregation indicator), and 30.77% (the road integration indicator) of the total number of streets, respectively. From Figure 16, the high green space accessibility indicators are concentrated in the newer areas near the city centre, and there is less low street area accessibility in the city centre. The same situation is observed for the green space aggregation indicator, but the opposite situation is observed for the green space shape complexity indicator and the road integration indicator, where the high values of both are concentrated in the city centre area. This shows that the distribution of green space supply indicators at the street level in the urban area of Fuzhou needs to be more equitable.

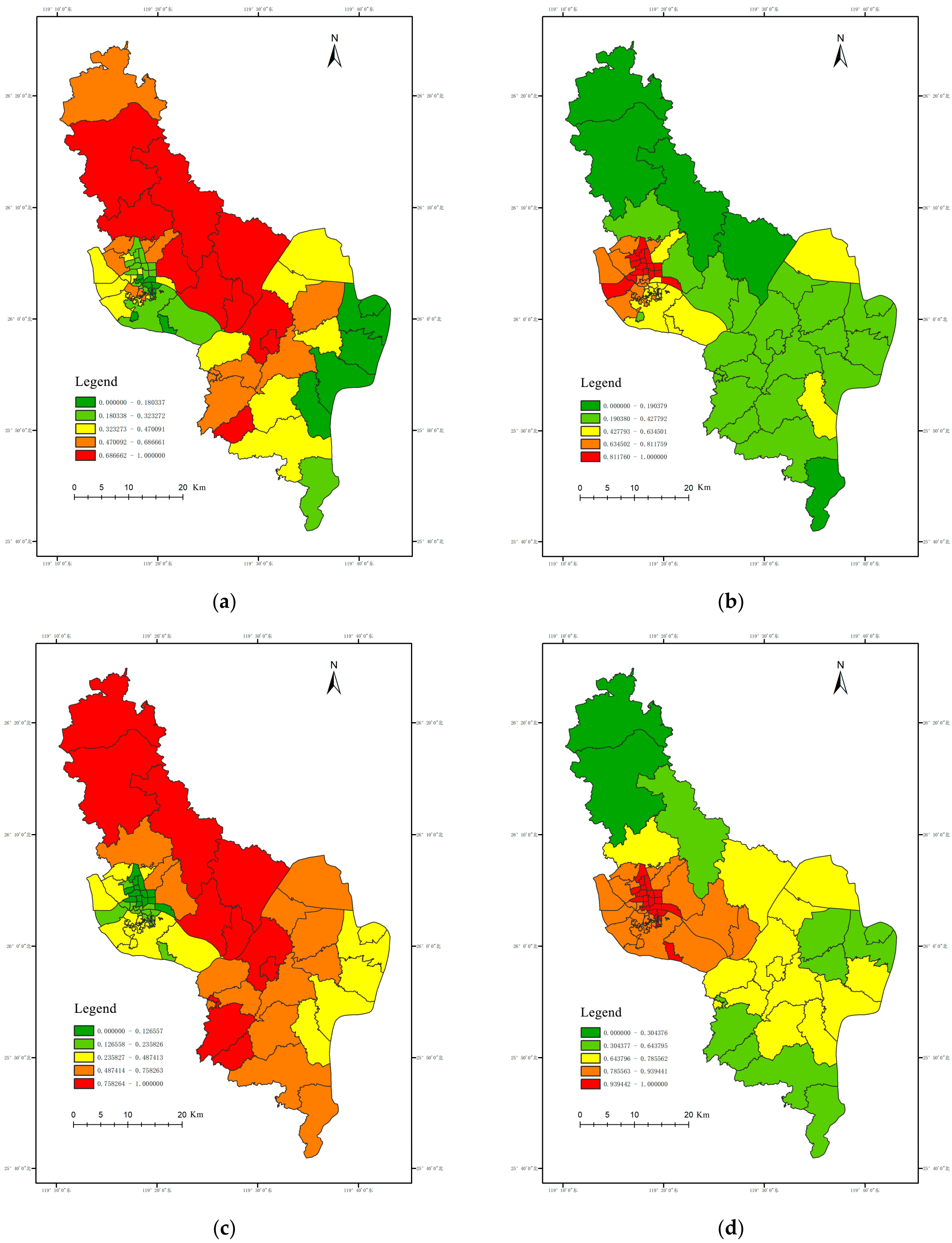


Figure 15. Spatial distribution of the single supply index of green space in urban areas of Fuzhou: (**a**) green space accessibility area index; (**b**) green space shape complexity index; (**c**) green space aggregation index; and (**d**) road integration index.

Table 9. Statistics of green space supply in urban areas of Fuzhou.

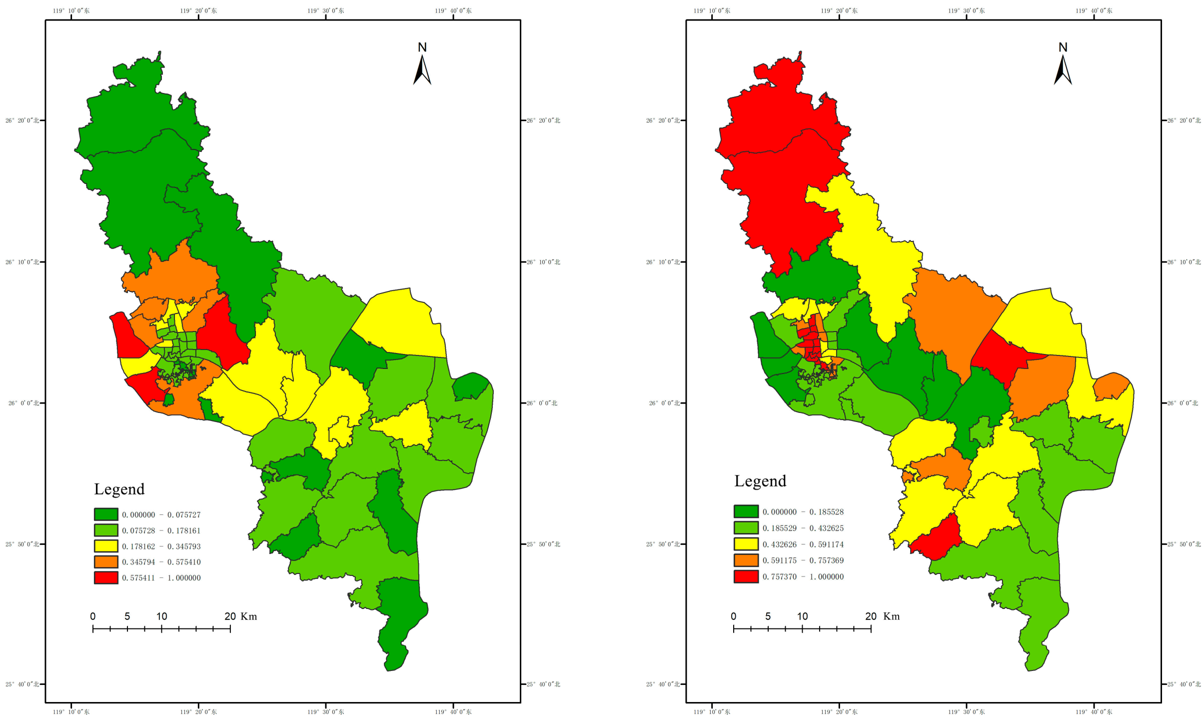
Level	Number of Streets (Blocks)				Average Value				Standard Deviation			
	CA	F1	F2	In	CA	F1	F2	In	CA	F1	F2	In
lower	13	5	14	2	0.098	0.109	0.083	0.152	0.058	0.075	0.039	0.152
low	17	21	13	9	0.274	0.332	0.193	0.587	0.038	0.591	0.026	0.034
moderate	14	13	15	13	0.398	0.543	0.372	0.717	0.041	0.056	0.052	0.042
high	11	10	13	21	0.598	0.745	0.668	0.908	0.058	0.046	0.069	0.026
higher	10	16	10	20	0.843	0.912	0.899	0.973	0.083	0.049	0.056	0.018

3.2.2. Green Space Demand Index in Fuzhou City

In previous studies on the layout of public resources such as urban green spaces, parks, and schools in foreign countries, the needs index has been widely used to evaluate the fairness of resource allocation [62,63]. According to the sixth census data of Fuzhou City, five indicators were considered as follows:

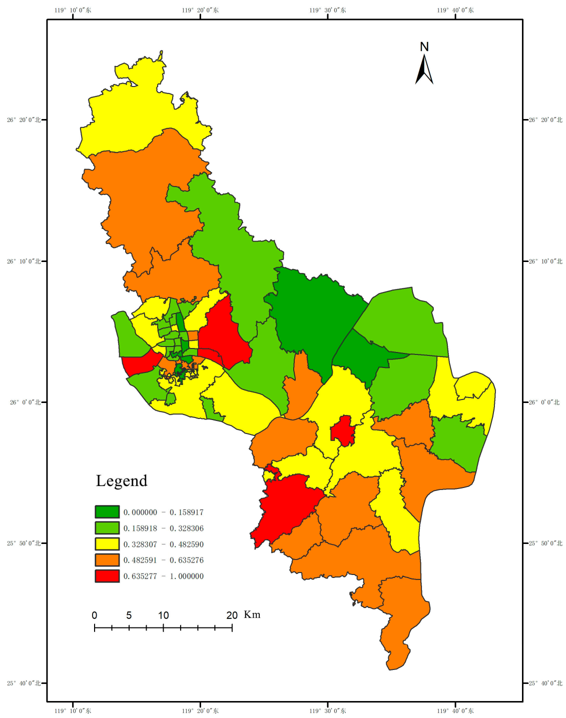
- total population
- the proportion of the population over 65 years old.
- the proportion of the population aged 0~14 years old.
- the proportion of the foreign population.
- the proportion of females.

The values of the green space demand indicators were calculated in terms of streets, and each indicator was normalized using the extreme difference standardisation method. Moreover, the ArcGIS natural breakpoint classification method was used to organise the values into five classes. (Figure 16, Table 10).

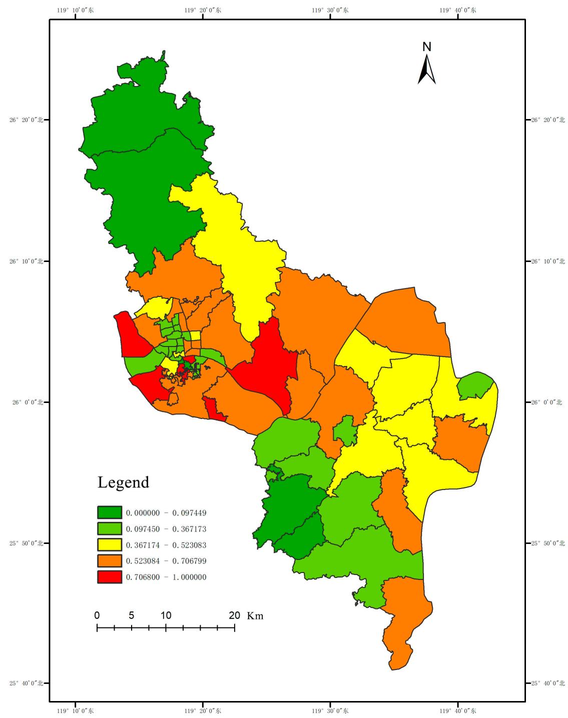


(**a**) (**b**)

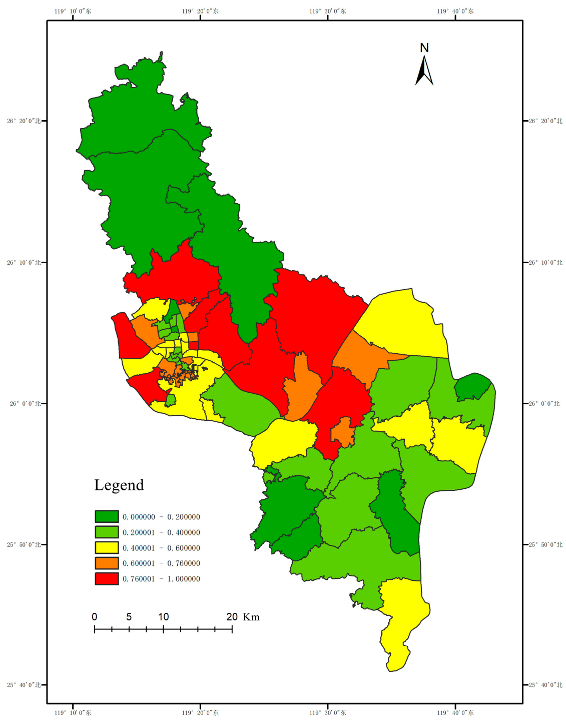
Figure 16. *Cont.*



(**c**)



(**d**)



(**e**)

Figure 16. Index of green space demand in urban areas of Fuzhou: (**a**) total population; (**b**) female population; (**c**) population aged 0 to 14; (**d**) aged 65 and above; and (**e**) foreign population.

Table 10. Green space demand index in Fuzhou city (blocks).

Level	Total Population	Female Population	Population Aged 0 to 14	Population Aged 65 and Above	Foreign Population
Lower	14	7	7	5	9
Low	31	19	21	23	17
Moderate	14	13	18	11	20
High	4	11	14	21	11
Higher	2	15	5	5	8

Table 10 shows that the number of streets in the low area is 31, accounting for 47.69% of the total number of streets. The lower and moderate areas both have the same number of streets, 14, whereas the high and higher areas only have 6 streets, accounting for only 9.23%. For the female population, although the most significant number of streets is 19 in the lower area, the high and higher areas reach 26 streets, accounting for 40% of the total number of streets. In contrast, the lowest percentage of the female population is found in only 7 streets. This shows that Fuzhou has more street pairs with a high percentage of the female population; however, the proportion of the population aged 0 to 14 years old has the opposite trend compared with the female population, with the highest number of streets with a high percentage being 21 blocks of low, which, together with the 7 blocks of low, account for 43.07% of the total number of streets. Furthermore, 14 and 5 blocks of high and higher streets are occupied by people aged 0 to 14 years—old. For people that are 65 years old and older, the lower and higher areas are similar in terms of the population percentage. There are 28 blocks of low streets and 26 blocks of high streets, accounting for 43.07% and 40% of the total number of streets, respectively. There are 5 blocks of lower and higher streets. The statistics of the foreign population show that lower areas have more streets than higher areas, with 26 blocks, which account for 40% of the total number of streets.

In summary, the distribution of population demand indicators in urban areas of Fuzhou is relatively even. The number of streets in higher-value areas is small, and the number in lower-value areas is also small. The number of streets with high numbers is concentrated between low and high values. The distribution map shows that the higher values of total population data are concentrated in the downtown area, whereas most streets with lower ratios are located far from the downtown area, with a few streets in the downtown area. The higher value of the female population is concentrated in the central part of the city, but a few streets are located far from the city centre. The low values for the population aged 0 to 14 years old are found in the majority of streets, and the distribution of higher-value areas is relatively scattered, with only a few higher-value streets in the city centre. The higher values for the population over 65 years old are relatively concentrated in the streets near the city centre. The higher-value distribution of the foreign population is more pronounced, mainly around the streets in the city centre.

3.2.3. Fairness Analysis of Green Space

The green space supply indicators and green space demand indicators were also overlaid and analysed using ArcGIS. Then, the combined spatial distribution of green space supply and demand was calculated. Moreover, the ArcGIS natural breakpoint classification method was used to categorise the values into five classes (Figure 17).

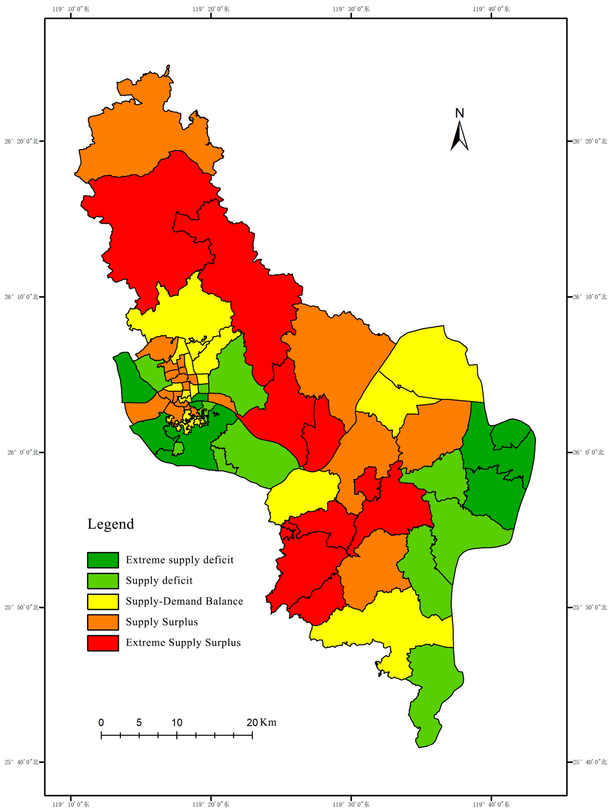


Figure 17. Fuzhou city's green space supply and demand balance results.

The statistics are shown in Table 11. The majority of streets (20 blocks) exhibited a surplus supply, accounting for 30.73% of the total number of streets and 30.76% of the total area. The most significant area belongs to the streets with extreme surplus supply; although their number is only nine, they contain 31.37% of the area. The next largest area is the balanced supply and demand area, with 17 streets, accounting for 26.15% of the number of streets and 18.66% of the total area. The total number of streets in these three sections is 46, containing 70.77% of the streets and 74.78% of the area. The total number of streets in the deficit part is 19, accounting for only 29.23% of the number of streets and 25.22% of the area. Thus, the urban areas of Fuzhou City occupy the majority of both the number of streets and the area of streets. This shows that the distribution of green space in the urban area of Fuzhou is relatively fair.

Table 11. Fuzhou city supply and demand balance statistics.

Supply and Demand Level	Number of Streets (Blocks)	Number of Streets (%)	Street Area (%)
Extreme supply deficit	7	10.77	9.57
Supply deficit	12	18.46	15.65
Supply-Demand Balance	17	26.15	18.66
Supply Surplus	20	30.76	24.75
Extreme Supply Surplus	9	13.85	31.37

4. Discussion

A large body of research has demonstrated that urban green space can affect people's health in various ways. For instance, via the physical environment, social interaction, and physical activity. Research has also presented evidence for uneven distributions of green space. An integrated description of the spatial distribution of urban green spaces and the services they provide has been widely discussed. Therefore, this paper investigates the spatial accessibility and equity of green space in urban areas of Fuzhou City based on telemetry image data, landscape patterns, road data, and spatial syntax. This not only helps to reveal the in-depth influences of green space but also provides a reference for rational planning and management of green space, which can be used to improve the quality and configuration of green spaces.

4.1. Street Network Topology Pattern

This paper uses space syntax theory to calculate and analyse the accessibility of urban roads. It obtains the street network of Fuzhou City, namely the road integration. It provides factors for the green space accessibility model. As a result, the distribution of road accessibility in Fuzhou City can be observed from the topological form, which is concerned with the distance people have to travel and the convenience of the destination. The accessibility of the urban centre of Fuzhou is higher than that of the peripheral areas. The integration of roads is one of the essential factors affecting the accessibility of green space.

4.2. Remote Sensing Images and Landscape Pattern Analysis

The development of landscape patterns in urbanisation has increased the alteration and disturbance of the landscape by human activities. The changes in landscape patterns can show the impact of humans on the urban environment under different natural environments and socioeconomic and socio-political conditions, which are caused by the inadequacy of numerous landscape pattern indices in indicating ecological processes. Therefore, in this study, the numerous and ecologically unclear landscape indices were screened and optimised through factor analysis to select representative factors of landscape patterns for a more accurate quantitative analysis of the spatial accessibility of green spaces. We first extracted the green space data of the Fuzhou urban area by analysing Landsat image data. We then used Fragstats software to calculate the relevant landscape pattern indices and then extracted the final landscape pattern index factors by factor analysis. Five landscape indices and two principal component factors were selected by factor analysis: ED, AREA_SD, SHAPE_SD, FRAC_AM, and COHESION. They were then renamed to derive the green space shape complexity factor and green space aggregation factor that can be quantitatively analysed. From these two factors, a calculation for the green space accessibility model can be provided.

4.3. Model of Green Space Accessibility

Based on the analysis of street network topology and landscape patterns, a model for measuring the spatial accessibility of urban green spaces was constructed using GIS spatial analysis tools. The model yielded valid results in the urban areas of Fuzhou. The results show that the accessibility of green space is decreasing from the centre to the edge of the city. From north to south, Fuzhou City shows a trend of "low-high-low"; the northern part of Fuzhou City is the lowest, followed by the southeastern and western parts.

4.4. Study on the Equity of Green Space

The spatial equity of green space was mainly calculated according to the accessibility index. Considering the indicators of green space accessibility supply and sociodemographic demand, variable correlation analysis and the spatial superposition of factors were used to quantitatively express the spatial equity of urban green space layout at the street scale. The spatial distributions of supply and demand for green space, based on roads, were derived using the supply and demand overlay model, which expressed the equity of urban green space. In terms of green space equity, Fuzhou City has a majority share in both the number of streets and the amount of area. This indicates that the distribution of green space in the urban area of Fuzhou is relatively fair.

5. Conclusions

5.1. To Improve the Fairness and Accessibility of Green Spaces in Line with Urban Planning

Urban green spaces are essential to green infrastructure in cities and play a crucial role in sustainable development because they provide vital ecological, social, and cultural functions. The spatial fairness of the layout of public service facilities, such as urban green spaces, directly affects residents' quality of life, especially low-income groups, the elderly, children, and people with disabilities who depend on public service facilities such as green spaces. Therefore, policymakers should focus more on urban green space planning in their spatial policies and pay more attention to the importance of natural environments such as green spaces. Furthermore, to make greenspace central to a city's infrastructure, there should be a review based on the fairness research evaluation model; green space planning should be improved, and relevant regulations should be modified.

5.2. Updating and Improving Research Methods and Tools

This study mainly uses GIS spatial analysis, spatial syntax theory, and landscape pattern analysis, which involve some data deficiencies and technical difficulties. For example, spatial syntax cannot handle slope problems, and the road data is analyzed at the same height by default. In subsequent research, high terrain should be removed or height differences should be analyzed. The analysis of landscape indices is based on the processing results of remote sensing images. Therefore, the clarity and classification of remote sensing results are essential, and subsequent improvements should be made to the accuracy of remote sensing images.

5.3. Adding Research Data from Different Time Periods

This study is based on a single time point as the time range. It is recommended that future discussions be cut from a longitudinal perspective, exploring the process of changes in the fairness pattern as the characteristics of green spaces, social demographics, landscape indices, and road data change over time.

5.4. Failure to Truly Understand the Public's Preferences for Green Space Characteristics and Usage Habits

This study mainly uses a quantitative approach for research and investigation. As for the actual opinions and willingness to use green spaces by the public, which involve more subjective feelings of the users, they have not been reflected. For example, the comfort, safety, and facility conditions of green spaces have not been evaluated.

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Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Demographic variables in urban areas of Fuzhou.

Administrative District	Street	Total Population	Female Population	Population Aged 0 to 14	Population Aged 65 and Over	Foreign Populations
Gulou	Gudong Street	40,769	21,064	4577	5208	13,148
Gulou	Guxi Street	67,420	34,483	7462	7568	25,096
Gulou	Wenquan Street	67,911	33,959	6461	6544	24,603
Gulou	Dongjie Street	32,438	17,033	4013	3891	8410
Gulou	Nanjie Street	45,663	23,480	5102	5537	17,157
Gulou	Antai Street	33,305	17,135	3812	4079	12,046
Gulou	Huada Street	101,489	51,259	10,718	8834	24,416
Gulou	Shuibu Street	45,746	23,463	5200	4930	20,402
Gulou	Wufeng Street	109,429	55,378	13,571	8760	54,162
Gulou	Hongshan Town	143,535	71,430	17,259	10,692	80,796
Taijiang	Yingzhou Street	54,186	26,768	6115	4581	26,184
Taijiang	Houzhou Street	44,047	21,443	3820	5654	13,232
Taijiang	yizhou Street	40,407	20,728	4363	5223	16,839
Taijiang	Xingang Street	49,609	23,930	4625	4298	19,177
Taijiang	Shanghai Street	73,010	37,027	7285	8872	30,579
Taijiang	Cangxia Street	43,654	22,250	4628	5817	15,720
Taijiang	Chating Street	34,441	17,293	3527	4193	13,899
Taijiang	Yangzhong Street	29,195	14,638	3031	3678	10,266
Taijiang	Aofeng Street	43,802	21,258	6981	2754	20,100
Taijiang	Ninghua Street	34,540	17,275	4144	3842	14,278
Cangshan	Cangqian Street	23,663	12,179	3235	2935	6957
Cangshan	Dongshen Street	13,195	6536	1636	1301	7230
Cangshan	Duihu Street	35,785	18,934	2756	2476	20,647
Cangshan	Linjiang Street	29,598	10,751	2457	2413	15,578
Cangshan	Sanchajie Street	23,993	12,170	2850	2696	11,147
Cangshan	Shangdu Street	43,622	22,292	5985	3284	23,736
Cangshan	Xiadu Street	36,275	18,388	5085	3677	15,177
Cangshan	Jinshan Street	80,791	39,762	15,436	3705	37,606
Cangshan	Cangshan Town	30,247	14,496	3663	2007	17,017
Cangshan	Chengmen Town	96,539	47,222	12,245	5893	31,972
Cangshan	Gaishan Town	122,018	58,475	15,630	7042	57,989
Cangshan	Jianxin Town	201,925	93,362	21,498	6348	147,161
Cangshan	Luozhou Town	18,462	8186	1948	1162	8780
Cangshan	Hongxing Street	6633	3217	663	508	1859
Mawei	Luoxing Street	60,117	28,972	8442	2849	34,630
Mawei	Mawei Town	63,299	29,695	6960	3000	41,325
Mawei	Tingjiang Town	39,624	20,896	3560	3857	24,885
Mawei	Langqi Town	68,889	34,770	7059	6025	28,592
Jinan	Chayuan Street	90,045	45,011	9022	7947	52,350
Jinan	Wangzhuang Street	46,980	24,122	6377	3479	26,241
Jinan	Xiangyuan Street	48,717	23,909	6182	3277	30,622
Jinan	Gushan Town	286,095	135,555	43,946	10,220	204,101
Jinan	Xindian Town	166,283	79,337	23,682	8524	116,719
Jinan	Yuefeng Town	130,403	64,362	16,943	8893	84,000
Jinan	Huanxi Town	11,965	5949	1297	1105	2716
Jinan	Shoushan hometown	8091	3900	1080	1076	1122
Jinan	Rixi hometown	3912	1797	498	541	580
Changle	Wuhang Street	76,306	39,429	11,701	5556	38,392
Changle	Hangcheng Street	71,320	34,714	9418	3385	47,713
Changle	Yingqian Street	35,408	17,089	4829	3073	13,863
Changle	Zhanggang Street	46,520	22,610	6446	3613	17,271
Changle	Shouzhan Town	21,559	10,681	2805	2136	6883
Changle	Yutian Town	32,841	15,927	5328	3107	5601

Table A1. *Cont.*

Administrative District	Street	Total Population	Female Population	Population Aged 0 to 14	Population Aged 65 and Over	Foreign Populations
Changle	Songxia Town	25,281	11,865	3439	1587	10,512
Changle	Jiangtian Town	44,552	21,213	6659	3352	14,809
Changle	Gukui Town	43,882	21,244	6347	3926	13,407
Changle	Wenwusha Town	19,985	9314	2593	1334	4631
Changle	Heshang Town	51,323	24,482	6285	4485	14,435
Changle	Hunan Town	27,375	13,014	3125	1981	11,307
Changle	Jinfeng Town	84,899	41,596	11,842	5713	39,156
Changle	Wenling Town	27,680	13,655	3414	2617	9226
Changle	Meihua Town	14,216	7214	1710	1502	3504
Changle	Tantou Town	48,026	23,713	5153	4887	17,371
Changle	Luolian hometown	6426	3152	953	780	1222
Changle	Houyu hometown	5027	2677	435	631	2944

(Statistics to: 2010 Sixth Census Population Data).

Table A2. Landscape pattern index analysis table.

Landscape Pattern Index	Expression Formula	Ecological Significance
Landscape (PLAND)	$PLAND = \frac{\sum_{j}^{n}=1^{a_{ij}}}{A}(100)$	Knowing what proportion of the landscape is covered by patches gives an idea of the abundance of a certain landscape type.
Largest Patch Index (LPI)	$LPI = \frac{max_{j}^{n}=1^{a_{ij}}}{A}(100)$	The maximum patch index at the type level describes the percentage of the largest patches in the landscape and is a simple measure of type dominance.
Edge Density (ED)	$ED = \frac{\sum_{k}^{m}=1^{e_{ik}}}{A}(10,000)$	Edge diversity reveals the extent to which a landscape or type is divided by a boundary and is a direct reflection of the degree of landscape aggregation factors.
Average Patch Area (AREA_MN)	$AREA\_MN = \frac{\sum_{i}^{n}=1^{a_{ij}}}{n_i}(10,000)$	AREA_MN represents an average condition that characterizes the fragmentation of the landscape type.
Area-Weighted Mean Patch Area (AREA_AM)	$AREA\_AM = \sum_{j=1}^{n}[a_{ij}(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}})]$	AREA_AM is a statistical form of patch area, which to some extent reflects the diversity of patch areas and the complexity of landscape patterns of landscape types.
Standard Deviation of Patch Area (AREA_SD)	$AREA\_SD = \sqrt{\frac{\sum_{j=1}^{n}[a_{ij} - \left(\frac{\sum_{j=1}^{n} a_{ij}}{n_i}\right)]^2}{n_i}}$	AREA_SD is a statistic of the area complexity of landscape type patches, reflecting the diversity and complexity of their landscape patches.
Density of Patches(PD)	$PD = \frac{N_i}{A_i}$	Landscape patches can reflect the degree of fragmentation of the landscape.
Landscape Shape Index (LSI)	$LSI = \frac{0.25E}{\sqrt{A}}$	When there is only one square patch in the landscape, LSI = 1; when the patch shape in the landscape is irregular or deviates from the square, the LSI value increases.
Average Shape Index (SHAPE_MN)	$SHAPE\_MN = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\frac{0.25p_{ij}}{\sqrt{a_{ij}}}\right)}{n_i}$	Reflecting the overall shape characteristics of the landscape pattern, SHAPE_MN = l when all patches in the landscape are square, and the value of SHAPE_MN increases when the shape of the patches deviates from square.

Table A2. *Cont.*

Landscape Pattern Index	Expression Formula	Ecological Significance
Area-Weighted Mean Shape Index (SHAPE_AM)	$SHAPE\_AM = \sum_{i=1}^{n}[(\frac{0.25p_{ij}}{\sqrt{a_{ij}}})(\frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}})]$	SHAPE_AM is one of the most important metrics for measuring the complexity of landscape spatial patterns and has implications for many ecological processes.
Standard Deviation of Patch Shape Index (SHAPE_SD)	$SHAPE\_SD = \sqrt{\frac{\sum_{j=1}^{n}[\frac{0.25p_{ij}}{\sqrt{a_{ij}}} - (\frac{\sum_{j=1}^{n}\left(\frac{0.25p_{ij}}{\sqrt{a_{ij}}}\right)}{n_i})]^2}{n_i}}$	SHAPE_SD is a statistic of landscape type patch shape complexity, reflecting the diversity and complexity of its landscape patches.
Fractal Dimension (FRAC_AM)	$D = 2\log\left(\frac{p}{4}\right) / \log(A)$	The number of sub-dimensions is an important pointer to reflect the overall characteristics of the landscape pattern; the higher the number of sub-dimensions, the more complex the geometry of the landscape.
Mean Euclidean Nearest Neighbor Index (ENN_MN)	$\mathrm{ENN}\_MN_i = \frac{\sum_{j=1}^{n} h_{ij}}{n_i}$	ENN_MN measures the spatial pattern of the landscape. Generally speaking, a large ENN_MN value reflects that the patches of the same type are far apart and have a discrete distribution; on the contrary, it indicates that the patches of the same type are close to each other and have a clustered distribution.
Isolation Index (SPLIT),	$I_i = \frac{\sqrt{n_i A}}{2A_i}$	The separation index shows the relationship between separation and the number of patches, and the effect of the area of patches in the landscape. The greater the separation, the more dispersed the distribution of patches in the landscape.
Aggregation Index(AI)	$AI = [\sum_{i=1}^{m}\left(\frac{g_{ii}}{max g_{ij}}\right)p_i](100)$	At the patch type level, the agglomeration index is obtained from the connectivity matrix calculation and is used to measure the maximum number of possible connections for a given patch type.
COHESION Index (COHESION)	$COHESION = \left[1 - \frac{\sum_{j=1}^{n} p_{ij}}{\sum_{j=1}^{n} p_{ij}\sqrt{a_{ij}}}\right][1 - \frac{1}{\sqrt{A}}]^{-1}()$	The cohesiveness of the landscape is related to the distance between similar patches, the presence or absence of corridors, the frequency of intersection of different types of corridors, and the size of the network formed.

Table A3. The Spearman analysis results of landscape metrics.

	PLAND	PD	LPI	ED	LSI	AREA_ MN	AREA_ AM	AREA_ SD	SHAPE_ MN	SHAPE_ AM	SHAPE_ SD	FRAC_ AM	COHE- SION	SPLIT	AI
PLAND	1.000														
PD	−0.569 **	1.000													
LPI	0.980 **	−0.664 **	1.000												
ED	−0.263 **	0.832 **	−0.370 **	1.000											
LSI	−0.541 **	0.933 **	−0.636 **	0.920 **	1.000										
AREA_ MN	0.820 **	−0.917 **	0.878 **	−0.637 **	−0.854 **	1.000									
AREA_AM	0.967 **	−0.708 **	0.996 **	−0.418 **	−0.677 **	0.901 **	1.000								
AREA_SD	0.493 **	−0.107 *	0.491 **	0.053	−0.133 **	0.276 **	0.484 **	1.000							
SHAPE_MN	0.401 **	−0.588 **	0.429 **	−0.200 **	−0.333 **	0.605 **	0.443 **	0.114 *	1.000						
SHAPE_AM	0.051	0.364 **	0.035	0.701 **	0.542 **	−0.196 **	0.019	0.379 **	0.134 **	1.000					
SHAPE_SD	0.075	0.311 **	0.044	0.599 **	0.473 **	−0.173 **	0.027	0.592 **	0.182 **	0.847 **	1.000				
FRAC_AM	−0.144 **	0.518 **	−0.172 **	0.786 **	0.691 **	−0.390 **	−0.190 **	0.247 **	0.037	0.970 **	0.824 **	1.000			
COHESION	0.942 **	−0.771 **	0.980 **	−0.460 **	−0.713 **	0.937 **	0.989 **	0.443 **	0.506 **	0.011	0.024	−0.196 **	1.000		
SPLIT	−0.986 **	0.651 **	−0.999 **	0.352 **	0.622 **	−0.874 **	−0.994 **	−0.492 **	−0.428 **	−0.039	−0.051	0.166 **	−0.978 **	1.000	
AI	0.756 **	−0.896 **	0.0823 **	−0.745 **	−0.937 **	0.949 **	0.848 **	0.266 **	0.397 **	−0.371 **	−0.331 **	−0.558 **	0.869 **	−0.815 **	1.000

* Significant at the 0.05 level. ** Significant at the 0.01 level.

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Leading or Constraining? Development of New-Type Urbanization under Economic Growth Targets

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Abstract: As an overarching goal, economic growth targets have a strong leading and constraining effect on the behavior of local governments. China's new-type urbanization strategy emphasizes balanced development across population, economic, social, space, ecological and income-gap dimensions and relies on multifaceted government policies. Therefore, setting reasonable economic growth targets has an important impact on the process of new-type urbanization. This paper uses panel data from 30 provinces between 2005 and 2020 to empirically examine the impact of economic growth targets on the new-type urbanization process. The results reveal an inverted U-shaped relationship between economic growth targets and new-type urbanization, with public expenditure and land finance acting as a mediator and a moderator through fiscal expenditure. The mechanisms of influence are as follows: economic growth target—infrastructure construction, regional innovation, energy structure, and financial development—population development, economic quality, ecological civilization, and income gap—new-type urbanization. Heterogeneity analysis shows that the inverted U-shaped relationship is significantly present in the western and central regions of China and before 2014. This paper not only clearly illustrates the institutional mechanism of urbanization in China but also highlights its government-led and "land-for-security" approach, which has important implications for urbanization in other regions of the world.

Keywords: economic growth target; new-type urbanization; inverted U-shaped; public expenditure; land finance

1. Introduction

Urbanization and regional economic development are mutually reinforcing [1,2] and represent a necessary path for developing countries. As the world's largest developing country, China has achieved remarkable progress in promoting urbanization. Since the implementation of the reform and opening-up policy, China's urbanization rate has rapidly increased. China took only 15 years to achieve a leap in its urbanization rate from 30% to 50%, which is much shorter than the time required for developed countries to achieve the same degree of growth, such as 40 years in the United States and 20 years in Japan [3]. The enormous labor force and consumer potential released by urbanization have also supported the country's high-speed economic growth.

The success of China's urbanization is largely attributed to the top-down urbanization model driven by the government [4]. In contrast to the market-driven approach adopted in Europe and the United States, Chinese local governments have employed various means to concentrate economic resources and guide rural-to-urban migration, such as establishing development zones and building infrastructure. This unique approach not only has allowed China to avoid the development trap that has plagued many African countries [5] but also has provided valuable experience for underdeveloped countries and regions in Africa, Asia, and South America in terms of promoting urbanization and regional economic development.

Despite these positive results, the government-led urbanization model has also resulted in numerous problems, including low energy efficiency [6], environmental pollution [7,8], urban sprawl [9], inadequate public services [10], and non-inclusive economic growth [3]. Addressing these issues and transitioning from a focus on "high speed" to "high quality" development is crucial both for China and for other countries and regions worldwide. By learning from China's successes and challenges in its urbanization process, other developing countries can strive for more inclusive, sustainable, and healthy urban development.

Starting from March 2014, the Chinese government implemented the "National New-Type Urbanization Plan (2014–2020)", which proposed the concept of "new-type urbanization." This approach emphasizes the coordinated development of the population, economy, society, and ecology with a focus on people, emphasizing livelihoods, quality, and sustainability. This marks a shift in China's urbanization from the traditional path of land expansion and population migration to a new practice that is people-oriented, resource-intensive, and scientifically planned and that seeks to achieve coordinated urban–rural development [11]. Furthermore, aiming toward the goal of "basically achieving socialist modernization by 2030", China's "14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035" also explicitly states that from 2021 to 2030, China will continue to deepen the implementation of new urbanization and promote high-quality urban development.

Promoting new-type urbanization has emerged as a key focus in regional and urban economic research. Scholars have conducted empirical studies on the factors that influence the level of new-type urbanization development from a variety of perspectives, including industry [12], investment [13,14], technology [15,16], and political incentives, such as fiscal decentralization [17,18]. However, compared with traditional urbanization, new-type urbanization requires a more balanced consideration of multiple dimensions, including the population, economy, society, and ecology. This means that there is a competitive relationship among different aspects when allocating resources. For example, economic indicators may take priority over social and ecological indicators in the short term. In China's top-down government-led urbanization model, this relationship may be magnified or coordinated by different preferences of local governments. To clarify this relationship, the decision-making mechanisms of local governments and the performance of new-type urbanization should be incorporated into a unified analytical framework.

As is well known, China has a hierarchical management system in which superior governments largely determine the appointment, dismissal, and promotion of subordinate officials. Empirical studies have shown that there may be multiple dimensions to assessing performance standards. Among them, GDP growth rate, which is easy to quantify, serves as the main indicator for assessing officials' performance [19]. It serves not only as a standard for superior government to evaluate local performance, but also as a "capability signal" that local officials send to their superiors. The setting of the annual GDP growth rate target in the government's work report has been a key factor driving and influencing China's economic development since the reform and opening-up policy. In principle, governments at all levels determine economic growth targets based on historical GDP data, empirical trend extrapolation, macroeconomic forecasting, or estimates of potential growth rates. However, in reality, local governments often "add weight" to the target based on superior government goals when setting economic growth targets, motivated by the desire to demonstrate their performance and achieve promotion [20]. When the target deviates from the actual endowments of the region, local governments will face great pressure in promoting economic growth and will inevitably invest more resources. This will lead to a significant reduction in resource allocation in areas such as ecological protection and people's livelihood construction that conflict with economic growth, causing imbalanced resource allocation. This not only damages the quality of economic development, but also ignores investment in people's livelihoods, distorts government public financial expenditures, and thus affects the level of new-type urbanization.

Within the mechanism through which the setting of economic growth targets affects the development level of new urbanization, land transfer plays a critical regulatory role. On the one hand, land transfers represent a significant source of fiscal revenue for local governments, which can contribute to improving their investment in infrastructure construction and advancing urbanization. On the other hand, extensive land expansion can also result in urban sprawl, serious resource mismatch, and environmental pollution, thereby compromising the quality of urbanization [21]. From the perspective of fiscal expenditure, exploring the effectiveness of land transfer can help clarify the mechanisms through which typical local government behaviors influence the relationship between economic growth and new urbanization.

This paper thus constructs a development indicator system for new-type urbanization from six aspects: population development, the quality of the economy, society's quality of life, space intensification, environmental protection, and urban–rural integration. Using panel data from 30 provinces in China from 2005 to 2020, the study explores the impact of economic growth targets on the level of new-type urbanization in different regions and analyzes the pathways through which economic growth targets affect new-type urbanization in each of the six dimensions.

The possible contributions of this paper are as follows: first, it proposes a unified research framework for exploring the nonlinear relationship between economic growth targets and the level of new urbanization development, which expands the research perspective on the institutional aspect of new urbanization construction. Second, it regards public expenditure as a key bridge for the interaction between the two and introduces local land finance as a moderating variable to explore the mechanism of the effect of economic growth targets and new urbanization from the perspective of fiscal expenditure. Third, to further investigate the mechanism of the effect of economic growth targets and new urbanization, this paper explores the relationship between the six dimensions of new urbanization and economic growth targets and systematically analyzes the influencing mechanisms, refining the research on the way of promoting urbanization from the government intervention perspective. This not only expands our understanding of China's institutional mechanisms but also provides theoretical recommendations for promoting the productive and livable urbanization process in other countries around the globe from the perspectives of target management and public expenditure.

The rest of this paper is structured as follows: Section 2 provides a literature review and theoretical framework. Section 3 presents the econometric model and data description. Section 4 discusses the empirical results and analysis. Section 5 concludes with policy recommendations.

2. Literature Review and Hypothesis

2.1. Literature Review

Unlike traditional urbanization that focuses on population and land, the new-type urbanization is a new path that achieves high-quality economic development and promotes common prosperity, reflecting the quality aspect of urbanization. Given that the urbanization process in China is government-led and the behavior of local governments is constrained by central institutional incentives, local government incentives may affect the urbanization process by changing and constraining government behavior. In the literature on local government incentives and new-type urbanization, scholars have almost exclusively explored the impact mechanism from the perspective of fiscal decentralization. Therefore, this paper briefly reviews the research on the impact of fiscal decentralization on new-type urbanization because the impact mechanism has important implications for exploring the relationship between economic growth targets and new-type urbanization.

The relationship between fiscal decentralization and the development level of new urbanization is closely related, but there is no consensus in the academic community on how the two interact. Some scholars consider that fiscal decentralization has a significant promoting effect on new urbanization and that its mechanism is influenced by the government's resource control situation [17] and fiscal pressure [18]. Yang and Qiu (2019) found that the degree of fiscal decentralization and the level of new urbanization have an inverted U-shaped relationship and studied its mechanism [22]. Ding (2020) posited that the impact of fiscal decentralization on new urbanization is uncertain. Increasing the level of fiscal decentralization is important for urban infrastructure construction, but it has a negative impact on improving the supply of public services [23].

Although Qian and Weingast (1997) attributed China's strong government incentives to fiscal decentralization [24], Zhou (2007) argued that the pursuit of economic growth is the most fundamental and long-term source of incentives for local governments [25]. This is reflected in the clear annual economic growth targets set by higher-level governments, which both constrain and stimulate the subjective initiatives of lower-level governments, emphasizing economic construction at all levels of government. Furthermore, peer governments refer to and compete with each other in setting economic growth targets, leading to a "yardstick competition" and "promotion tournament" effect [26], further driving incentives. This approach has been widely adopted in 49 countries and regions as a macroeconomic management system and a means of promoting economic growth [27]. China has successfully maintained high-speed economic growth for nearly 30 years since the reform and opening-up period, largely attributed to the establishment and implementation of economic growth targets. Xu et al. (2018) found that economic growth targets drive actual economic growth and increase the contribution of capital and investment rates [28]. Liu et al. (2019) conducted empirical tests on urban samples, revealing that for every 1% increase in economic growth targets, regional investment significantly increased by approximately 0.44% [29]. Huang et al. (2015) studied foreign investment and found that for every 1% increase in economic growth targets, the level of foreign investment utilization in the region increased by approximately 0.34 percentage points. Thus, the role of economic growth targets in promoting "quantity" and "speed" growth cannot be underestimated [30].

Since 2010, China has entered a "new normal" stage of development, shifting from pursuing high-speed economic growth to high-quality development. As a result, economic research has started to shift its focus from "speed" to "quality" when examining the impact of economic growth targets on various development qualities. However, drawbacks of economic growth targets have become apparent. Xu et al. (2018) found that for every 1% increase in economic growth target, there is a 1% decline in economic development quality when studying different policy tools [28]. The methods of setting economic growth targets, such as the "layer by layer" and "hard constraint" methods, have distorted public spending [31], inhibited the upgrading of the local service industry structure [32], and slowed the improvement of total factor productivity [33]. In the "new normal" stage, economic structure optimization and upgrading require a shift from factor-driven and investment-driven growth to innovation-driven growth. However, Wang et al. (2021) found an inverted U-shaped curve relationship between economic growth targets and regional innovation. That is, when the economic growth target exceeds a certain value, it significantly inhibits regional innovation [34]. Additionally, because economic growth targets use GDP growth rate as a single performance measurement standard, local governments have pursued a "short, flat, and fast" development model, leading to radical urbanization [35]. When government pressure increases, environmental protection is often neglected, leading to a U-shaped relationship between economic growth targets and environmental pollution [36], enterprise environmental protection investment [37], and regional energy consumption scale and structure [27].

Both fiscal decentralization and economic growth targets are just types of government incentive mechanisms and have only an indirect effect on the development of new-type urbanization. The direct effect still needs to be achieved through specific government actions. A large number of research results have shown that the government can promote the development of new urbanization by increasing investment in scientific and technological innovation [15], attracting foreign investment [13], and promoting local industrial agglomeration [38]. However, attention should be paid to the degree of government intervention, and the government should play its role in improving the degree of marketization [39].

2.2. Theoretical Hypothesis

2.2.1. Economic Growth Targets and New-Type Urbanization

The establishment of an economic growth target during a specific period can motivate local governments to introduce a series of policies and support resources aimed at promoting economic growth. When the target is set within a reasonable range, local governments can gain a sense of control and confidence in achieving the economic growth target. After formulating corresponding policy measures, they can listen to various policy recommendations from higher authorities, actively carry out livelihood construction, focus on investment in technology innovation, ecological environment protection, and human capital, increase fiscal expenditure on people's livelihoods, and shift their focus to long-term economic development processes, thereby promoting sustainable economic development. Additionally, the attention given to long-term development allows the government to play a more significant role in promoting market self-regulation, correspondingly reducing the level of government intervention. At this point, as the economic growth target increases, the leading role of the market will gradually become prominent [40], and the construction and development of the population, economy, and ecological environment will advance in tandem, improving the level of new urbanization development. In this way, the growth target becomes a positive driving force.

When the economic growth target is too high compared with normal trends, however, the driving force will become pressure, which directly affects local officials who are subject to promotion performance assessments. To achieve significant economic growth within the year, on the one hand, the government will focus its efforts on changes in GDP and neglect long-term construction in ecology and livelihoods, sacrificing the quality of urbanization in pursuit of quantitative economic growth. On the other hand, to achieve the target within a year, the government will inevitably adopt short-term and quick-effect government intervention measures, such as continuously increasing the input of production factors and issuing stronger economic policies. As the target is raised, the government will increase its level of intervention, ultimately resulting in excessive land development [9], a low utilization rate of corporate production capacity [41], and crowding out of investment in the corporate environment [37], among other issues. These consequences will ultimately reduce the level of new urbanization development in terms of population, economy, ecological environment, urban–rural disparities, and other aspects. On the basis of this, this article proposes the following:

Hypothesis 1. *There is a nonlinear inverted U-shaped relationship between economic growth targets and the level of new-type urbanization.*

2.2.2. Economic Growth Targets, Public Fiscal Expenditure, and New-Type Urbanization

Public expenditures cover a wide range of areas, including education, science and technology, social security, and environmental protection. As a crucial instrument for local governments to pursue regional development, public expenditures play a direct role in promoting the level of new-type urbanization [42]. Setting economic growth targets within a reasonable range can boost local governments' economic development initiatives, encouraging them to mobilize various resources and methods to achieve development. As the completion of these goals is relatively easy, local governments are more adept at promoting economic sustainability while focusing on political policy incentives beyond GDP, such as the "dual carbon" plan, technological innovation, and the construction of people's livelihoods to showcase their achievements to higher authorities. To fully develop the economy, local governments inevitably increase total government spending while maintaining a reasonable expenditure structure. Public financial spending will increase together with constructive spending to promote new-type urbanization development.

When economic growth targets continue to increase and exceed a reasonable threshold, development momentum, however, turns into pressure. Local governments may then begin to pursue short-term economic interests, continuously increasing constructive fiscal spending to expand investment and production capacity, neglecting people's livelihood development, and squeezing out public expenditures. This phenomenon may lead to investment distortion [9] and inefficient resource allocation, hindering the development of new-type urbanization. Therefore, local governments should exercise caution when increasing economic growth targets and strive to maintain a balance between economic development and public expenditures to achieve sustainable new-type urbanization.

Hypothesis 2. *Public expenditures play a mediating role in the inverted U-shaped relationship between economic growth goals and the level of new-type urbanization development.*

2.2.3. Economic Growth Targets, Land Finance, and New-Type Urbanization

The relationship between land finance and urbanization has been a topic of debate in academic circles. On the one hand, some scholars argue that large-scale land transfers by local governments accelerate land urbanization [43] but can also create imbalances between the population and land area, resulting in problems such as "ghost cities" and urban sprawl. Additionally, the imbalanced price structure of land can inflate the semi-urbanization rate [44], which damages the sustainability of urban development [9,45]. On the other hand, some scholars have acknowledged the positive role of land finance in urbanization from the perspective of public expenditure. For example, Lin and Yi (2011) have argued that land finance increases public financial expenditure, thus promoting land urbanization in Jiangsu Province in China from a political economy perspective [46]. Similarly, Lu et al. (2019) have found that while land finance generally increases semi-urbanization, it can also weaken the effect of half-urbanization by raising public expenditure [47].

In this paper, we consider the role of land finance in the relationship between economic growth targets and new-type urbanization, which depends on the balance between its contribution to new-type urbanization through public expenditure and the harm caused by the distortion of the population-land relationship, as well as the magnitude of the various dimensions of new-type urbanization indicators. If the level of new-type urbanization brought about by land finance through public expenditure is too high compared with the structural imbalances that it causes, then land finance will have a negative effect on the inverted U-shaped relationship between economic growth targets and new-type urbanization. The inflection point will shift to a higher target level, the curve will flatten, and the negative effect will be delayed. Conversely, if the level of new-type urbanization brought about by land finance through public expenditure is low compared with the structural imbalances that it causes, then land finance will have a positive effect. It will shift the inflection point to a lower target level, the curve will flatten, and the negative effect will occur earlier. On the basis of this, the following two possible hypotheses are proposed:

Hypothesis 3. *Land finance negatively moderates the inverted U-shaped relationship between economic growth targets and new-type urbanization by increasing public expenditure, delaying the negative impact to a higher target level.*

Hypothesis 4. *Land finance positively moderates the inverted U-shaped relationship between economic growth targets and new-type urbanization, bringing forward the negative impact to a lower target level.*

2.2.4. Pathway Mechanisms

The impact of economic growth targets on new-type urbanization may be realized through the six dimensions of new-type urbanization, and their relationship needs to be further tested. Meanwhile, the various expenditures related to public spending, such as science, education, culture, health, social security, and environmental protection, need to be implemented through specific construction measures. This study investigates the pathways and mechanisms of their impact within this framework.

The following is a translation of the text into academic English using "new-type urbanization" and "economic growth targets" for the corresponding Chinese terms.

Economic growth targets and population development: The construction of infrastructure and public services is an important driving force for promoting population migration to cities [48,49]. An increase in economic growth targets within a reasonable range may stimulate local governments to be more proactive in infrastructure and public service development, improve transportation, and raise the levels of healthcare and education, thereby attracting rural and even out-of-province residents to migrate inward and improve population development. However, when the pressure to achieve economic growth targets is too great, investments in infrastructure and public services may be deferred or reduced in the short term, hindering population development.

Economic growth targets and economic quality: Innovation is an important engine for improving the quality of regional economic development. As economic growth targets increase, governments may increase subsidies and investment in corporate innovation to enhance the core competitiveness of their regions. However, when economic growth targets reach a certain limit, further increases may make governments subservient to GDP growth, leading them to adopt "quick and dirty" economic development strategies and gradually abandon long-term development methods such as technological innovation.

Economic growth targets and people's livelihoods: Social security is a fundamental project in urban construction that enhances citizens' social welfare and raises their living standards. When economic growth targets are relatively low, local governments may pay more attention to the sustainable development of people's livelihoods and social development, which also maintains their political reputation. Governments will prioritize the improvement of social security and employment protection, thereby raising people's living standards. However, when economic growth targets are set too high, social security may be neglected, and people's living standards may not be sustained.

Economic growth targets and spatial intensification: As economic growth targets increase, local governments are bound to use land transfers to increase revenue and carry out economic development. However, large-scale land transfers can directly lead to an imbalance between population and land area, resulting in urban sprawl, which is unfavorable for spatial intensification development.

Economic growth targets and ecological civilization: Energy structure reflects the use of clean and highly polluting energy in a region, and optimizing energy structure is conducive to ecological civilization progress. An increase in economic growth targets may cause governments to neglect the adjustment of energy structure, thereby affecting regional environmental levels.

Economic growth targets and rural–urban integration: Finance, as a manifestation of science and technology in public expenditure, has an important influence on rural–urban integration. In the primary stage of financial development, financial resources tend to concentrate in cities, leading to an increasing gap in technology, capital, and other resources between urban and rural areas, reducing rural–urban integration. However, as financial levels improve, financial resources begin to spread from cities to rural areas, narrowing the urban–rural gap and increasing integration [50]. An increase in economic growth targets may reduce a company's total factor productivity and financial technology innovation, thereby inhibiting financial development.

The research framework of this article is illustrated in Figure 1:

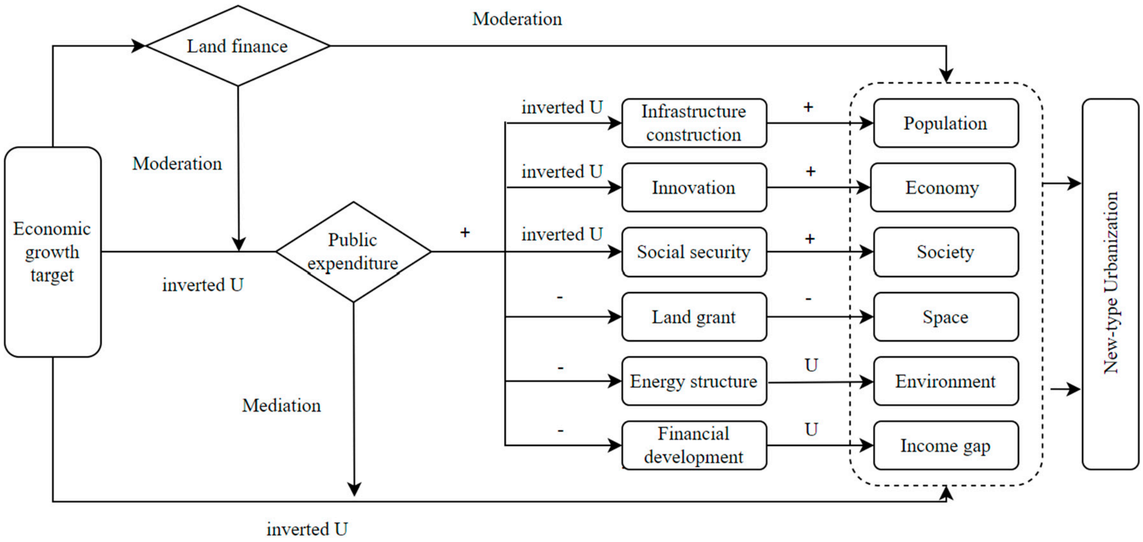

Figure 1. Research framework.

3. Materials & Methods

3.1. Model Settings

3.1.1. Benchmark Model

To test the nonlinear relationship between economic growth targets and the level of new-type urbanization, this study refers to Chai (2022) [27] and establishes the following model:

$$nurb_{it} = \beta_0 + \beta_1 target_{it} + \beta_2 target_{it}^2 + \sum \varphi X_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \tag{1}$$

where $nurb_{it}$, $target_{it}$, and X_{it} represent the level of new-type urbanization, economic growth targets, and other control variables of province i in year t, respectively. γ_i and λ_t are province fixed effects and year fixed effects, respectively, and ε_{it} is the random disturbance term. When $\beta_2 < 0$, there is an inverted U-shaped relationship between the two. Notably, owing to the large differences in sample data values, this paper takes the logarithmic form of the variables for regression.

3.1.2. Mediation Effect Model

This paper refers to MacKinnon (2000) [51] to test the mediating effect of public expenditure between economic growth targets and the level of new-type urbanization. The model is set as follows:

$$M_{it} = \theta_0 + \theta_1 target_{it} + \theta_2 target_{it}^2 + \sum \varphi X_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \tag{2}$$

$$nurb_{it} = \theta_0' + \theta_1' target_{it} + \theta_2' target_{it}^2 + \theta_3' M_{it} + \sum \varphi X_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \tag{3}$$

where M_{it} is the intermediate variable of government intervention, and the intermediate variable model consists of Equations (2) and (3). Equation (3) tests the effect of economic growth targets on the intermediate variable, while Equation (4) tests the effect of economic growth targets and the intermediate variable on new-type urbanization. There are two forms of the inverted U-shaped mediating effect model, and the other form is as follows:

$$M_{it} = \eta_0 + \eta_1 target_{it} + \sum \varphi X_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \tag{4}$$

$$nurb_{it} = \eta_0' + \eta_1' target_{it} + \eta_2' target_{it}^2 + \eta_3' M_{it} + \eta_4' M_{it}' + \sum \varphi X_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \tag{5}$$

There is a nonlinear relationship between the intermediate variable and the dependent variable.

3.1.3. Moderate Effect Model

To further investigate the impact of economic growth targets on the level of new-type urbanization and to examine the moderating effect of land finance on the overall relationship as well as the effect of public financial expenditure, the following interaction term between land finance and economic growth targets and its square are added to models (2) and (3):

$$pexp_{it} = \alpha_0 + \alpha_1 target_{it} + \alpha_2 target_{it}^2 + \alpha_3 target_{it} \times r\_price_{it} + \alpha_4 target_{it}^2 \times r\_price_{it} + \sum \varphi X_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \quad (6)$$

$$nurb_{it} = \alpha'_0 + \alpha'_1 target_{it} + \alpha'_2 target_{it}^2 + \alpha'_3 target_{it} \times r_{priceit} + \alpha'_4 target_{it}^2 \times r_{priceit} + \alpha'_5 pexp_{it} + \sum \varphi X_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \quad (7)$$

The variable r_price_{it} represents land finance. Haans et al. (2016) [52] stated that when $\alpha_4 > 0$, the moderating effect makes the original inverted U-shaped curve flatter, indicating a negative moderating effect. When $\alpha_1 \alpha_{4-} \alpha_2 \alpha_3 > 0$, the inflection point shifts to the right.

3.2. Description of Variables

3.2.1. Explanatory Variable: The Development Level of New Urbanization

On the basis of the theoretical connotation of new-type urbanization as human-centered, synergistic, inclusive, and sustainable, the new-type urbanization development level system established in this paper contains 27 indicators in six dimensions, as shown in Table 1: population development, quality of the economy, ecological civilization, people's quality of life, spatial intensification, and urban–rural integration.

Table 1. New urbanization development level index system.

Target	Dimension	Index	Direction
New-type urbanization level	Population development	Urbanization rate	+
		Unemployment rate	−
		Number of students enrolled in higher education per 100,000 population	+
	Economic quality	Per GDP	+
		Share of secondary and tertiary industries in GDP	+
		Fixed asset investment per capita	+
	Social life	Urban disposable income per capita	+
		Share of education spending in GDP	+
		Number of health technicians per 1000 population	+
		Number of beds in medical and health institutions per 1000 population	+
		Public transport vehicles per 10,000 people	+
		Public toilets per 10,000 people	+
		Library collection of 100 people	+
		Urban pension insurance coverage rate	+
		Urban unemployment insurance penetration rate	+
		Urban water access rate	+
		Urban gas penetration rate	+
	Space intensification	Built-up area	+
		Urban population density	+
		Paved road area per capita	+
	Ecological civilization	Urban wastewater treatment rate	+
		Green space per capita	+
		Greening coverage of built-up areas	+
		Pollution-free domestic waste disposal rate	+
		Industrial sulfur dioxide emissions	−
	Income gap	Income ratio between urban and rural residents	−
		Expenditure ratio of urban and rural residents	−

Population development: The urbanization rate shows the process of rural labor force concentrating in cities, and the proportion of urban resident population rises. The urban unemployment rate is both a consideration for the transfer of the rural population to cities and a measure of the substantive results of urbanization based on the employment rate, and the rural labor force must achieve employment after transfer to be considered urbanized. Gradually, the quality of the population is improved as the rural population is exposed to the educational resources in the cities, and the number of students in higher education per 100,000 population is used as an evaluation of the quality of the population.

Economic quality: Urbanization and economic development mutually interact and promote each other. In addition to GDP per capita, which measures economic growth, industrial restructuring, and fixed asset investment are important tools to promote economic construction and improve the quality of economic development.

Social life: The quality of people's lives is the direct manifestation of the "people-oriented" concept of new urbanization. The construction and protection level of regional public services is the key to reflecting whether the rural migrant population is truly integrated into the city. As the degree of social humanity increases, it becomes more attractive to the rural population, and people's sense of belonging becomes stronger.

Spatial intensification: The construction of new urbanization requires a scientific and compact spatial pattern. It means increasing the urban land area at the same time as the urbanization rate of the population rises so as to realize the balanced development of urban and rural areas. The built-up area, paved road area per capita, and population density reflect the spatial layout of urbanization.

Ecological civilization: The degree of ecological civilization reflects the sustainable development level of the new urbanization, and handling pollution and environment-friendly construction are two important criteria for evaluating the ecological livability of an area. In terms of pollution control, the pollution-free treatment rate of urban sewage and domestic garbage and sulfur dioxide emissions are selected, and for ecological protection, the area of green space in parks and the greening coverage of built-up areas are effective statistical factors.

Urban-rural integration: Urban-rural integration is a comprehensive, coordinated, and fair view of development, which emphasizes urban-rural equality to solve the dual-structure problem. This paper selects two indicators to evaluate the degree of urban–rural integration: the ratio of the income level of urban and rural residents and the ratio of the consumption level of urban and rural residents.

This paper adopts the entropy weighting method to calculate the weights of the indicators. The entropy method is an objective assignment method in the specific use of the process; according to the dispersion of the data of each indicator, the entropy weight of each indicator is calculated using the information entropy so as to obtain a more objective indicator weight. To a certain extent, it circumvents the bias of subjective factors.

To eliminate the influence brought by the index scale and unit, standardized dimensionless processing is carried out first. The specific steps are as follows.

For the indexes with larger entropy weights indicating a higher development level of new urbanization, the positive index calculation formula is used for processing, as in Equation (8).

$$X_{it} = \frac{x_{ij} - min\{x_{ij}\}}{max\{x_{ij}\} - min\{x_{ij}\}} \quad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{8}$$

When a larger entropy weight of the indicator indicates a lower level of new urbanization development, the negative indicator calculation formula is used for processing, as in Equation (9).

$$X_{it} = \frac{max\{x_{ij}\} - x_{ij}}{max\{x_{ij}\} - min\{x_{ij}\}} \quad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{9}$$

Calculate the weight of the indicator value of the *j* indicator in the *i* year.

$$r_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \tag{10}$$

Calculate the entropy value of the *j* indicator.

$$e_j = -\frac{1}{lnm}\sum_{i=1}^{m} X_{ij} \times lnX_{ij} \tag{11}$$

Calculate the coefficient of variability of the *j* indicator.

$$g_j = 1 - e_j \tag{12}$$

Calculate the weight of the *j* indicator.

$$\omega_j = \frac{g_i}{\sum_{j=1}^{n} g_i} \tag{13}$$

The final composite score of each indicator S_i.

$$S_i = \sum_{j=1}^{n} \omega_j X_{ij} \tag{14}$$

3.2.2. Explanatory Variables

Core explanatory variable: Following Chai (2022) [27], this study obtained economic growth targets from the annual government work reports released in January each year by 30 provinces in China.

Mediating and moderating variables: This study selected the sum of six categories of government public expenditures, including science, education, culture, health, social security and employment, and environmental protection, as measures of government public financial expenditure. The proportion of land transfer prices to government fiscal revenue was used as a measure of land finance.

Control variables: This study introduced control variables from the aspects of trade, financial development, regional innovation, infrastructure construction, energy structure, and wages. The ratio of total import and export trade volume to regional GDP was used as the trade factor (trade), the proportion of financial value-added to GDP was used as the local financial development level (fc), the number of patents per capita was used to measure regional innovation (ppat), traffic density was used to measure infrastructure construction (inf), the proportion of coal consumption to primary energy consumption was used as the energy structure (ES), and average employee wages were used as income status (wage).

3.2.3. Data Source and Description

The present study uses panel data from 30 provinces in China from 2005 to 2020. The variables are mainly obtained from government work reports, including the "China Statistical Yearbook", "China Environmental Statistical Yearbook", and other sources. Owing to changes in statistical methods, public fiscal expenditure data for the period from 2007 to 2020 were used, while land transfer data were obtained from the Land Market Network and aggregated at the provincial level. Missing data were imputed using linear interpolation and mean value methods. Descriptive statistics for all variables are presented in Table 2.

Table 2. Descriptive statistics of variables.

Variables	Obs	Mean	Std. Dev	Min	Max
nurb	480	0.288	0.099	0.089	0.633
target	480	9.227	2.045	3.800	15.000
pexp	420	1855.523	1362.883	101.347	8981.460
r_price	480	1.450	11.414	0.000	212.268
trade	480	28.824	32.573	0.711	166.816
fc	480	5.763	3.234	0.607	19.910
ppat	480	8.189	11.554	0.145	74.383
inf	480	89.268	51.043	4.267	222.542
ES	480	0.952	0.410	0.025	2.461
wage	480	5.018	2.758	0.739	17.818

Using the aforementioned indicators and entropy weighting method to obtain data, this study presents the development level of new urbanization in 2005, 2010, 2015, and 2020 in a visual form to observe changes and distribution characteristics. The results are shown in Figure 2.

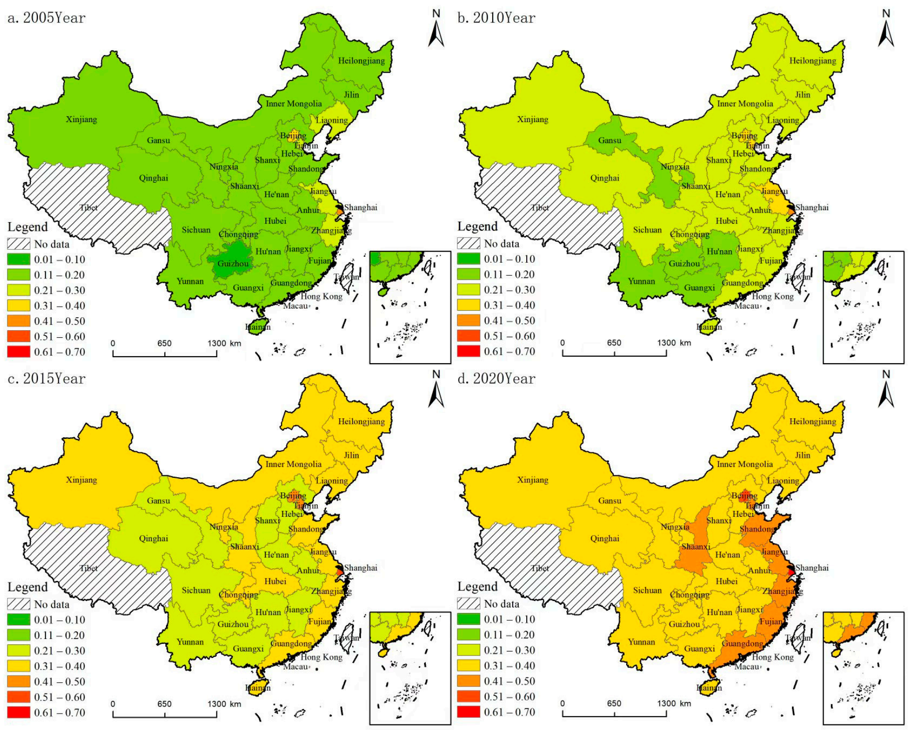

Figure 2. Development level of new-type urbanization.

From 2005 to 2020, the overall level of new-type urbanization gradually increased, with the new-type urbanization development level of the 30 provinces reaching above 0.3 in 2020. The regional distribution of the new-type urbanization level is also very evident, with Beijing, Tianjin, and the coastal provinces in eastern China maintaining a relatively high level of new-type urbanization development, while the provinces in central and western China have been developing more slowly and have always lagged behind the southeastern coastal areas. This visualization result provides a theoretical basis for the subsequent analysis of regional and temporal heterogeneity.

4. Results

4.1. Baseline Regression Result

Table 3 presents the baseline regression results of the relationship between economic growth targets and the new-type urbanization development level. The first column of Table 3 reports the results without control variables but controlling for province and time effects. The coefficient of the first-order term of economic growth targets is significantly positive at the 1% level, whereas the coefficient of the second-order term is significantly negative at the 1% level. Columns (2)–(4) gradually add control variables while controlling for province and time effects. The coefficients of the first- and second-order terms are still significantly different from zero at the 1% level, indicating a nonlinear inverted U-shaped relationship between economic growth targets and the new-type urbanization development level. Thus, hypothesis 1 is supported, indicating that the effect of economic growth targets on new-type urbanization is first to promote and then to inhibit. The inflection point is $X_1 = -\alpha_1/2\alpha_2 = 11.94$. It was found that 13.5% of the economic growth targets are above 11.94, and these provinces are mostly located in the central and western regions. Therefore, most of the economic growth targets currently formulated in China are in the promotion stage of new-type urbanization.

Table 3. Impact of economic growth targets on the level of urbanization development.

Variables	Nurb			
	(1)	(2)	(3)	(4)
target	0.0241 ***	0.0207 ***	0.0196 ***	0.0191 ***
	(7.848)	(6.728)	(6.607)	(6.396)
target2	−0.0011 ***	−0.0009 ***	−0.0009 ***	−0.0008 ***
	(−6.957)	(−5.913)	(−5.873)	(−5.721)
lntrade		0.0056 **	0.0075 ***	0.0078 ***
		(2.380)	(3.317)	(3.432)
fc		−0.0029 ***	−0.0032 ***	−0.0032 ***
		(−4.136)	(−4.809)	(−4.735)
ppat			0.0006 ***	0.0007 ***
			(5.416)	(5.697)
lninf			0.0351 ***	0.0351 ***
			(5.220)	(5.226)
ES				0.0064
				(1.165)
lnwage				0.0175 *
				(1.653)
_cons	0.0417 ***	0.0514 ***	−0.0713 **	−0.0802 ***
	(2.589)	(2.835)	(−2.491)	(−2.718)
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
N	480	480	480	480
R-sq	0.9695	0.9711	0.9737	0.9739

t-statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.2. Mechanism Analysis

4.2.1. Mediating and Moderating Effect

The inverted U-shaped relationship between economic growth targets and the level of new-type urbanization is directly related to government behavior, which intervenes in economic development by allocating different fiscal expenditures. Table 4 presents the mediating effects of public expenditure on this relationship in models (2) and (3). In model (2), which examines the effect of economic growth targets on public expenditure, the first-order coefficient is significantly positive at the 1% level, while the second-order coefficient is significantly negative at the 5% level. This suggests an "initial promotion, then suppression" inverted U-shaped relationship between economic growth targets and public expenditure. Column (2) examines the relationship between public expenditure and new-type urbanization and finds that public expenditure promotes the development of new-type urbanization and is significant at the 1% level. This indicates that public expenditure plays a partial mediating role in the inverted U-shaped relationship between economic growth targets and the level of new-type urbanization, as higher economic growth targets lead to increased government expenditure on people's livelihoods, which promotes the development of new-type urbanization but eventually results in a decline in its level. Therefore, hypothesis 2 is verified.

Table 4. Mediating and moderating effects.

Variables	Lnpexp	Nurb	Lnpexp	Nurb
	(2)	(3)	(6)	(7)
target	0.0586 ***	0.0129 ***	0.1147 ***	0.0202 ***
	(3.605)	(4.823)	(5.784)	(5.916)
target2	−0.0017 **	−0.0006 ***	−0.0042 ***	−0.0009 ***
	(−2.151)	(−4.758)	(−4.428)	(−5.854)
lnpexp		0.0523 ***		0.0436 ***
		(6.215)		(5.055)
c.target#c.r_price			−0.1061 ***	−0.0127 ***
			(−4.930)	(−3.456)
c.target2#c.r_price			0.0046 ***	0.0005 ***
			(4.863)	(3.423)
r_price			0.6134 ***	0.0731 ***
			(4.996)	(3.490)
_cons	3.6731 ***	−0.2848 ***	3.4410 ***	−0.2812 ***
	(14.067)	(−5.442)	(13.398)	(−5.433)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
N	420	420	420	420
R-sq	0.9889	0.9768	0.9897	0.9777

t-statistics in parentheses. ** $p < 0.05$, *** $p < 0.01$.

The regulatory effect of land finance in the first stage of mediation was examined, and after adding the cross-product terms of land and targets and their quadratic terms, the first- and second-order terms of economic growth targets on public expenditure passed the significance test at 1%, still showing an inverted U-shaped relationship. The coefficient of the square cross-product term between land finance and economic growth targets is significantly positive, indicating that the negative regulatory effect of government competition on the inverted U-shaped relationship between economic growth targets and new-type urbanization is significant, and the inverted U-shaped curve becomes flatter. According to the inflection point displacement discrimination, $\alpha_1\alpha_4 - \alpha_2\alpha_3 > 0$, indicating that the inflection point shifts to the right, the existence of land finance makes the reduction effect of economic growth targets on public expenditure occur at a higher level of economic growth target. As a moderated mediation model, land finance plays a negative regulatory role in the relationship between economic growth targets and new-type urbanization, making the overall inflection point shift to the right and the inhibitory effect of economic growth targets on new-type urbanization occurs at a higher level of economic growth target. This indicates that the positive impact of land finance through public expenditure outweighs its negative effects, such as land expansion. Thus, Hypothesis 3 is confirmed.

To visually demonstrate the moderating effect of the moderator variable on the inverted U-shaped relationship in the first stage of the mediation model, this study presents a quadratic function plot showing the shape and position of the inverted U-shaped curve at two levels of land finance, high and low (selected at the 25th and 75th percentiles, respectively), as shown in Figure 3.

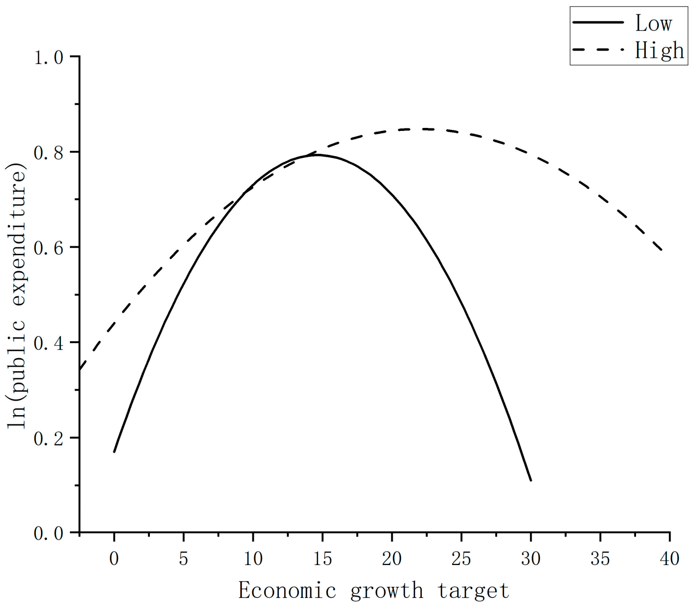

Figure 3. Moderating effect of land finance on public expenditure.

The above figure shows that as land transfer income increases, the turning point of the curve occurs at a higher economic growth target and a higher level of public expenditure. This indicates that through increasing financial revenue and expenditure, land finance also raises the level of public expenditure, causing the inhibitory effect of economic growth targets on public expenditure to occur at higher target levels.

4.2.2. The Pathway of Economic Growth Targets on New-Type Urbanization

On the basis of theoretical analysis and research hypotheses, this paper further examines the paths through which economic growth targets affect new-type urbanization from six aspects: population development, quality of the economy, people's livelihoods, spatial intensification, ecological civilization, and urban–rural integration, and explores the specific impacts of economic growth targets on these six dimensions. Table 5 reports the effects of economic growth targets on each component.

Table 5. Impact of economic growth targets on the six dimensions of new urbanization.

Variables	Popu	Eco	Soc	Space	Envi	Gap
target	0.0254 ***	0.0574 ***	0.0056	−0.0013	0.0282 **	0.0504 ***
	(4.065)	(7.387)	(1.505)	(−0.846)	(2.407)	(3.769)
target2	−0.0010 ***	−0.0028 ***	−0.0002		−0.0012 **	−0.0019 ***
	(−3.383)	(−7.319)	(−0.889)		(−2.093)	(−2.893)
_cons	−0.1519 **	−0.2014 ***	−0.0522	0.2061 ***	−0.1583	−0.6052 ***
	(−2.463)	(−2.621)	(−1.422)	(2.876)	(−1.369)	(−4.580)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
N	480	480	480	480	480	480
R-sq	0.8189	0.9579	0.8860	0.7973	0.9082	0.8555

t-statistics in parentheses. ** $p < 0.05$, *** $p < 0.01$.

The above models all include control variables that control for provincial and time effects. It can be found that in the dimensions of population development, quality of the economy, ecological civilization, and urban–rural coordination, there are significant positive coefficients for the linear term and significant negative coefficients for the quadratic term, indicating that there is an inverted U-shaped relationship between economic growth targets and the above four dimensions. However, the regression results of economic growth targets on people's livelihoods and spatial intensification are not significant, which is not consistent with the above hypothesis. Subsequent path analysis will not discuss the mediating mechanism in the dimensions of people's livelihoods and spatial intensification.

Path analysis indicates that the economic growth target mainly affects the new urbanization through four aspects: population development, economic quality, ecological civilization, and urban-rural coordination. When the economic growth target is raised within a reasonable range, the reasons for the improvement in population development, economic quality, ecological construction, and urban-rural coordination may come from two aspects. First, the means by which local governments promote economic growth include various aspects, such as increasing the urbanization rate, adopting green technologies, and narrowing the urban-rural gap. These means promote the development of the other three dimensions while enhancing the economy. Second, from the perspective of multiple political achievements, when officials estimate that strong incentive targets, such as GDP growth rates, can be achieved, they may allocate their efforts to other political achievements. Some aspects of population development, ecological construction, and urban-rural coordination may be the government's goals. However, when the economic growth target is set too high, the government overly focuses on short-term economic growth, which squeezes out resources from the other three aspects and also constrains the improvement of economic quality. Overall, there is actually a resource competition rather than a coordinated development relationship between economic growth and population development, economic quality, ecological construction, and urban-rural coordination. The reason why there is no significant effect on people's lives and space intensity may be due to insufficient incentives from the central government in these two aspects, which results in officials not paying attention to their development compared to other aspects, or there is no coordinated development or resource competition between economic growth and these two aspects. This provides evidence and inspiration for the relationship and trade-offs among various indicators of new urbanization.

4.2.3. The Pathway Mechanism Analysis

Columns (1) and (2) in Table 6 show the mediating effect of infrastructure investment on population development. The coefficient of the first-order term of economic growth targets is significantly positive at the 5% level, while the coefficient of the second-order term is significantly negative at the 10% level in Column (1), indicating that an increase in economic growth targets initially leads to an increase and then a decrease in infrastructure investment. In Column (2), infrastructure investment significantly promotes population development at the 1% level. Columns (3) and (4) show the mediating effect of regional innovation on the quality of the economy. The coefficient of the first-order term of economic growth targets is significantly positive at the 1% level, while the coefficient of the second-order term is significantly negative at the 1% level in Column (3), indicating that a rise in economic growth targets initially leads to an increase and then a decrease in innovation investment. In Column (4), regional innovation significantly promotes economic quality at the 1% level. Columns (5) and (6) show the mediating effect of energy structure adjustment on environmental protection. Economic growth targets suppress energy structure adjustment at the 1% level in Column (5), while the coefficients of the first-order and second-order terms of energy structure adjustment are significantly positive at the 1% level in Column (6), indicating a U-shaped relationship between energy structure adjustment and environmental protection. Columns (7) and (8) show the mediating effect of financial development on urban–rural coordination. Economic growth targets significantly suppress financial development at the 1% level in Column (7), while the coefficient of the second-order term of financial development is significantly positive at the 1% level, indicating a U-shaped relationship between financial development and urban–rural coordination.

Table 6. Pathway mechanism.

Variables	Lninf	Popu	Lnppat	Eco	lnES	Envi	Lnfc	Gap
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
target	0.0433 **	0.0254 ***	0.2669 ***	0.0574 ***	−0.0267 ***	0.0284 **	−0.0255 ***	0.0552 ***
	(2.028)	(4.065)	(4.637)	(7.387)	(−3.212)	(2.432)	(−3.099)	(4.190)
target2	−0.0017 *	−0.0010 ***	−0.0127 ***	−0.0028 ***		−0.0012 **		−0.0022 ***
	(−1.666)	(−3.383)	(−4.491)	(−7.319)		(−2.149)		(−3.328)
ppat	−0.0052 ***	−0.0018 ***		0.0041 ***	−0.0156 ***	−0.0025 ***	−0.0088 ***	−0.0042 ***
	(−6.363)	(−7.065)		(13.063)	(−9.587)	(−5.105)	(−5.286)	(−7.503)
lninf		0.0587 ***	0.6800 ***	0.0191	0.1064	0.0661 **	−0.0413	0.1912 ***
		(4.182)	(5.491)	(1.091)	(1.110)	(2.511)	(−0.441)	(6.424)
lnES						0.1059 ***		
						(4.717)		
lnES2						0.0269 ***		
						(4.583)		
lnfc								−0.0960 ***
								(−3.276)
lnfc2								0.0323 ***
								(3.068)
_cons	3.3472 ***	−0.1519 **	−4.2384 ***	−0.2014 ***	−0.0325	−0.0542	1.2503 ***	−0.5981 ***
	(24.343)	(−2.463)	(−7.912)	(−2.621)	(−0.088)	(−0.484)	(3.378)	(−4.615)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	480	480	480	480	480	480	480	480
R-sq	0.8738	0.8189	0.9446	0.9579	0.3474	0.9084	0.8316	0.8590

t-statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The results indicate that although local governments have certain discretion in governing local affairs, their behavior is constrained by the incentives set by the central government. The impact of economic growth targets on government behavior also reveals a "crowding-out effect" of the pursuit of economic growth by local governments on measures such as energy structure adjustment, financial development (which reflects the degree of regional marketization to some extent), and other related measures. With regard to infrastructure construction and regional innovation, within a reasonable range, pursuing economic growth goals can have a promoting effect. However, beyond a certain limit, the government will reduce investment in measures that have slow effectiveness, such as infrastructure and innovation incentives, and allocate more resources to promote economic growth.

4.3. Heterogeneity Analysis

4.3.1. Time Heterogeneity

In 2014, the Chinese economy entered the "new normal" phase, and the central government began to consciously lower its economic growth targets. On the one hand, the size of the Chinese economy had reached a certain scale and its growth had undergone structural deceleration, making it no longer realistic to pursue high growth rates. On the other hand, the central government gradually became aware of the drawbacks of rapid growth and began to transition from high-speed economic growth to high-quality development. At the same time, the concept of "new urbanization" was officially proposed in that year, and local officials responded to the call, striving to stand out and set an example in the movement of new-type urbanization construction in order to achieve promotion. Therefore, this paper takes 2014 as a time node and conducts empirical research on the data from 2005 to 2013 and from 2014 to 2020.

Table 7, Column (1) and (2) indicate that the effect of economic growth targets on new-type urbanization exhibits time heterogeneity. Prior to 2014, the impact of economic growth targets on new-type urbanization followed an inverted U-shaped curve, while after 2014, economic growth targets promoted the improvement of the level of new-type urbanization. This suggests that the relationship between the two factors changes with the evolution of central policies and priorities. Before 2014, economic growth was the core task, so GDP growth rate had a stronger incentive effect. Local officials often set higher growth targets to showcase their personal abilities, which led to excessive concentration of local government resources on a single indicator, causing the level of new-type urbanization construction to increase first and then decrease with the increase of economic growth targets. After 2014, high-quality development became the core task, and economic growth targets remained within a reasonable range. Local officials have been steadily promoting coordinated development in various areas of the region, thus ensuring the high-level development of new-type urbanization involving multi-dimensional efforts.

Table 7. Regional and time heterogeneity.

Variables	**Year < 2014**	**Year ≥ 2014**	**East**	**Middle**	**West**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
target	0.0210 ***	0.0016 *	0.0068 ***	0.0189 ***	0.0146 ***
	(2.806)	(1.746)	(4.878)	(2.918)	(4.006)
target2	−0.0008 **			−0.0009 ***	−0.0007 ***
	(−2.439)			(−2.660)	(−4.396)
_cons	−0.0863	0.1353	0.1135	0.1128 **	−0.0579
	(−1.652)	(1.553)	(1.454)	(2.092)	(−1.344)
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes
N	270	210	176	128	176
R-sq	0.9451	0.9392	0.9728	0.9907	0.9871

* *t*-statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.3.2. Regional Heterogeneity

The data suggest that the central and western regions of China have higher actual economic growth rates and growth targets compared to the eastern region. This is mainly due to the inclination of national regional development policies, acceleration in absorbing foreign investment, and concentration of advanced manufacturing industries, which are reflected in the GDP growth rate. However, the eastern developed regions may slow down their economic growth targets strategically due to the central government's preference for adjusting the regional economic structure towards underdeveloped areas, resulting in the phenomenon of higher growth targets in the west and lower targets in the east. Therefore, this paper divides China into three regions: east, central, and west, and conducts empirical research on the relationship between economic growth targets and new-type urbanization.

Table 7, Columns (3)–(5) show that the effect of economic growth targets on new-type urbanization has regional heterogeneity. In the eastern region, economic growth targets have a significant promoting effect on the level of new-type urbanization; in the central and western regions, the inverse U-shaped relationship remains, with promotion followed by suppression. This may be due to differences in regional economic development levels, where local governments at similar economic levels compete with each other. The task of underdeveloped regions in central and western China is to improve the economic level and narrow the regional economic gap. Therefore, the competition among local governments is focused on the GDP growth rate to showcase their political achievements. On the other hand, as the pioneers and demonstration areas of China's development, the eastern region should undertake the staged task of high-quality national development, simultaneously promoting the development of people's livelihoods, ecology, and other aspects while ensuring a certain level of economic growth. At this time, the competition for political achievements will be more reflected in other areas beyond economic growth.

This inference is also validated by the path analysis of the eastern region presented in Table 8. In the eastern region, economic growth targets have a significant promoting effect on the local ecology and people's livelihoods, indicating that after a certain level of economic development is achieved, local governments will pay more attention to the governance of non-economic affairs in the region. Although this emphasis may be attributed to the decisions and choices of local governments to some extent, it is mainly due to the issuance and incentive setting of non-economic policies by the central government.

Table 8. Path analysis of the eastern region.

Variables	Popu	Eco	Soc	Space	Envi	Gap
target	0.0362 **	0.0609 ***	0.0093 ***	0.0035	0.0191 ***	0.1029 ***
	(2.100)	(3.088)	(4.907)	(1.053)	(4.179)	(3.699)
target2	−0.0020 **	−0.0030 ***				−0.0059 ***
	(−2.271)	(−3.010)				(−4.120)
_cons	0.1959	0.6845 ***	−0.2510 **	0.3042	−0.1736	−0.2062
	(1.019)	(3.115)	(−2.365)	(1.636)	(−0.681)	(−0.665)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
N	176	176	176	176	176	176
R-sq	0.7483	0.9692	0.8761	0.8410	0.9010	0.7877

t-statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. * Since the results of the central and western regions are consistent with the overall results, they are not presented in the article.

4.4. Robustness Analysis

4.4.1. Regression with a Single Indicator as the Dependent Variable

As multidimensional indicators may suffer from problems such as multicollinearity, endogeneity, and masking of causal relationships between variables in causal analysis, this paper adopts a single indicator to represent the robustness test of the new urbanization results. Regardless of whether the pilot work of new urbanization progresses vigorously or the connotation of urbanization continues to enrich, it ultimately reflects the rural residents' migration to cities. Moreover, although China's urbanization is mainly driven by the government, residents still have the right to "vote with their feet". As the level of urban economic development improves, public infrastructure is optimized, and the public welfare system is improved, rural residents will spontaneously choose to migrate to cities [53]. Therefore, this paper selects population urbanization (urb), which measures the ratio of the number of urban residents to the total population of the region, as a single dimension measure of the new urbanization. The benchmark results and mechanism test results are shown in Table 9:

Table 9. Regression with a single indicator as the dependent variable.

Variables	Urb	Lnt_Exp	Urb	Lnt_Exp	Urb
	(1)	(2)	(3)	(4)	(5)
target	2.0263 ***	0.0586 ***	1.1210 ***	0.1147 ***	2.3425 ***
	(4.909)	(3.605)	(2.879)	(5.784)	(4.728)
target2	−0.0851 ***	−0.0017 **	−0.0508 ***	−0.0042 ***	−0.1043 ***
	(−4.203)	(−2.151)	(−2.656)	(−4.428)	(−4.454)
lnt_exp			7.2145 ***		5.7916 ***
			(5.887)		(4.634)
c.target#c.r_price				−0.1061 ***	−2.1056 ***
				(−4.930)	(−3.961)
c.target2#c.r_price				0.0046 ***	0.0913 ***
				(4.863)	(3.928)
r_price				0.6134 ***	12.1260 ***
				(4.996)	(3.996)
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes
_cons	12.9710 ***	3.6731 ***	−14.5281 *	3.4410 ***	−14.0345 *

Table 9. *Cont.*

Variables	Urb	Lnt_Exp	Urb	Lnt_Exp	Urb
	(1)	(2)	(3)	(4)	(5)
	(3.179)	(14.067)	(−1.907)	(13.398)	(−1.872)
N	480	420	420	420	420
R-sq	0.9300	0.9889	0.9335	0.9897	0.9367

t-statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.4.2. Robustness Test

This paper employed the variable substitution method to test the robustness of the model by introducing the lagged economic growth targets. The results of the test, as shown in Table 10, indicate that the significant results of the first- and second-order terms of the new-type urbanization level and its six dimensions remain the same after the variable substitution, demonstrating the robustness of the model.

Table 10. Robustness test.

Variables	Nurb	Popu	Eco	Soc	Space	Envi	Gap
L.target	0.0247 ***	0.0259 ***	0.0847 ***	0.0046	−0.0021	0.0299 **	0.0480 ***
	(7.362)	(3.507)	(9.590)	(1.085)	(−1.461)	(2.278)	(3.154)
L.target2	−0.0011 ***	−0.0010 ***	−0.0039 ***	−0.0002		−0.0012 **	−0.0015 **
	(−6.712)	(−2.802)	(−9.166)	(−0.775)		(−1.976)	(−2.109)
_cons	−0.1172 ***	−0.1306	−0.4013 ***	−0.1868 ***	0.3691 ***	0.6486 ***	−1.2408 ***
	(−2.844)	(−1.442)	(−3.702)	(−3.555)	(3.651)	(4.028)	(−6.636)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	450	450	450	450	450	450	450
R-sq	0.9752	0.8048	0.9602	0.8913	0.8002	0.9065	0.8675

t-statistics in parentheses. ** $p < 0.05$, *** $p < 0.01$.

4.4.3. Endogeneity Test

The endogeneity problem arises for two reasons: first, the explanatory variable and the dependent variable are mutually causal; and second, important explanatory variables are omitted. In this study, the government formulates corresponding growth targets based on the recent economic development status of the region, while the new-type urbanization development level involves multiple dimensions. When the government sets targets, it may also consider a certain factor of new-type urbanization, causing mutual causality between the two and resulting in the endogeneity problem.

Due to the fact that the formulation of economic growth targets in a given year is based on the previous year's targets and the actual GDP growth rate, but the previous year's economic growth targets and the actual GDP growth rate are not affected by the level of new-type urbanization in that year, it conforms to the setting of instrumental variables. Therefore, following the approach of Xu et al. (2018) [28], this study selects the lagged economic growth target and the lagged actual economic growth rate as instrumental variables and conducts two-stage least squares regression to re-examine the baseline results. As shown in Table 11 the results indicate that the first- and second-order terms of the economic growth target and the effect of public expenditure on new-type urbanization are still significant after introducing the instrumental variables and pass the significance test at the 1% level, indicating that the mediation effect model still holds.

Table 11. Endogeneity test.

Variables	Nurb	Lnpexp	Nurb
	(1)	(2)	(3)
target	0.0376 ***	0.1145 ***	0.0313 ***
	(7.760)	(4.217)	(6.500)
target2	−0.0017 ***	−0.0040 ***	−0.0015 ***
	(−7.463)	(−3.010)	(−6.689)
lnpexp			0.0440 ***
			(4.776)
_cons	0.0289	3.1011 ***	−0.0830
	(0.527)	(9.468)	(−1.358)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
N	450	420	420
R-sq	0.9855	0.9941	0.9878

t-statistics in parentheses. *** $p < 0.01$.

5. Conclusions

We use panel data from 30 provinces in China from 2005 to 2020 to investigate the role of economic growth targets in guiding and constraining new urbanization. The main findings are as follows: first, there is an inverted U-shaped relationship between economic growth targets and new urbanization. As the economic growth targets increase, new urbanization first increases and then decreases. Second, public expenditure plays a mediating role in the relationship between economic growth targets and new urbanization, as economic growth targets affect new urbanization through the inverted U-shaped relationship with public expenditure and the positive effect of government intervention on new urbanization. Land use, however, regulates the effect of public expenditure and causes the inflection point to occur at a lower level of economic growth target. Furthermore, the study examined the pathways through which economic growth targets affect new urbanization and found that economic growth targets affect new urbanization through infrastructure construction, population development, regional innovation, energy structure improvement, and financial development. We also explored the regional and temporal heterogeneity of the results and found that the inverted U-shaped relationship between economic growth targets and new-type urbanization was evident in the central and western regions before 2014 but not after 2012, while in the eastern region and after 2014, economic growth targets had a promoting effect.

Our study reveals both the positive and negative effects of economic growth targets on urbanization and the quality of economic development in China, providing a better understanding of China's institutional mechanisms. The use of economic growth targets as a measure of local officials' performance evaluation by the central government has increased the enthusiasm of local governments to develop the economy. However, the intensifying competition among officials for promotion has led to a focus on short-term profit-seeking behavior, neglecting long-term livelihood construction and hindering sustainable development. Despite these challenges, the "land-for-security" urbanization promotion method and China's government-led model have an important significance as referents for underdeveloped regions seeking to break away from low-productivity traps and achieve balanced urbanization.

Meanwhile, the article also provides insights for goal management in regional development strategies that involve multiple dimensions such as "new-type urbanization." Path analysis shows that there may be a certain resource competition between economic growth and population development, economic quality, ecological civilization, and rural-urban integration, with smaller relationships with people's livelihoods and spatial intensification. Therefore, the central government needs to control the economically led growth targets within a reasonable range to enable local governments to take into account multiple dimensions and achieve rational allocation of resources. For aspects of people's livelihoods and spatial intensification, which may not be affected by economic growth targets, the central government may introduce corresponding goals and incentive measures to ensure the balanced development of new-type urbanization in all dimensions.

The implications of China's urbanization experience for other countries, especially underdeveloped nations, cannot be overlooked. The positive role of land finance in promoting new-type urbanization through public expenditure, coupled with the potential negative effects of imbalances in the population–land relationship, provides a valuable lesson for other nations seeking to achieve balanced urbanization. Similarly, the challenges faced by China's economic growth targets and their impact on sustainable development highlight the importance of considering the long-term effects of policy decisions. As such, the lessons learned from China's urbanization can help guide other countries toward a more sustainable path of urban development.

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Optimizing Urban Stock Space through District Boundary Reorganization: Hangzhou's Administrative Adjustment

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Abstract: Since China is the largest developing country in the world, its urban reconstruction has significance for countries undergoing rapid urbanization. The recent development of its central cities has gradually changed from large-scale incremental expansion to stock optimization. District boundary reorganization has become a new trend in reforming China's administrative division of central cities. From the perspective of scalar reorganization and regional reconstruction, the adjustment of urban administrative divisions can be regarded as a regional construction strategy initiated by city governments to reshape the spatial structure, improve the governance relationship, and enhance the cities' competitiveness. This study takes Hangzhou, an important central city in eastern China, as a case study to illustrate two ways in which a central city can optimize its urban spaces through district boundary recombination: scale recombination and regional recombination. The findings demonstrate two advantages of district boundary reorganization for China's central cities: it eases the integration of new city districts and urban areas and promotes balanced development within the city. In the future, more Chinese cities will likely choose to reorganize their district boundaries.

Keywords: central city; scale restructuring; regional reconstruction; Hangzhou; urban administrative district adjustments

1. Introduction

Urban restructuring has become a significant topic worldwide. Different urbanization development and city reconstruction stages require different methods, and developed countries reach high urbanization levels at an early stage. Generally, cities in developed countries face problems such as municipal government bankruptcy, urban population decrease, urban economic decline, industrial iteration, and environmental pollution [1]. The main motive of urban spatial reconstruction is to avoid urban recession and maintain the sustainable growth of the urban economy [2]. Cities adopt urban spatial reconstruction and urban government reconstruction to manage those problems [3]. In Western and Northern Europe, some developed countries have adopted voluntary or compulsory merging to restructure urban areas, thereby reducing the degree of fragmentation of local governments and improving the economies of scale of public service supply [4–7]. However, in countries such as those in Africa and Southeast Asia, dividing administrative regions and redrawing administrative boundaries have become important ways of promoting urbanization development and meeting heterogeneous needs for public services [8–10]. In the United States, Canada, and Australia, urban administrative regions are frequently split and merged, and they adjust dynamically with the stage of urbanization development [11–14]. Restructuring administrative divisions is an important measure used to adapt to the stages of urbanization. The rapid urbanization in developing countries makes it necessary to adjust administrative divisions and develop rational plans and designs for urban spaces to meet the needs of urban populations [15].

Since China is the largest developing country in the world, its central government projects power into spaces through its administrative division management system. China's urbanization is carried out against the backdrop of economic and social transformation, globalization, and informatization. Compared with developed countries, the organizational form and power structure of the Chinese government mean that the reconstruction of urban space in China is dominated by the strong administrative power of the government; this is the most important feature of China's urbanization. Strong evidence for this can be seen in the fact that the adjustment of urban administrative divisions is frequent in China, whereas the reorganization of urban boundaries is rare in developed countries. However, this type of adjustment in China has effectively promoted urban development and economic growth. Therefore, it is necessary to investigate the influence path of urban administrative division adjustment on urban spatial optimization in China.

Specifically, administrative boundaries have a strong attribute of power in China. By the end of 2022, China's urbanization rate had reached 65.22% [16], reflecting the country's transition period of transforming urban space to promote economic and social development. Its central cities have now entered a new stage of development—from incremental expansion to inventory optimization [17].

Since 1978, China's central cities have generally reorganized their spaces by changing boundaries to meet urban development needs. As an important part of urban administrative division adjustment, district boundary reorganization promotes urban development from extensive regional expansion to refined spatial production, thus becoming the choice of many central cities in recent years. For example, in 2010, Beijing merged the Dongcheng and Chongwen districts into the new Dongcheng District and the Xicheng and Xuanwu districts into the new Xicheng District. Shanghai merged the Nanhui District and Pudong New Area into the new Pudong New Area in 2009, the Huangpu District of Luwan District into the new Huangpu District in 2011, and the Jing'an and Zhabei districts into the new Jing'an District in 2015. In 2014, Guangzhou merged the Huangpu and Luogang districts into the new Huangpu District. Thus, the research questions are as follows: How can urban stock space be optimized and the urban governance structure be reorganized? That is, how does the change in urban physical space boundaries shape the relationship between different levels of government and then affect the governance structure of the city? At the same time, what impact will the change of governance structure bring to urban space development? In this process, the population and resources are diverted to the outer urban areas, relieving the pressure on the urban center, making the urban spatial layout more reasonable, and promoting the development of urban suburbs and rural areas. To answer these questions, we must study the reorganization of regional boundaries and summarize the experience of urban spatial reconstruction in China.

The theories of scalar reorganization and regional reconstruction consider both physical and social space, having strong explanatory power for the changes in urban physical space (region) and social relations in space (scale) brought about by the reform of administrative divisions. This paper uses the theoretical tools of scalar and regional reorganization and takes Hangzhou as a case study to conduct a detailed analysis of the logic of central city district reorganization in China and its ability to optimize stock space (physical space) and reconstruct the governance structure (social space).

2. Theoretical Basis and Dimensions for Analysis

2.1. Theoretical Basis

The concept of scale comes from geography. In the globalized world, geographical space increasingly demonstrates the characteristics of "flowing space": fluidity and plasticity [18,19]. We can extend the concept of scale to measure differentiations in the geographical landscape, including physical spaces and social relationships in geographical spaces [20,21]. Scale theory focuses on the shift of power and control between different geographical scales and the rearrangement of institutions and changes in governance. Scalar reorganization refers to changes in and transfer of the organizational mode, with scale characteristics such as rank, scale, relationship, and power. Scalar reorganization involves "rescaling" the power structure, institutional arrangements, policymaking, and governance modes to form new political and economic scales [22,23].

In this paper, region refers to the space occupied by a specific subject. Harvey argued that capital must be attached to a specific space and that "regionalization" is capital that remains in a particular bounded space and regional organization [24]. The regionalization of capital is not once and for all but resolves the inherent contradictions of capitalism through repeated de-regionalization and re-regionalization, collectively referred to as regional restructuring. De-regionalization means that with the emergence of "flow space" (e.g., information, capital, and commodities), social and economic relations are separated from regions and administrative boundaries become blurred or even disappear, marking the disappearance of regionalism [25]. Re-regionalization refers to capital leaving the original regional social structure and reconstructing a region in a new political, social, and economic space. Regional restructuring starts with the regionalization of capital and circulates between de-regionalization and re-regionalization.

Scale and region recombination are two closely related concepts. As illustrated in Figure 1, capital is constantly attached to new regional spaces in regional restructuring. The attachment of capital causes changes in power and control in the regional space, namely, scalar restructuring, so that it can better meet the capital's requirements. The object of scale reconstruction is usually implemented in a specific regional space, so the regional reconstruction and scale reconstruction are closely connected, and the interaction between the two forms an integrated and two-sided process.

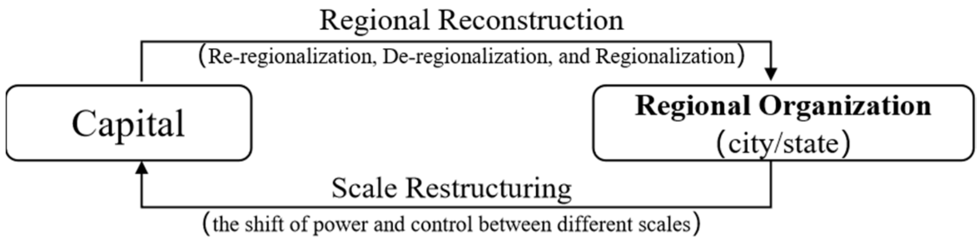

Figure 1. The relationship between scale restructuring and regional reconstruction [26].

2.2. Dimensions for Analysis

District boundary reorganization means adjusting the administrative divisions of a district based on the municipality's districts. It mainly involves the internal reorganization of municipal districts and the expansion of municipal and county districts [17]. There are several types:

1. A large range of mergers or the separation of one or several municipal districts;
2. Some towns and villages formerly belonging to counties or county-level cities are classified as being under the jurisdiction of municipal districts of central cities, or there is local fine-tuning between municipal districts;
3. Part of the administrative region is removed from the municipal district or the surrounding counties (county-level cities) and set up as a new municipal district [4];
4. Two or more municipal districts formerly belonging to prefecture-level cities are merged to form municipal districts directly under the central government.

Currently, Chinese cities with sufficient development space use options 1 or 2. The first involves a city's large-scale reorganization and regional reconstruction, especially its central urban area, which greatly impacts the urban governance structure. The second involves fine-tuning, which has less impact on the urban governance structure. Some scholars call category 1 "strong district boundary reorganization" and category 2 "weak district boundary reorganization" [27]. Currently, cities with insufficient urban development space struggle to set up districts by withdrawing counties (county-level cities); they are more likely to use option 3, appropriately reorganizing district boundaries to meet the needs of urban spatial development and avoid a large-scale withdrawal of counties (county-level cities). This paper will not discuss option 4 in detail since it is relatively rare, applies only to the specific period of establishing municipalities directly under the central government, and involves inter-municipal administration.

In the adjustment of urban administrative divisions, scale reorganization demonstrates that the urban government generates a new political system space and governance scale by reorganizing hierarchy, power, relationship, and scale, namely the reorganization of governance structure, focusing on the production of the political system space. Regional restructuring manifests itself as the generation of a new social economic space and regional organization by adjusting and reorganizing the boundaries of administrative divisions, which is the focus of the production of socio-economic space. Administrative division adjustment is a rigid scale adjustment tool; its occurrence period, main types, and power sources are embedded in the scale strategies adopted by countries or regions to enhance competitiveness and the corresponding scale reconstruction methods [28].

From the perspective of scale theory, the administrative level of the spatial unit is a special scale type; this is a unique perspective from which to study the relationships among the constituent units of administrative division adjustment [29]. Scholars use scale theory to explain changes in the administrative levels and physical spaces of Chinese cities [30], conduct classification research on the adjustment of urban administrative divisions at the scale level [31], and study the dynamic mechanisms and spatial influences of reforming urban administrative divisions in China [32]. However, many studies conduct process simulation and type interpretation only at the phenomenon level [33] and do not investigate urban administrative division reform over time and larger spatial dimensions. Furthermore, the deep logic research on the impact of administrative division reform on urban spatial production is insufficient.

The time and space of administrative division adjustment in central cities might differ under national and regional macro-strategy development; however, the logic of space production is roughly similar [34]. Most studies have focused on first-tier cities such as Beijing and Shanghai, largely ignoring second-tier cities such as Hangzhou and Nanjing. Therefore, this study's case study is Hangzhou, a vibrant central city in eastern China. In 2021, Hangzhou adjusted its administrative divisions by splitting large districts, merging small districts, upgrading functional districts into administrative districts, and including other forms of district boundary reorganization common in China's central cities. Hangzhou's administrative division adjustments provide abundant data for investigating urban space optimization through reorganizing district boundaries. The study conducted an in-depth analysis of Hangzhou's regional boundary reorganization from the perspectives of scalar reconstruction and regional reorganization, thus adding to the literature.

3. Materials and Methods

3.1. Case Study

China's local administrative regions are divided into four levels (Figure 2). The provincial units are subdivided into provinces, autonomous regions, centrally administered cities, and special administrative regions. The prefecture-level cities (orange block) under general provinces can be subdivided into districts (dark blue block), county-level cities (light blue block), counties, and autonomous counties. Our case study, Hangzhou, is a prefecture-level city in the northern part of Zhejiang Province in eastern China, the provincial capital of Zhejiang Province, and the central city of Hangzhou Metropolitan Circle.

As shown in Figure 3, Zhejiang Province is located in the eastern coastal area of China, while Hangzhou is located in the southwest of Zhejiang Province. It is the capital city and the largest city of Zhejiang Province. Hangzhou has jurisdiction over thirteen county-level administrative districts: ten districts (Shangcheng, Xiacheng, Jianggan, Gongshu, Xihu, Binjiang, Xiaoshan, Yuhang, Fuyang, and Lin'an), two counties (Tonglu and Chun'an), and one county-level city (Jiande). Since the 1990s, Hangzhou has experienced five adjustments of its administrative divisions. In 1996, three towns (Xixing, Changhe, and Puyan) were formed into a new district called Binjiang. In 2001, 2014, and 2017, four county-level cities, Xiaoshan, Yuhang Fuyang, and Lin'an, were divided into the districts of Hangzhou, and Hangzhou's urban area expanded from 430 km^2 to 8000 km^2. The administrative division adjustment during 1996–2017 expanded the development space of the main city by creating county-level city municipal districts, laying the foundation for coordinating the urban system patterns [35].

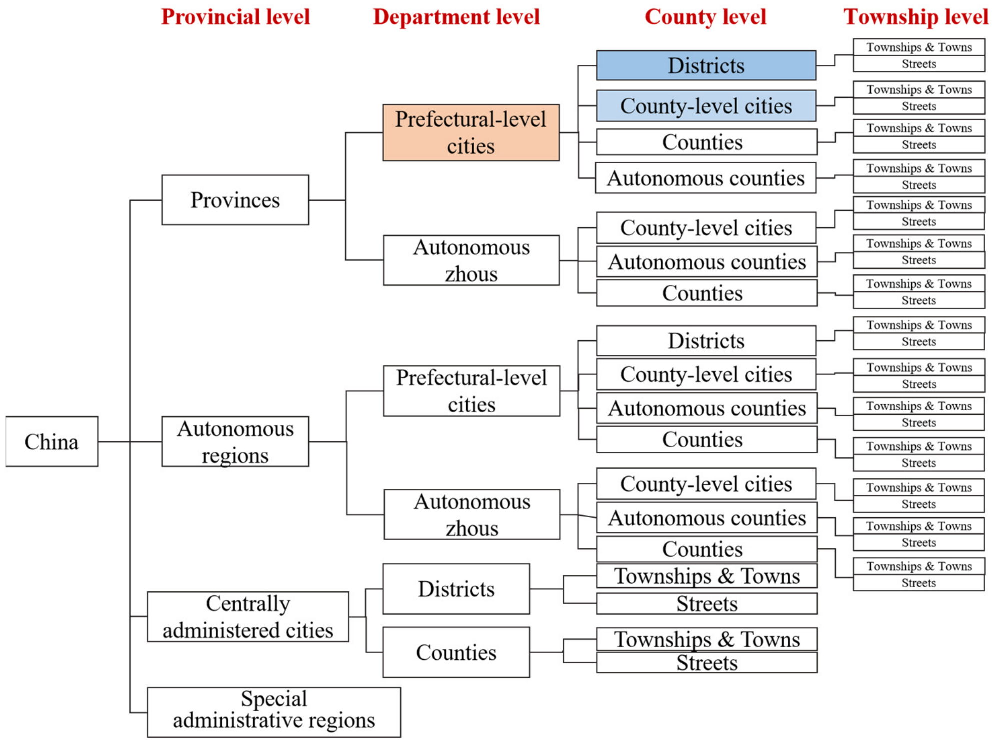

Figure 2. Administrative divisions in China.

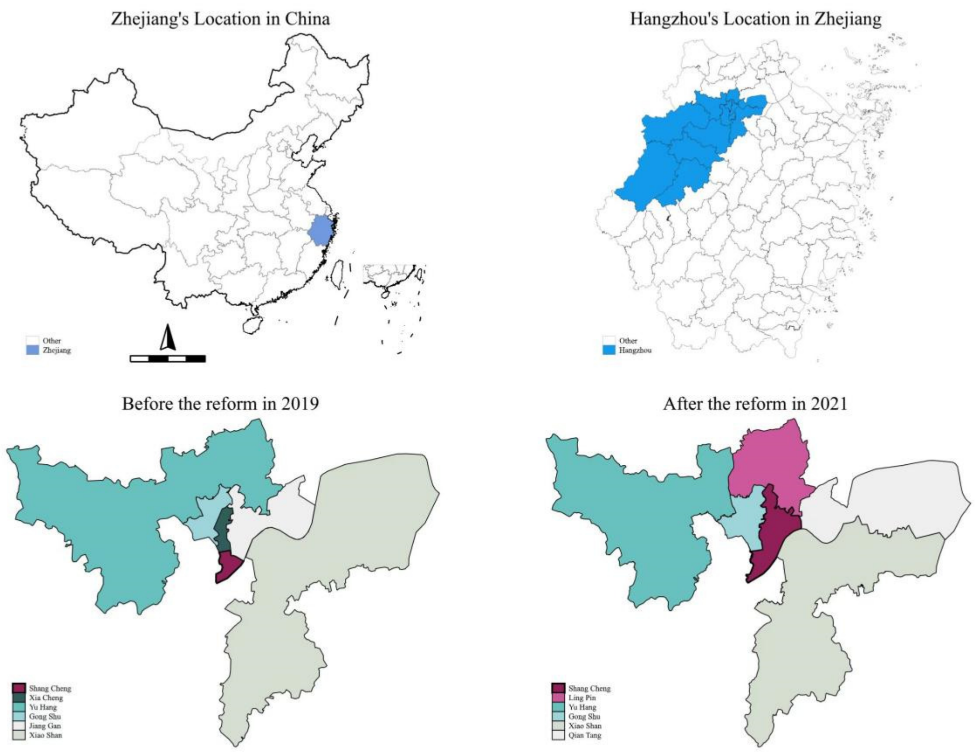

Figure 3. Before and after the reorganization of Hangzhou's district boundaries in 2021.

Chinese cities are moving from external macroscopic and regional restructuring to internal microcosmic and regional restructuring [36]. After the four administrative division adjustments, Hangzhou became the largest city in the Yangtze River Delta urban agglomeration. However, the city's structural contradictions became increasingly prominent; there was a mismatch between area and scale. Therefore, in April 2021, Hangzhou implemented a fifth administrative division adjustment. As shown in Figure 3, this restructuring readjusted the district boundaries, merging the Shangcheng and Jianggan Districts to form the Shangcheng District and merging the Xiacheng and Gongshu districts to form the Gongshu District. It also split the Yuhang District into the Yuhang and Linping districts, with the Beijing–Hangzhou canal as the boundary. Finally, it upgraded the Qiantang New Area to the Qiantang District, which included the Xiasha District (once part of the Jianggan District) and Dajiangdong District (once part of the Xiaoshan District) [37].

3.2. Research Methods: Content Analysis, Literature Review, and Interviews

This study used the case study method and data obtained from a field investigation in Hangzhou. Before and after the adjustment of administrative divisions (2020, 2021, and 2022), we traveled to Hangzhou for data collection and observation. We observed the administrative division adjustment process to collect first-hand data such as application and approval plans, risk assessment reports, approval process information, complaint and visit stability maintenance work plans, and information from public opinion solicitation forums in each municipal district of Hangzhou in 2021. From the Hangzhou City Planning Exhibition Hall, we obtained the statistical yearbook of various municipal districts of Hangzhou, newspapers and archives of Zhejiang Province and Hangzhou, overall plans of Hangzhou city, the adjustment process of administrative divisions since 1996, a history of urban development, and other materials. As shown in Table 1, we interviewed government staff who had participated in Hangzhou's administrative division adjustment, including representatives from the Hangzhou Municipal Government Office, Hangzhou Civil Affairs Bureau, Hangzhou Municipal Planning Bureau, and Hangzhou Municipal Public Security Bureau; and relevant staff from the Gongshu, Shangcheng, Yuhang, Linping, and Qiantang districts.

Table 1. Interview data regarding the Hangzhou District boundary reorganization.

<table>
<tr><th>Interview Record Coding</th><th>Department</th><th>Position</th><th>Interview Form</th><th>Date</th></tr>
<tr><td>20191102AASH</td><td>Hangzhou Municipal Government Office</td><td>Secretary</td><td>One-to-one semi-structured interview</td><td>2 November 2020</td></tr>
<tr><td rowspan="6">20200705BAM</td><td>Hangzhou Municipal Government Office</td><td>Secretary</td><td rowspan="6">Group semi-structured interview</td><td rowspan="6">5 July 2020</td></tr>
<tr><td>Hangzhou Civil Affairs Bureau</td><td>Office manager</td></tr>
<tr><td>Hangzhou Civil Affairs Bureau</td><td>Office clerk</td></tr>
<tr><td>Hangzhou Municipal Planning Bureau</td><td>Office manager</td></tr>
<tr><td>Hangzhou Municipal Planning Bureau</td><td>Office clerk</td></tr>
<tr><td>Representatives from Gongshu, Shangcheng, Yuhang, Linping, and Qiantang districts</td><td>Office managers</td></tr>
</table>

Table 1. *Cont.*

Interview Record Coding	Department	Position	Interview Form	Date
20200706BBX	Xiaoshan Municipal Government Office	Secretary	Group semi-structured interview	6 July 2020
	Xiaoshan Municipal Public Security Bureau	Office manager		
	Xiaoshan Civil Affairs Bureau	Office manager		
	Xiaoshan Municipal Bureau of Finance	Office manager		
	Xiaoshan Municipal City Administration Commission	Office manager		
20200708BBX	Xiaoshan Municipal City Administration Commission	Office manager	Group semi-structured interview	8 July 2020
	Xiaoshan City Brain Project Department	Project leader		
	Xiaoshan City Brain Project Department	Project clerk		
20210106BBF	Fuyang Civil Affairs Bureau	Office manager	Group semi-structured interview	6 October 2021
	Fuyang Municipal Bureau of Finance	Office manager		
	Fuyang Municipal City Administration Commission	Office manager		
	Fuyang Municipal Planning Bureau	Office manager		
20210106ABFL	Fuyang Civil Affairs Bureau	Office clerk	One-to-one semi-structured interview	6 October 2021
20210314AAMZ	Hangzhou Civil Affairs Bureau	Office manager	One-to-one semi-structured interview	14 March 2021
20210314AAMY	Hangzhou Civil Affairs Bureau	Office clerk A	One-to-one semi-structured interview	
20210314AAMS	Hangzhou Civil Affairs Bureau	Office clerk B	One-to-one semi-structured interview	
20210714BBG	Gongshu Civil Affairs Bureau	Office manager	Group semi-structured interview	14 July 2021
	Gongshu Municipal Bureau of Finance	Office manager		
	Gongshu Municipal City Administration Commission	Office manager		
	Gongshu Municipal Planning Bureau	Office manager		
20220716BBQ	Qiantang Civil Affairs Bureau	Office manager	Group semi-structured interview	16 July 2022
	Qiantang Municipal Bureau of Finance	Office manager		
	Qiantang Development and Reform Commission	Office manager		
	Qiantang Municipal City Administration Commission	Office manager		

We conducted six symposia and nine in-depth interviews. Our interviews included the following questions:

1. What is the reason for the boundary reorganization?;
2. What must be done to split/merge municipal districts and upgrade functional areas into administrative districts? Who is responsible for this?;
3. What changes to government institutions and power distribution will occur after the change in the scale of municipal districts?;
4. During the ongoing transition period, the finances will still be under the direct management of Zhejiang Province, with the financial stock still belonging to Zhejiang Province and the increased part belonging to Hangzhou. What impact will the reorganization of the boundaries have on the original transitional policy?;
5. What impact will the reorganization bring?;
6. What impact will the reorganization of district boundaries have on urban planning?

4. Results of Case Analysis

4.1. Reasons for District Boundaries Reorganization in Hangzhou

There were three main reasons for the Hangzhou District boundary reorganization. First, the disparity in the municipal districts' areas was not conducive to balanced development. The ten districts under the jurisdiction of Hangzhou differed significantly in area, population scale, and economic aggregates. Small areas such as Shangcheng and Xiacheng were only 20 km^2, while the areas of the largest cities (Xiaoshan, Yuhang, Fuyang, and Lin'an) were above 1000 km^2; the largest, Lin'an, had an area above 3000 km^2. The central urban area was too small and the development space insufficient to meet the needs of the increasing population, industry, infrastructure, and other factors. The vast outer urban area had abundant land stock resources, hindering the balanced distribution of public services and industrial resources, and this problem needed to be resolved.

Second, the limited distribution of resources was not conducive to industrial upgrading. Among the six districts of Hangzhou, Shangcheng, Xiacheng, Jianggan, and Gongshu, the old core cities were geographically adjacent; Yuhang and Qiantang became districts in 2021. Tertiary industries had been developed to create industrial isomorphism, including trade, tourism, and manufacturing. Yuhang District had manufacturing facilities in the east and high-end scientific and technological innovation industries in the west. Xiasha Industrial Park and Dajiangdong Industrial Park in the Qiantang New District were problematic because, as one official said, "some people have no industry, while others have industry but no human resources".

Third, the administrative barriers were not conducive to the flow of goods and services. In the mid-1990s, Hangzhou formulated the strategic "Yongjiang Development" plan to determine the city's eastward expansion. With the city's development, the new and old cities gradually developed into a cross-administrative form that did not facilitate the integration of old and new areas. The existence of administrative barriers impeded the free flow of production factors.

Scale politics describes "the struggle for the absolute control of local, regional, and spatial control" in urban geography and regional governance studies [21]. The adjustment of urban administrative divisions is a scale political event dominated by the central city government and characterized by strengthening the administrative control of the central city and the regional reorganization of horizontal regionalization. The essence of the adjustment of the urban administrative divisions is a process of scale reengineering and regional reconstruction that is also a process of regional construction initiated by the central city government to increase the city's competitiveness through the regionalization of capital. As a subregional construction, Hangzhou's boundary reorganization delimited the new regional organization by administrative means to complete the reconstruction of the geographical space. Then, it rearranged the power and systems in the new regional organization to promote the de-regionalization and re-regionalization of capital [38–40].

4.2. Scale Restructuring: Reshaping of Power Structure and Upgrading of Governance Structure

Depending on the completion stage of the power reconstruction of the regional organization, the scale reconstruction of urban administrative divisions can be divided into complete and incomplete scale reconstruction [26]. The goal of the Hangzhou District boundary reorganization was to establish a governance structure and system on the scale of municipal districts. As shown in Table 2, this reorganization of district boundaries did not change the administrative level and subordination of each city. The most striking changes were in the Xiaoshan, Yuhang, Fuyang, and Lin'an districts, which were divided into districts by county-level cities in the early years. At that time, Hangzhou agreed to remove the county-level cities gradually to ensure a smooth adjustment period. During the ongoing transition period, the removed county-level cities continue to maintain provincial administration of finance and county management while enjoying a high degree of autonomy in planning, transportation, education, medical care, and other responsibilities.

Table 2. Scale restructuring in the reorganization of the Hangzhou District boundaries. *

<table>
<tr><th colspan="2">District</th><th rowspan="2">Executive Power</th><th colspan="3">Spatial Scale (km^2)</th><th colspan="2">Government Location</th></tr>
<tr><th>Before</th><th>After</th><th>Before</th><th>After</th><th>Variation</th><th>Before</th><th>After</th></tr>
<tr><td>Shangcheng</td><td rowspan="2">Shangcheng</td><td rowspan="6">No change</td><td>18</td><td rowspan="2">122</td><td rowspan="4">Increase</td><td>77 Wangchao Road, Wangjiang Street</td><td rowspan="2">77 Wangchao Road, Wangjiang Street</td></tr>
<tr><td>Jianggan</td><td>210</td><td>1 Qingchun East Road, Sijiqing Street</td></tr>
<tr><td>Xiacheng</td><td rowspan="2">Gongshu</td><td>31</td><td rowspan="2">119</td><td>200 Qingchun Road, Wulin Street</td><td rowspan="2">1 Taizhou Road, Gongchen Bridge Street</td></tr>
<tr><td>Gongshu</td><td>88</td><td>10 Zhuetan Lane, Hushu Street</td></tr>
<tr><td colspan="2">Xihu</td><td colspan="2">263</td><td rowspan="2">No change</td><td colspan="2">1 Zhejiang University Road, Lingyin Street</td></tr>
<tr><td colspan="2">Binjiang</td><td colspan="2">73</td><td colspan="2">100 Jiangnan Avenue, Xixing Street</td></tr>
<tr><td rowspan="2">Xiaoshan</td><td>Xiaoshan</td><td>Remains unchanged and then decreases *</td><td>1163</td><td>931</td><td>Decrease</td><td colspan="2">685 Jincheng Road, Beigan Street</td></tr>
<tr><td>Qiantang</td><td>Increases in power</td><td>—</td><td>338</td><td>No change</td><td>—</td><td>499 Qingliu North Road, Hezhuang Street</td></tr>
<tr><td rowspan="2">Yuhang</td><td>Yuhang</td><td rowspan="4">Remains unchanged and then decreases</td><td rowspan="2">1222</td><td>940</td><td rowspan="2">Decrease</td><td rowspan="2">33 Xida, Linping Street</td><td>1500 Wenyi West Road, Cangqian Street</td></tr>
<tr><td>Linping</td><td>282</td><td>33 Xida, Linping Street</td></tr>
<tr><td colspan="2">Fuyang</td><td colspan="2">1808</td><td rowspan="2">No change</td><td colspan="2">25 Guihua Road, Fuchun Street</td></tr>
<tr><td colspan="2">Lin'an</td><td colspan="2">3124</td><td colspan="2">398 Yijin Street, Jincheng Street</td></tr>
</table>

* During the ongoing transition, the finances remain under the direct management of Zhejiang Province, with the financial stock belonging to Zhejiang Province and the increased part belonging to Hangzhou.

The transitional period effectively avoids the contradictions and conflicts related to subsuming the county-level cities into districts. However, it also obscures some of the complications. More than 20 years after Xiaoshan and Yuhang became part of its municipal district, Hangzhou still has not integrated these two cities into the main city. The adjustment splitting Yuhang District erased the geospatial scale on which the transitional system was based. Meanwhile, it assigned new scales to the new Yuhang and Linping districts and created two new municipal districts that gradually transitioned from financial "provincial management of counties" to "provincial management of counties in stock and municipal management of districts in increment". This new scale was extrapolated to Xiaoshan, and since the integration of county-level cities into districts, the transitional system was improved, further strengthening the control over these peripheral municipal districts.

First, the scale balance has been realized horizontally and the power structure of each city reshaped. The complete scale recombination can be subdivided into three categories:

1. Yuhang District was split into the new Yuhang and Linping districts. Hangzhou established a city-district-level governance structure in the two new regional organizations, giving administrative power at the district level to the two administrative districts. The regional scope of power is smaller, but that does not mean less control over regional organizations; the New Yuhang and Linping districts have their own power at the municipal district level, and a complete governance system has been built.
2. In the main cities of Hangzhou, Shangcheng, and Jianggan, Xiacheng and Gongshu were merged. The original two district levels were integrated into one. The power structure and system did not change. After the merger, the regional organization of the power function of the new municipal district system was wider, but it did not affect the control of Hangzhou over each municipal district.
3. The Qiantang New Area belongs to the all-controlling management committee, which manages the economic and social affairs in the region in a unified way. Some scholars call functional areas such as the Qiantang New Area "quasi-administrative regions". Although the Qiantang New Area has partially reconstructed its multidimensional administrative, spatial, and industrial relations, its scale reconstruction remains incomplete because of the boundary of the administrative division. In the adjustment, the district-level scale was assigned to the regional organization of the Qiantang District, completing its scale reconstruction, realizing the complete adherence of scale to the regional organization, and optimizing the governance structure and function of the former Qiantang New Area [41].

Second, the adjustment completed the scale adaptation vertically and upgraded Hangzhou's governance structure. In the first 20 years, Xiaoshan, Yuhang, Fuyang, and Lin'an were included in the urban map of Hangzhou, which has achieved rapid urban area and development space expansion. At the same time, the upgrade poses challenges to integrating new and old urban areas. From the view of the nationwide withdrawal of counties or integrating county-level cities into districts, there are several problems in certain areas, such as a large gap in the urban management level between central and peripheral urban areas; an uneven quality of public services; inadequate and unbalanced use of space, which requires the re-division of the internal power structure of the city; and the adjustment and reshaping of the governance structure to meet needs [42–44]. This district boundary reorganization focused on resolving the differences in the size of Hangzhou's municipal districts. Regionally cutting and reorganizing the municipal districts changed the power scale, reshaped each municipal district's power structure, strengthened Hangzhou's control over the municipal district, matched the power scale more to the regional scale, and reshaped and upgraded Hangzhou's governance structure.

4.3. Regional Reconstruction: Optimization of Resource Elements and Urban Structure Transformation

Effective ways to optimize and integrate the resource elements of urban development on the micro-scale are scale reorganization among municipal districts' allocation of resources, expanding the urban scale, and transforming urban structure. After reorganizing district boundaries, Hangzhou has jurisdiction over ten districts; however, new regional organizations have emerged in the city and district scales—new Hangzhou and several new municipal districts. Among them, Binjiang, Xihu, Fuyang, and Lin'an districts have the same regional scale. In contrast, Shangcheng, Gongshu, Xiaoshan, Yuhang, Linping, and Qiantang have all become new regional organizations at the district level.

First, to promote regional restructuring, Hangzhou carried out industrial optimization and collaborative layout, focusing on optimizing the urban structure of the eastern and western parts of the city. As shown in Figure 4, focusing on the high-tech industry, the western part of the city focused on the innovation corridor platform, human resources, policies, and mechanism innovation to lead future economic development. The eastern part of the city relies on abundant higher education resources, high-end and intelligent manufacturing, and e-commerce. The eastern and western parts of the city should advance together, and the re-regionalization of capital should be promoted to create the high-quality development of the digital economy and manufacturing. The Yuhang and Linping districts have been divided geographically; according to their different development priorities, the re-regionalization of capital has been completed. The Yuhang District relies on the Science and Technology Innovation Corridor to develop high-end scientific and technological innovations and the digital economy. It focuses on digital industrialization, including artificial intelligence, cloud computing, and Big Data; emerging frontier industries, such as the metauniverse and quantum technology; and new business forms such as the digital economy and Smart Cities. The Linping District will connect workshop production equipment for biomedicine, home textiles, and equipment manufacturing to the industrial internet digital platform through 5G technology to accelerate industrial digitalization. The Qiantang New Area has been upgraded from an incomplete scale to a full-scale Qiantang District. Although the regional spatial entity has not changed, the power structure and relations have been reshaped systematically. The identity transformation from a functional area to an administrative region has made this district significantly more attractive to capital. Five leading industries (semiconductors, life and health, intelligent automobiles and intelligent equipment, aerospace, and new materials) have begun to take shape.

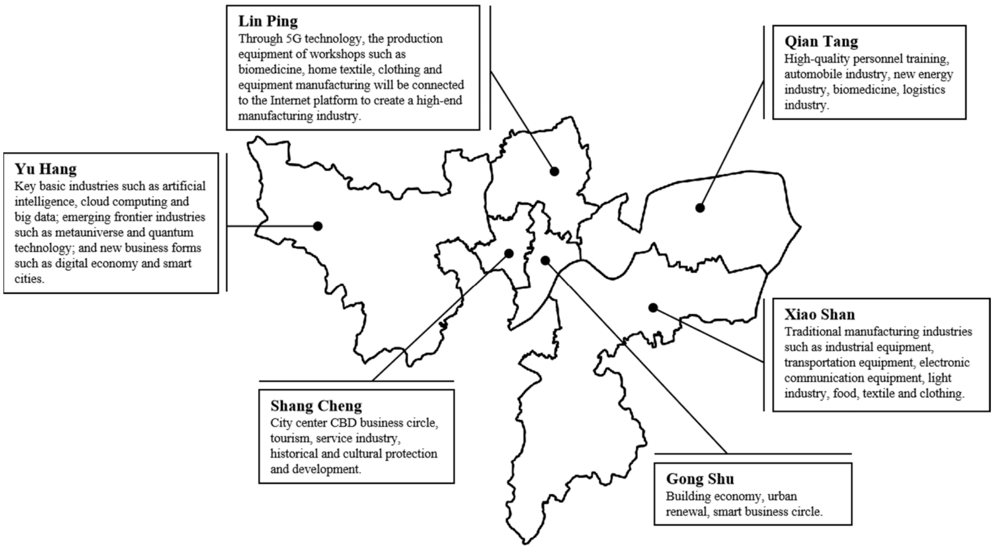

Figure 4. Industrial layout of Hangzhou.

Second, Hangzhou promotes the construction of transportation and communication infrastructure for the regional reconstruction of capital to improve the urban construction environment, break barriers, and increase the speed of capital flow. Constructing transportation and communication facilities has the powerful effect of "space-time compression", which can change traditional social relations; strengthen personnel interactions, economic liaisons, factor flows, and other spatial connections between the central urban area and the new jurisdiction; and promote the scalar reconstruction of capital. Following the layout of "one main city, three secondary cities, and six clusters", Hangzhou has planned and built more than twenty new cities and more than one hundred urban complexes along the bank of the Qiantang River, including Qianjiang Century City, Zhijiang New City, Xianghu New City, Binjiang New City, and Airport New City.

In a functionally integrated but geographically dispersed production network, the smooth flow of information and materials is key to ensuring the continuity of the production process and improving production efficiency, so the construction of circulation space is particularly important. *Circulation space* mainly refers to urban roads and other transportation infrastructure. Hangzhou will extend Jiefang Road east to Qianjiang New City; construct the Qingchun Road tunnel, Zizhi Tunnel, Wenyi West Road viaduct, and other traffic arteries, linking the new and old urban areas and north Jiangnan as a whole;

open the Airport Express to connect Qianjiang New City with Hangzhou East Railway Station, Xiaoshan Airport, and other important transportation hubs; form a circulation network of resource elements connecting inside and outside areas; and connect the multi-group spatial layout of Hangzhou with an organic integrated regional space. Constructing circulation space has enhanced the communication and cooperation between the central city and the new districts, promoted the de-regionalization and re-regionalization of capital, and attracted capital to be embedded in the new municipal district [45].

4.4. Summary

The administrative division adjustment patterns are closely related to the urbanization process. From 1983 to 1999, the urbanization development of China was characterized by the expansion of the absolute number of cities and the scalar expansion of key cities [27]. The adjustments of administrative divisions in this stage are mainly registered as "region upgraded to city" and "county upgraded to city", among which the division of counties (county-level cities) into districts (including the combination of districts and counties) was mainly concentrated in cities with higher administrative levels. Since 2000, urbanization in China has undergone large-scale urban expansion, primarily through withdrawing counties (county-level cities) by setting up districts or merging counties [46]. The adjustment frequency is closely related to the level of economic development: the more developed the area, the higher the frequency of adjustment [36]. Recently, Chinese urbanization has entered a new stage, moving from the expansion of the city scale to the enhancement of city function and connotation. The adjustment model of the administrative division has gradually changed from the integration of counties (county-level cities) into districts and the merger of districts and counties to the reorganization of district boundaries.

Hangzhou began its district boundary reorganization in 2021. First, it solved the problems of unbalanced urban scale and unreasonable spatial layout. Specifically, following the urban scale expansion, the area of Hangzhou's outer city districts was too large, and the development of the inner-city space was insufficient and unbalanced. These problems have been effectively solved through district boundary reorganization, including city mergers and splits. Second, Hangzhou neatly reconstructed its urban governance structure with the district boundary reorganization. The purpose of urban administrative division adjustment was not simply to expand the scale but to optimize the spatial pattern and reshape the governance structure, releasing the city's development potential [47]. Third, it reduced the political cost of administrative division reform. Integrating counties (county-level cities) into districts involves inter-governmental maneuvering at the province, city, and county levels; the political costs and risks are correspondingly high. Many cases of fierce resistance from the counties (county-level cities) have been resolved. In contrast, reorganizing district boundaries involves power struggles only at the same level. The administrative subordination of each district is the same, and the difficulty coefficient and risk of the integration and coordination of the management system between them are low. Therefore, Hangzhou is gradually integrating its resources by reorganizing district boundaries, optimizing the layout of urban functions, upgrading the industrial structure, and improving the efficiency of urban governance.

Under the guidance of the "strong provincial capital" strategy, Zhejiang Province adjusted the scale strategy and regional development path in the new development stage to increase the central city and improve the urban competitiveness of Hangzhou, the provincial capital. Under the new regional strategic goal of integrating the development of the Yangtze River Delta, Hangzhou plays a leading role; its regionalization adjustment aims to strengthen the importance of this scale unit. From the perspective of scale reconstruction, Hangzhou used district boundary reorganization to adjust the power scale of municipal districts, promote coordinated development, and concentrate more local jurisdiction and development power on the Hangzhou scale level to create a new regional integrated development map.

5. Discussion and Conclusions

Since 1978, after two phases of integrating counties (county-level cities) into districts from 1994 to 2003 and establishing districts since 2013, the number of municipal districts in China has increased. Many cities' reserves for country-district mergers have become limited. Regional central cities such as Beijing, Shanghai, Tianjin, Guangzhou, Shenzhen, and Nanjing have entered the "district-wide model" where they can no longer rely on large-scale mergers of peripheral counties and cities to strengthen themselves as they did before. Instead, they need to intensively cultivate their own internal space.

Urban space production is a continuous process. In addition to the reorganization of district boundaries, Chinese city governments often use another approach—"setting up functional zones"—to optimize urban space without adjusting administrative divisions. However, the continuous development of functional areas will increase the chaos of governance relations, which is not conducive to the long-term development of the city. Therefore, in the long run, the reorganization of regional boundaries is still necessary. It is evident that, similar to the urbanization process in many developing countries, the increasing heterogeneous demand for city development in countries such as Indonesia, South Africa, and Brazil has led to the redefinition of urban boundaries and the addition of new administrative divisions, which in turn have prompted regional boundary restructuring. The boundary reorganization of Hangzhou District aims to optimize the internal relationship of urban space to meet the new needs of urbanization development. However, in Europe and North America, the merging of administrative divisions is used to optimize urban space to provide public services, indicating that Hangzhou's experience can be an important reference for the urbanization process of other developing countries.

From the perspective of scale and regional restructuring, regional boundary restructuring is a regional construction scale strategy initiated by the central city government to enhance its competitiveness. It mainly achieves its goals in two ways. First, it promotes integration through segmentation. However, integrating cities and counties is problematic in China. Hangzhou removed the Xiaoshan District from the Dajiangdong area and the Jianggan District from the Xiasha area to form the Qiantang District. Hangzhou integrated the outer urban areas into the main urban area. Separating the old Yuhang District improved the transitional system; it used scale politics to extrapolate its adjustments to Xiaoshan, Fuyang, and Lin'an, which were divided into districts by counties (county-level cities) in the early years to strengthen Hangzhou's control over peripheral municipal districts and integrate old Yuhang with the main city.

Second, this process promoted equilibrium through restructuring. Hangzhou's broad spatial scale had caused a mismatch between regional scale and economic size and excessive differences in economic development. After the reorganization of the district boundaries, Hangzhou had jurisdiction over ten districts. However, it reorganized and optimized regional spaces by merging smaller districts and dividing larger ones to balance the development of various municipal districts.

Recently, different cities' development demands have followed the expansion and structural adjustment of central city districts. Their expansion has been mainly conducted by withdrawing counties (county-level cities) to set up districts; structural adjustment has mainly relied on reorganizing district boundaries. Generally, after the number of central city districts expands to a certain scale, district boundary reorganization is carried out to adjust the power and regional scales of municipal districts, optimize the urban structure, and promote urban development. Thus, withdrawing counties and setting up districts can expand urban development space. According to the different development needs of the city, scale reorganization and regional reconstruction are carried out at different stages to promote development. In the future, the role of physical space expansion in enhancing urban competitiveness will become increasingly limited. Focusing on the structural adjustment and governance optimization of internal space is an effective way to enhance the central cities' competitiveness. Urban development must solve the problems related to urbanization *and* urban development. Thus, district boundary reorganization will become a first choice as an effective and practical way of reforming the administrative divisions of central cities.

China is a typical developing country undergoing rapid urbanization. As an important central city in East China, Hangzhou is also a critical megacity in the Yangtze River Delta region. Using the Hangzhou District's boundary reorganization as an example, this study has shown how Chinese city governments make urban spatial reconstruction serve urban growth by adjusting administrative boundaries. Reorganizing district boundaries reconstructs urban spaces to transform urban governments and adjust and redistribute the forces of urban governments, markets, and society. District boundary reorganization is the basis of urban planning, urban renewal, and other spatial optimization strategies, and it is important for urban space optimization and urban government reconstruction. This research can provide a general lesson for many cities in underdeveloped areas.

The contribution of this paper is mainly reflected in three points. First, the paper uses the theory of scale restructuring to analyze Hangzhou District's boundary reorganization, expanding the scope of theoretical interpretation and further demonstrating its universal value. Second, by analyzing the case of Hangzhou, the intrinsic mechanisms of this process are summarized, providing a reference for the urbanization process of other developing countries. Finally, this paper's research further enriches the discussion on Territorial Reforms, providing examples from a Chinese case for observing the methods and performance of Territorial Reforms.

Hangzhou District's boundary reorganization incorporated several common forms of the spatial optimization of central cities in China. This study conducted a deep but not broad analysis of how China's central cities optimize urban structure. Future studies should investigate internal structure optimization in more central cities in China—preferably all of them. Comparative studies should be conducted in various regions to identify differences in optimizing the inner spaces of central cities elsewhere in China.

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The Effects of Urban Sprawl on Electricity Consumption: Empirical Evidence from 283 Prefecture-Level Cities in China

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Abstract: Under the urban development trend of sprawl, improving energy use efficiency is a proper way to promote green and low-carbon construction in cities. This paper uses panel data from 283 prefecture-level and above cities in China from 2008 to 2019 to measure the urban sprawl index, and analyze the spatial-temporal evolution law of urban sprawl and electricity consumption. The relationship between urban sprawl and electricity consumption is empirically examined, and the differential effect of urban sprawl on electricity consumption is analyzed. Finally, the impact of urban sprawl on electricity consumption based on a spatial perspective is explored in depth by establishing a spatial error model. We found the following: (1) The levels of urban sprawl and urban electricity consumption are on the rise. The spatial distribution of urban sprawl is more dispersed, and cities with high electricity consumption levels are mostly concentrated in the eastern coastal areas. (2) Urban sprawl exacerbates electricity consumption, and this conclusion is still robust after a series of robustness tests were conducted and endogeneity issues were taken into account. In terms of the influence mechanism, urban sprawl mainly affects electricity consumption by changing the allocation of land resources, increasing the dependence on private transportation, and inhibiting green technology innovation. (3) The incremental effect of urban sprawl on electricity consumption is more pronounced in cities with high sprawl levels, weak environmental regulations, and low green innovation levels, as well as in west cities. (4) Urban sprawl and electricity consumption both have a significant positive spatial correlation. Electricity consumption of cities is not only related to their own regions but also influenced by the adjacent regions, and the spatial correlation is mainly reflected in the random error term. This paper deepens the understanding of the basic laws of urban sprawl affecting urban low-carbon development, which also has implications for new urbanization strategies and green development.

Keywords: urban sprawl; electricity consumption; land resource allocation; spatial econometric model; low-carbon development

1. Introduction

Cities are spatial carriers where capital, labor, and infrastructure are highly aggregated, and they are the main battlegrounds for economic activities such as the allocation of resources and trade transactions in human societies [1]. The development and construction of cities is an important task for many countries, and the urbanization process of each country is advancing by leaps and bounds [2,3]. According to the *World Cities Report 2022* published by UN-Habitat, the world's urbanization rate has reached 56% in 2021. By 2050, this figure will rise to 68%, with an increase of about 2.2 billion urban dwellers, and a significant increase in urbanization levels is expected in all regions of the world [4]. Similarly, China's urban development has been dramatic, with the country's urbanization level growing at an unprecedented rate, from 17.92% in 1978 to 64.7% in 2022 [5]. Promoting urbanization is a powerful engine and an important strategy for China's socio-economic development [6]. Urbanization is regarded as a necessary path to modernization, and the 20th National Congress of the Communist Party of China further rationalized the idea of a new urbanization strategy. Rational urbanization promotes the modernization of industrial structures and also helps improve energy efficiency and environmental quality [7,8].

However, in reality, disorderly expansion of urban space and reckless development of land resources have become common problems in the urbanization process of countries around the world [9]. Land element-based urbanization promotes land development and utilization, but land expansion that is detached from the actual needs of the population and economic development may lead to the phenomenon of a mismatch in land development in China [10], which is called urban sprawl [11]. The impacts of urban sprawl on ecological quality persist, and the impacts have considerable variability and complexity [12–14]. At the same time, the problem of climate change caused by large amounts of carbon emissions is extremely serious [15], and energy consumption is the main "culprit" affecting carbon emissions. The consumption of basic resources such as energy is exacerbated during rapid urbanization [16], and cities have become an important carbon source for carbon emissions [17]. The Chinese government pays more attention to the dynamic change in total energy consumption and makes a solemn commitment to energy conservation and emission reduction, and reducing energy consumption is a must for sustainable development [18]. Electricity is an important energy source to promote the sustainable development of China's economy, and it has a fundamental role in the national economy [19]. However, as China's electricity consumption continues to grow, there has not been an effective shift in the structure of electricity production, which is dominated by "thermal power" [20]. This type of power generation, which is based on the consumption of coal, a disposable energy source, generates large amounts of carbon emissions during the production process [21]. China faces energy constraints from urbanization [22] and carbon reduction targets [23], and there is an urgent need to clarify the ways in which the complex urbanization system affects electricity consumption [24]. Meanwhile, China is the world's second-largest economy and the world's largest CO_2 emitter [25], and rationally promoting urbanization and reducing energy consumption are important elements of the visionary blueprint for socialist modernization.

The issue of urban land use has also attracted widespread academic attention. However, most of the existing studies have focused on examining the impact of urban sprawl on economic performance and haze pollution, while less consideration has been given to its impact on energy consumption. How to promote urban green and low-carbon construction remains a key component of China's sustained high-quality development. In view of this, in the context of rapid urbanization, we try to elaborate on the impact and mechanism of urban sprawl on electricity consumption. Firstly, the urban sprawl index is measured with 283 prefecture-level and above cities in China from 2008 to 2019. Meanwhile, the mechanism of urban sprawl affecting electricity consumption is explained at the theoretical level. Secondly, a series of robustness tests, such as instrumental variables, are used to identify the impact of urban sprawl on electricity consumption as accurately as possible and unfold the heterogeneity. Finally, the spatial econometric model is utilized to expand the analysis of the spatial spillover effects of urban sprawl and electricity consumption. And, in order to provide intellectual support for urban spatial layout as well as green and low-carbon development.

The marginal contribution of this paper may be reflected in three aspects. Firstly, in terms of research perspective, it combines urban sprawl with electricity consumption. It also examines the intrinsic mechanism of urban sprawl affecting electricity consumption from land resources, private transportation, and green technology innovation. It expands the study of the environmental effects of urban sprawl in the context of urbanization and construction in China. Secondly, the impact of urban sprawl on electricity consumption is examined in detail. Based on the spatial structure of cities, the strength of environmental regulation, the level of technological innovation, and the geographic location, this paper further analyzes the differentiated impacts of urban sprawl on electricity consumption so as to put forward more targeted recommendations. This paper analyzes the spillover effects of urban sprawl and electricity consumption from the perspective of spatial correlation. It makes up for the lack of spatial effects in the current research perspective and further enriches the research in the field of urban sprawl.

The rest of the study is structured as follows: Section 2 is a literature review. Section 3 attempts to elucidate the mechanism of action of urban sprawl in affecting electricity consumption. Section 4 is the model setting and variable descriptions. Section 5 is the empirical results, including the benchmark regression, robustness test, endogeneity problem test, mechanism of action, heterogeneity test, and extended analytical analysis. Section 6 is the discussion and analysis. Section 7 is the conclusions of research and policy recommendations.

2. Literature Review

The research in this paper deals with urban sprawl and electricity consumption. In order to organize the research progress in these two areas in recent years, the literature closely related to the research topic of this paper is divided into the following three categories for review.

2.1. Connotation and Measurement of Urban Sprawl

Early on, the concept of "urban sprawl" was characterized by the continuous expansion of urban boundaries and a shift to urban land at the expense of rural land [26]. In contrast to "compact" cities, urban sprawl tends to be a haphazard and decentralized, single-use and inefficient pattern of urban spatial expansion [27]. Urban sprawl refers to the expansion of land beyond the needs of population growth, the gradual expansion of urban economic activities to the periphery of the city, and the increasing decentralization of the urban form [28]. Although there is no specific and unified definition of urban sprawl, there is a consensus on its characteristics. And it is generally recognized that urban sprawl is characterized by inefficient, low-density, and "frog-hopping" expansion [29–31]. Conceptual uncertainty has led to a diversity of approaches to measuring urban sprawl. Urban sprawl measurement is categorized into single-indicator and multi-indicator methods. Among the single indicators, employment density [32,33], residential density [34], and population density [35] are used to assess the extent of urban sprawl based on the "low-density" nature of urban sprawl. Unlike the above literature, the urban sprawl index is also derived by comparing the growth rate of urban areas with the growth rate of the urban population [36,37]. On this basis, the degree of urban sprawl is assessed from the dimensions of urban land expansion and urban population expansion with the help of lighting data [38–40], thereby further broadening the scope of the study. In addition, unlike single-indicator measures, urban sprawl measures have been extended to multi-indicator measures [41]. Based on the characteristics of urban sprawl, density, utilization mix, and centrality are usually important dimensions of multi-indicator measures of urban sprawl [42,43]. Frenkel and Ashkenazi [44] used factor analysis to measure the three dimensions of density, scatter, and land use mix with a total of 13 indicators to finally obtain a composite index for assessing urban sprawl. Taking into account the local context and available data, the dimensions of urban sprawl, urban compactness, and urban form have also been used to measure the degree of urban sprawl in Shanghai [45].

2.2. Study on the Effects of Urban Sprawl

Much of the research on the effects of urban sprawl has focused on assessing the socioeconomic and environmental effects of urban sprawl. In terms of socioeconomic effects, urban sprawl negatively affects the frequency of community interactions and class upward mobility [46–48]. In addition, there is a threshold effect of urban sprawl on economic development, with appropriate urban sprawl promoting economic development and excessive urban sprawl inhibiting economic development [49]. Regarding the environmental effects of urban sprawl, existing views generally agree that urban sprawl reduces the quality of the ecological environment [50,51] and significantly and negatively affects urban green total factor productivity [52]. Urban sprawl exacerbates $PM_{2.5}$ emissions [53], and fiscal decentralization also significantly strengthens the contribution of urban sprawl to $PM_{2.5}$ [54]. The expansion of urban space and the surge in urban population both have a negative impact on CO_2 [55]. And urban sprawl mainly increases carbon emissions from transportation, construction, and industrial sectors, which in turn raises the total urban carbon emissions [56]. Similarly, urban sprawl increases urban air pollutant concentrations through increased energy consumption and higher industrial production [57,58]. However, there are differences in the impacts of different dimensions of urban morphology on air quality, and while the urban scale has a significant impact on air quality, it is urban fragmentation that is the most important factor contributing to the deterioration of urban air quality [59]. In addition to affecting air quality, urbanization with a lower percentage of developed land use per capita tends to have higher concentrations of water pollution in watersheds [60]. Overall, urban sprawl has had a negative impact on sustainable urban development [61]. Unlike the above literature, another viewpoint claims that urban sprawl can optimize land resource use efficiency and positively affect regional ecology and that low sprawl can reduce per capita NOx and $PM_{2.5}$ emissions from roads [62].

2.3. Study of the Factors Influencing Electricity Consumption

In a study on the influencing factors of electricity consumption, scholars discuss the driving factors of electricity consumption at the micro level and macro level. At the micro-individual level, personal moral constraints and positive expected emotions are important factors influencing residents' electricity consumption behavior [63]. Habits are more important factors influencing residents' electricity consumption behavior, and residents with electricity-saving habits use an average of 15.54 kWh more electricity per month compared to residents without electricity-saving habits [64]. Household appliances and household size also contribute to household electricity consumption, and the positive effect is greater for urban households [65]. In addition, household income also positively affects electricity use, and electricity use behavior varies across age groups [66]. At the macro level, the level of financial development [67,68] and the digital economy [69,70] both affect electricity consumption. Electricity price is the most direct factor affecting the behavior of residential electricity consumption, and an increase in electricity price can reduce residential electricity consumption [71], and a marginal electricity price increase of about 40% leads to a decrease in electricity consumption of about 35% [72]. Electricity consumption changes in response to climate change, with higher cooling demand in the summer and higher heating demand in the winter leading to an increase in electricity consumption [73], and total electricity consumption is more sensitive to warming than residential electricity consumption [74]. The urban form is also one of the important factors affecting electricity consumption, with neighborhood density negatively correlating with single-family residential summer electricity consumption [75]. The urban built-up area of Chongqing is the center of urban electricity consumption, and the electricity consumption in the urban built-up area accounts for 34.34–45.69% of the electricity consumption in the urban administrative area [76]. The urbanization process promotes residential electricity consumption, which is heterogeneous at different stages of urbanization, and has a more pronounced impact on rural residential electricity consumption compared to urban residential electricity consumption [22].

By combing through the literature, the current results on urban sprawl and electricity consumption are relatively rich, laying the foundation for further research in this paper. However, taking a comprehensive view, there is still some room for improvement in the research of the existing literature. In terms of research content, most studies focus on assessing the impact of urban sprawl on the ecological environment, $PM_{2.5}$, etc., and less on exploring the impact of urban sprawl on electricity consumption, which is crucial for urbanization and low-carbon development. Therefore, this paper focuses on the relationship between urban sprawl and electricity consumption and its mechanism. In addition, in terms of analyzing the differences in impacts, existing literature mostly analyzes the impacts from the perspective of city size, etc., while this paper will meticulously examine the differences in the impacts of urban sprawl on electricity consumption from the perspective of urban spatial structure, the level of environmental regulation, the level of technological innovation, and the geographic location of the city. Moreover, the related literature focuses on assessing the linear or nonlinear relationship of urban sprawl on environmental pollution. Additionally, this paper will further explore the spatial spillover effects of urban sprawl and electricity consumption from the perspective of spatial correlation.

3. Research Hypothesis

3.1. The Impact of Urban Sprawl on Electricity Consumption

The impact of urban sprawl on electricity consumption can be categorized into two dimensions: production and living. Firstly, urban sprawl affects the way land resources are allocated, bringing about a shift in production activities and an adjustment of the industrial structure, while there are obvious differences in the electricity demand of different industries. At the present stage, government intervention and determination of spatial allocation of land resources are still relatively common. In pursuit of economic construction, local governments restrictively provide residential land, provide more industrial land, and create industrial parks to track economic growth targets. The allocation of land resources in favor of large-scale industrial land grants has led to the relocation of energy-consuming and low-end industries, restricting the development of the service sector and the supply of service products, and hindering the improvement of energy resource efficiency. Urban sprawl is inherently characterized by inefficient land resource allocation, and crude production patterns contribute to the increase in industrial electricity consumption. Secondly, urban sprawl leads to low-density expansion, resulting in urban spatial disorder, which makes residents more demanding in terms of mobility and so on. Urban sprawl increases residents' transportation demand, and the supply of public transportation is difficult to meet residents' emergent requirements in a short period of time, leading to a rapid increase in private car ownership. Urban sprawl increases the number of cars in the city and also increases electricity consumption. Finally, excessive urban sprawl is not conducive to the formation of agglomeration effects and inhibits green technological innovation. Technological innovation has obvious spatial agglomeration characteristics. Sharing, matching, and learning mechanisms are important for the diffusion and spillover of innovative knowledge [77]. The urban spatial structure with over-expansion of land weakens knowledge learning and technology spillover among firms, leading to inertia in industrial green transformation and thus adversely affecting energy-efficient production. In summary, the hypothesis was proposed as follows. The theoretical mechanism analysis diagram is shown in Figure 1.

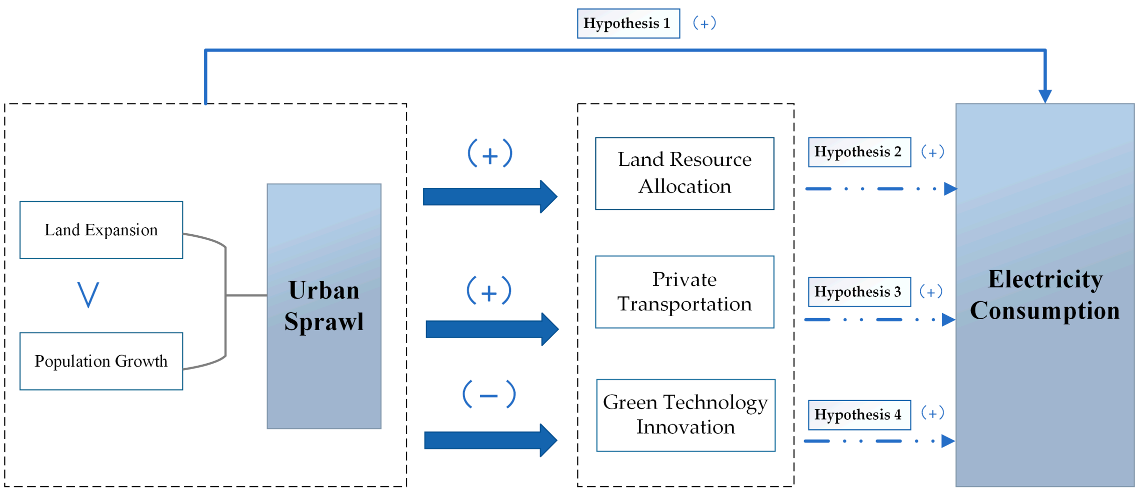


Figure 1. Mechanism analysis diagram.

Hypothesis 1. *Urban sprawl can exacerbate electricity consumption.*

3.2. Urban Sprawl, Land Resource Allocation, and Electricity Consumption

Land resources in the process of urban sprawl are allocated to land developers and bidders who can bring the greatest profit returns, leading to changes in the scale and efficiency of urban industries and affecting electricity consumption. First, local governments may enhance land supply incentives and intensify urban sprawl under the influence of multiple factors such as economic growth patterns, fiscal and land systems, and performance appraisals. By controlling the primary market of land, local governments cheaply use sprawl land for industrial use on a large scale in a variety of ways such as agreement transfer [78]. They lead the development of the industry and accelerate the process of industrialization in order to achieve rapid economic growth in the short term and increase employment, thus forming a "land for development" economic growth model [79]. Therefore, the mismatch of land resources centered on the large-scale granting of industrial land and the unsaturated supply of commercial and residential land has led to the rapid development of energy-consuming and low-end industries, which is not conducive to the transformation of the industrial structure. In addition, the formation of a crude economic growth pattern may eventually lead to increasing electricity intensity. Second, the mismatch of land resources brought about by urban sprawl leads to the inertia of the industrial system to reduce power intensity. Local governments have, to a certain extent, acquiesced in the negative impact on the environment brought about by the introduction of energy-intensive industries in their development, which has contributed to their inertia in improving the efficiency of energy utilization. This has led to high industrial electricity consumption in some areas. Moreover, the lack of pressure and incentives for industrial firms that have acquired cheap land to reduce industrial electricity consumption may also create negative incentives to reduce electricity consumption. On the basis of this, the following hypothesis is proposed:

Hypothesis 2. *Urban sprawl exacerbates electricity consumption by altering land resource allocation.*

3.3. Urban Sprawl, Private Transportation, and Electricity Consumption

Urban sprawl changes the accessibility of urban space, affecting the lives of residents and the way they travel on a daily basis. Urban sprawl leads to spatial decentralization of the population and separation of jobs and housing. As the land area in the central city is limited, the "sprawl" development model drives real estate development in the suburbs, making central city housing prices much higher than those in the suburbs. As a result, many residents who work in the central city choose to live in the suburbs, which are relatively remote and inexpensive, creating a spatial mismatch between their place of residence and their place of work. Under the living pattern of work–life separation, commuting distance and commuting time increase, and people are highly dependent on transportation. Transportation is also an important area of energy consumption, and the increasing number of road vehicles increases electricity consumption. On the one hand, private transportation involves the construction and maintenance of infrastructure such as roads, and this process inevitably increases electricity consumption. On the other hand, in the short term, public transportation cannot match the expanding and dispersed urban space. And due to the accessibility of private cars in time and space, residents' dependence on private cars for travel is becoming stronger. Urban sprawl affects the mode of transportation used by residents for their daily trips and increases their dependence on private transportation. And, the increase in private automobiles on the consumer side invariably increases electricity consumption on the production side of the vehicle. With the implementation of new energy vehicle development strategies, private transportation might evolve into "driving with electricity", further increasing electricity consumption [80]. Based on this, the following hypothesis is proposed:

Hypothesis 3. *Urban sprawl exacerbates electricity consumption by increasing reliance on private transportation.*

3.4. Urban Sprawl, Green Technology Innovation, and Electricity Consumption

Urban sprawl has led to a gradual diffusion of economic activities concentrated in urban centers to the surrounding areas. Compared with peri-urban areas, urban centers have external economic and spillover effects such as specialized labor and capital, which give them an advantage in the knowledge economy [81,82]. Urban sprawl promotes the relocation of industries to peri-urban areas, impedes the flow and matching of factors such as knowledge, and weakens the agglomeration effect of industries. However, industrial agglomeration is an environment for technological innovation [83]. On the one hand, industrial agglomeration promotes inter-firm competition and incentivizes technological transformation, upgrading and renewal [84]. On the other hand, industrial agglomeration facilitates complementarities among firms, which is conducive to the enhancement of regional innovation capacity [85]. Compared with other activities, technological innovation is more dependent on spillover effects and has spatial externalities. Urban sprawl lengthens the spatial distance within cities, which is not conducive to the diffusion and sharing of knowledge, technological information and human capital, and inhibits green technological innovation. Green technology innovation follows the principle of ecological economy and is an important means to improve energy utilization efficiency. Green technological innovation can be used in the production side of the industry to promote clean production, enhance energy saving, and reduce industrial electricity consumption. At the same time, green technology innovation can be used in the field of new energy by reduce the use of traditional fossil energy, helping to promote the transformation of the energy structure, and reducing electricity consumption [86]. In general, urban sprawl is not conducive to knowledge diffusion and technological innovation, which creates great resistance to the green transformation of industrial enterprises and becomes a shackle to reduce electricity consumption. Accordingly, the following hypothesis is proposed:

Hypothesis 4. *Urban sprawl exacerbates electricity consumption by inhibiting green technology innovation.*

4. Materials and Methods

4.1. Model Setting

4.1.1. Baseline Regression Modeling

Based on the mechanism analysis, in order to test the impact of urban sprawl on electricity consumption, the following benchmark model is constructed. The specific form of the setup is shown in Equation (1).

$$\mathrm{lnElec}_{it} = \alpha + \beta \mathrm{Sprwal}_{it} + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

Where i denotes city and t denotes year. lnElec_{it} denotes the logarithmic value of total electricity consumption of the i city in t year, Sprwal_{it} denotes urban sprawl index of the i city in t year, X_{it} is a control variable that may affect electricity consumption, μ_i is city fixed effects, γ_t is the time fixed effects, and ε_{it} is random error terms. The main coefficient of interest in this paper is the β, whose meaning is the effect of urban sprawl on electricity consumption after controlling for regional characteristics.

4.1.2. Spatial Correlation Analysis

The global spatial autocorrelation index (Global Moran's I) was used to determine whether urban sprawl and electricity consumption are spatially correlated between regions, as shown in Equation (2).

$$\text{Global Moran's I} = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (2)$$

Where n is the sample size, x_i and x_j are the urban sprawl index (electricity consumption) in i city and j city, respectively, and $\bar{x}$ is the mean value. Global Moran's I is in the range of [−1, 1]. When Global Moran's I > 0, it means the spatial distribution is positively correlated. Conversely, when Global Moran's I < 0, it means that the spatial distribution is negatively correlated. And, when Global Moran's I = 0, it means that there is no spatial correlation [87]. W_{ij} is the inverse distance spatial weight matrix.

The Local Moran's I index scatter plot can well characterize the spatial agglomeration of urban sprawl (electricity consumption), and the Local Moran's I measurement is shown in Equation (3).

$$\text{Local Moran's I} = \frac{n(x_i - \bar{x}) \sum_{j=1, j \neq i}^{n} W_{ij}(x_j - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \tag{3}$$

the variables are defined as shown in Equation (2).

4.1.3. Spatial Econometric Models

Compared with traditional regression methods, spatial econometric models consider the spatial dependence and spatial correlation of samples. And common spatial econometric models are classified as spatial autoregressive model (SAR), spatial error model (SEM), and spatial Durbin model (SDM), and the model settings are shown in Equations (4)–(6), respectively [88].

$$\text{lnElec}_{it} = \rho W_{ij} \text{lnElec}_{it} + \beta_1 \text{Sprwal}_{it} + \beta_2 X_{it} + \mu_i + \eta_t + \varepsilon_{it} \tag{4}$$

$$\text{lnElec}_{it} = \beta_1 \text{Sprwal}_{it} + \beta_2 X_{it} + \mu_i + \eta_t + \varphi_{it}\ ,\ \varphi_{it} = \lambda W_{ij} \varphi_{it} + \varepsilon_{it} \tag{5}$$

$$\text{lnElec}_{it} = \rho W_{ij} \text{lnElec}_{it} + \beta_1 \text{Sprwal}_{it} + \beta_2 X_{it} + \beta_3 W_{ij} \text{Sprwal}_{it} + \beta_4 W_{ij} X_{it} + \mu_i + \eta_t + \varphi_{it} \tag{6}$$

Where i denotes city and t denotes year. lnElec_{it} denotes the logarithmic value of total electricity consumption of the i city in t year, Sprwal_{it} denotes the urban sprawl index of the i city in t year, X_{it} is a control variable that may affect electricity consumption, μ_I is city fixed effects, γ_t is the time fixed effects, and ε_{it} is random error terms. W_{ij} is the inverse distance spatial weight matrix. β_3, ρ, and β_4 are the spatial lag terms for urban sprawl, electricity consumption, and other control variables, respectively.

4.2. Variable Measurement and Descriptive Analysis

4.2.1. Independent Variable

The urban sprawl index is the independent variable of this paper. Currently, there are generally single-indicator measures and multiple-indicator measures for urban sprawl. The multiple-indicator measures weaken the essential feature of excessive spatial growth within urban sprawl. And, comparing with the data and technical processing of multiple indicators, the single-indicator measure is more suitable for the analysis of econometric models [31]. However, measuring urban sprawl using only methods such as the share of construction land is too unitary. For this reason, based on existing studies [46,89] and considering land expansion and population elements, this paper utilizes the ratio of the growth rate of the built-up area of a city to the growth rate of the population in the urban area to portray urban sprawl characteristics. The calculation method is shown in Equation (7).

$$\text{Sprwal}_{it} = \frac{(\text{LUR}_{it}/\text{LUR}_{i0})}{(\text{POP}_{it}/\text{POP}_{i0})} \tag{7}$$

In the formula, the LUR_{it} is the built-up area of the i city t year, and LUR_{i0} is the built-up area of the base period. The POP_{it} is the population of urban area of the i city t year, and POP_{i0} is the population of the base period. The base period was chosen to be

2008. When the Sprwal > 1, it means that the growth rate of the built-up area of the city is greater than the growth rate of the population in the urban area. This indicates that the phenomenon of urban sprawl, and the more the value deviates from 1 indicates that the higher the degree of urban sprawl. When the $0 <$ Sprwal$\ll 1$, it means that the growth rate of the built-up area of the city is smaller than the growth rate of the population in the urban area, and there is no urban sprawl phenomenon.

4.2.2. Dependent Variable

The dependent variable in this paper is total urban electricity consumption, which is logarithmized. With regard to city electricity consumption data, the caliber of city-level statistics changed in 2017. For this reason, the urban electricity consumption data used in this paper comes from the results of lighting data [90]. This data is a 1 km $\times$ 1 km resolution electricity consumption raster data. This paper further utilizes ArcGIS to parse this gridded data into panel data of urban electricity consumption in China.

4.2.3. Control Variables

In addition to the above core explanatory variables, this paper also selects a series of control variables to control other factors that may affect urban electricity consumption. Based on the findings of the existing literature, six indicators, namely, the level of economic development, the degree of government intervention, the level of educational input, industrial structure, the level of opening up to the outside world, and the level of urbanization, are selected as the control variables of the model. The specific descriptions are as follows.

(1) Level of economic development (Lnpgdp). Economic growth is usually an important factor contributing to the growth of electricity consumption [91,92]. And in this case, the logarithm of real GDP per capita is used as a proxy variable for the level of economic development.

(2) Degree of government intervention (Govern). The government may financially invest in environmental protection programs and intervene in environmental quality objectives, thereby negatively affecting electricity consumption [93]. In contrast, inappropriate interventions can cause resource allocation distortions and efficiency losses, thereby increasing electricity consumption. This paper uses the share of fiscal expenditure in GDP for measurement.

(3) Level of educational input (Educate). Educational input is conducive to improving the education level and energy-saving concepts of residents, affecting their energy-saving behavior, which in turn has a negative impact on electricity consumption. In this paper, it is expressed as the proportion of regional education expenditure to financial expenditure.

(4) Industrial structure (Instru). Generally speaking, a larger proportion of secondary industry greatly increases urban electricity consumption. In this paper, the ratio of the output value of the tertiary industry to the output value of the secondary industry is used to characterize the transformation of the advanced industrial structure [94].

(5) Opening-up level (Openne). Increasing the level of openness to the outside world may generate technological spillover effects and improve the efficiency of energy use. But, it may also affect the local industrial structure, such as increasing the proportion of local polluting industries and increasing electricity consumption [95]. In this paper, we characterize the opening-up level by the share of actual FDI in GDP.

(6) Level of urbanization (Urbani). With the increase in the urbanization rate of the population, lifestyle changes have prompted greater demand for basic domestic energy consumption, such as household appliances and private cars, and population urbanization has become an important driver of the increase in electricity consumption [76]. In this paper, the level of urbanization is expressed as the share of the non-farm population in the total population.

4.2.4. Mechanism Variables

According to the relevant theoretical analysis and existing literature, this paper selects land resource allocation and private transportation dependence as mechanism analysis variables. (1) Land resource allocation (Landra): The spatial expansion brought by urban sprawl may be more reflected in the large-scale use of industrial land. The expansion of industrial land will inevitably squeeze commercial and residential land and cultivated forest land and increase electricity consumption. For this reason, this paper chooses the ratio of industrial land to urban construction land to measure the mismatch of land resources. Among them, the area of industrial land is the sum of the area of industrial land and storage land [96,97]. (2) Private transportation dependence (Ptrans): Urban sprawl leads to a spatial decentralization of the population and a separation of jobs and residences. Under the living pattern of job–residence separation, due to the increase in commuting distance and commuting time, residents' dependence on motor vehicles for travelling becomes stronger, thereby increasing electricity consumption. For this reason, this paper chooses the logarithmic value of private car ownership to characterize the degree of private transportation dependence [98]. (3) Green technology innovation (Pgpatt): Urban sprawl lengthens the spatial distance within cities and weakens the agglomeration effect. It is not conducive to the diffusion and sharing of knowledge, technical information, and human capital, which inhibit green technological innovation and thus become a shackle to reduce electricity consumption. Therefore, this paper chooses the per capita green patent acquisition to characterize green technology innovation [99,100].

4.3. Data Source

The sample data in this paper is a panel dataset based on Chinese cities at the prefecture level and above, covering 283 cities (due to missing data, cities with more missing values such as Bijie and Tongren are excluded, and Tibet, Hong Kong, Macao, and Taiwan are not involved). Due to the availability of data, the sample data spans from 2008–2019. Built-up area, population of urban area, urban construction land area, and industrial and warehousing land area were obtained from the "China Urban Construction Statistical Yearbook". The total urban electricity consumption was obtained from lighting data. The control variables were obtained from the "China City Statistical Yearbook". The data on private car ownership were obtained from the CEIC database (https://www.ceicdata.com/zh-hans (accessed on 1 June 2023)), and the number of green patents acquired by each city was derived from the China Innovation Patent Research Database (CIRD) of the China Research Data Service Platform (CNRDS). Among them, the real GDP was deflated to eliminate the price effect with 2008 as the base period, and the missing data were filled in using the interpolation method. The variable selection and descriptive statistics are shown in Table 1.

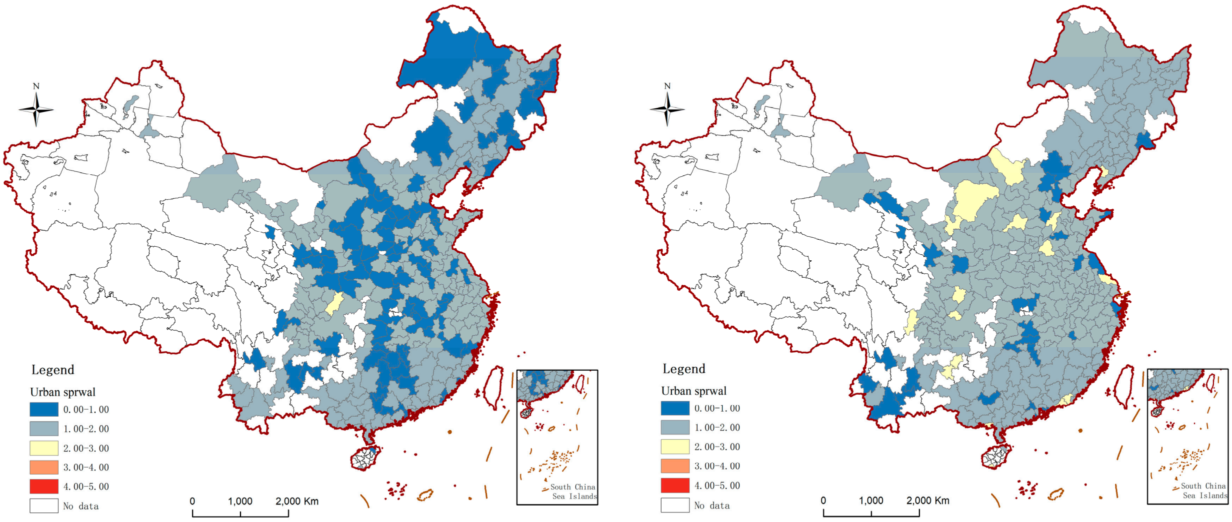
Table 1. Descriptive description of variables.

Variables	Obs	Mean	SD	P25	P75
lnElec	3396	22.9006	0.8026	22.3090	23.4516
Sprwal	3396	1.2060	0.2941	1.0022	1.3188
lnPgdp	3396	10.4790	0.6275	10.0673	10.9088
Govern	3396	0.1879	0.0937	0.1248	0.2233
Educat	3396	0.1800	0.0416	0.1513	0.2067
Instru	3396	0.9295	0.5152	0.6230	1.0689
Openne	3396	0.0173	0.0174	0.0041	0.0246
Urbani	3396	52.6688	15.3768	41.4365	62.3275

5. Results

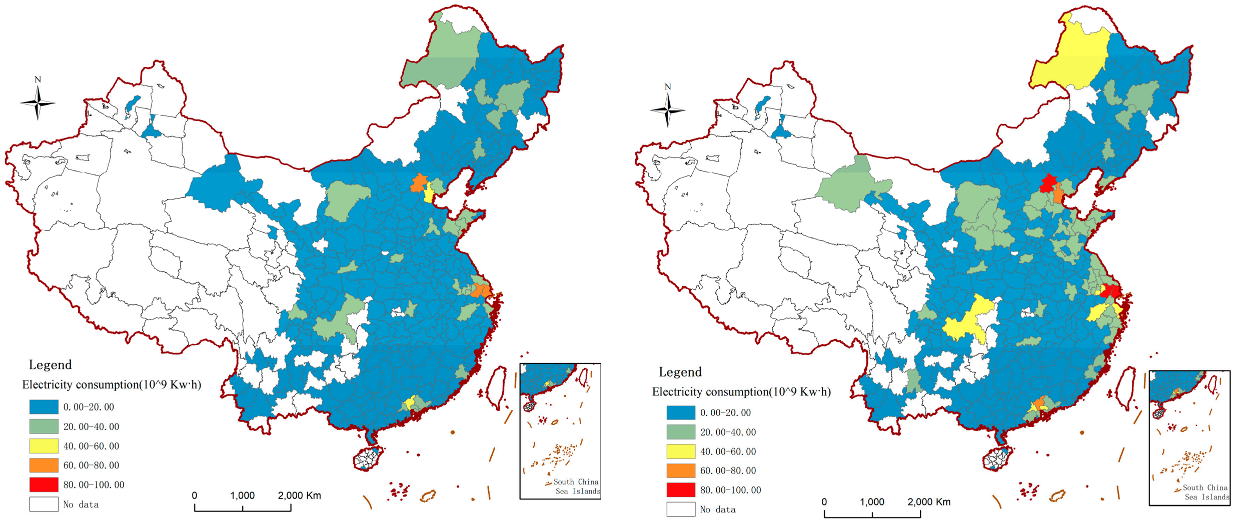
5.1. Trends in Spatial-Temporal Evolution of Urban Sprawl and Electricity Consumption

In order to visualize the spatial and temporal evolution trend of urban sprawl and electricity consumption, this paper uses ArcGIS to map the spatial distribution of urban sprawl and electricity consumption in 2009 and 2019, respectively. As shown in Figures 2 and 3.



(**a**) (**b**)

Figure 2. Spatial-temporal evolution at the urban sprawl level. (**a**) 2009; (**b**) 2019. Note: Produced based on the standard map with review number GS (2019) 1822 on the Ministry of Natural Resources of the People's Republic of China Standard Map Service website (http://bzdt.ch.mnr.gov.cn/ (accessed on 1 June 2023)), with no changes to the base map boundary.



(**a**) (**b**)

Figure 3. Spatial-temporal evolution of electricity consumption. (**a**) 2009; (**b**) 2019. Note: Produced based on the standard map with review number GS (2019) 1822 on the Ministry of Natural Resources of the People's Republic of China Standard Map Service website (http://bzdt.ch.mnr.gov.cn/ (accessed on 1 June 2023)), with no changes to the base map boundary.

In terms of trends in temporal evolution, the level of urban sprawl increases significantly over time during the period 2009–2019. A small number of cities were in the not-yet-spreading stage, 63.60% of the cities had a sprawl index greater than 1, and the growth rate of the built-up area of cities was smaller than the growth rate of the urban population in 2009. Up until 2019, the majority of Chinese cities showed the urban sprawl phenomenon and were dominated by low sprawl types, 89.40% of cities had a sprawl index greater than 1, and the sprawl indexes were in the range of 1.00–2.00. A small number of cities have medium sprawl status. No city reached a high state of sprawl, i.e., an urban sprawl index of 3.00 and above. The proportion of cities with different types of urban sprawl is not balanced, and the spatial distribution is relatively decentralized. The overall situation is characterized by "sporadic high-spread". On a smaller administrative scale, a significant increase in the degree of sprawl could be found in some cities such as Erdos, Ya'an, and Anshun during the study period. Overall, urban sprawl is increasing, but it is not out of control in China. This may be influenced by the price of land urban construction gradually migrating from the central area to the periphery. Moreover, investment in land development is an important source of funding for renovation and new town development. A combination of factors has led to an increase in overall urban sprawl. At the same time, however, urban sprawl is not yet uncontrollable, due to China's two-way control of the usage and quantity of land for urban construction.

In terms of general evolutionary trends, during the study period, the total electricity consumption of cities has been increasing year by year. The electricity consumption of most cities was less than 20 billion Kw·h in 2009, and urban electricity consumption increased significantly in 2019. China's average urban electricity consumption grew from 9.89 billion Kw·h to 14.17 billion Kw·h from 2009 to 2019, with an overall growth rate of 43.30% and an average annual growth rate of 4.33%. Cities with high electricity consumption levels are mostly concentrated in the eastern region, such as Beijing and Shanghai, and are clearly and progressively consuming more than 80 billion Kw·h of electricity. And individual cities in the western region are also increasing their electricity consumption, but overall urban electricity consumption is less than 60 billion Kw·h. The reason for this phenomenon may be that electricity is also an essential production factor in industrial production and is vulnerable to economic conditions and other factors. And industrial electricity consumption occupies a large proportion of the city's total electricity consumption. The eastern coastal cities are economically ahead of the inland cities, which makes the eastern coastal cities become the main force of electricity consumption.

5.2. Baseline Regression Results

Based on the econometric model constructed above, this paper examines the study of the effect of urban sprawl on electricity consumption, and the results are presented in Table 2. Column (1) of Table 2 shows the estimation results with only time and individual fixed effects and without the inclusion of control variables, and columns (2) to (7) gradually include city-level control variables. The regression results show that the estimated coefficient of the effect of urban sprawl on electricity consumption without the inclusion of control variables is 0.0232 and is significant at the 1% level. This result remains largely stable with the gradual addition of city-level control variables. The result of column (7), which includes the full set of control variables, shows that the sign of the regression coefficient for the core explanatory variable, urban sprawl, is significantly positive at the 1% level. The results of the baseline model estimation tentatively indicate that urban sprawl significantly increases urban electricity consumption, validating Hypothesis 1.

As far as the control variables are concerned, the level of economic development significantly increases the consumption of electricity. As the main energy substance in production and life, electricity is highly relevant to modern economic and social development. In the secondary industry-dominated economic model to promote economic development, the industry is still the most important sector of electricity consumption. Therefore, economic development is the most important factor to increase electricity consumption, which is similar to the finding of Song et al. [101]. The government is the main body of "emission reduction and energy saving", and the government's policies and behaviors will have an important impact on electricity consumption. At this stage, with the promotion of ecological civilization construction, local governments begin to pay attention to environmental protection, promulgate policies to guide the development of energy-saving and emission-reduction technologies, and force enterprises to green transformation and technological innovation, which has a negative impact on electricity consumption. An advanced industrial structure significantly reduces urban electricity consumption. Compared with the traditional manufacturing industry and other secondary industries, the tertiary industry's power demand is smaller. Moreover, the upgrading of the industrial structure is essentially the transfer of resource elements from inefficient to efficient sectors, which is conducive to the improvement of urban energy efficiency and thus reduces electricity consumption, and the result is basically consistent with the finding of Guang et al. [102]. Openness to the outside world significantly increases electricity consumption. This may be due to the fact that the increase in the level of openness to the outside world is accompanied by a large inflow of FDI, which leads to the agglomeration of pollution-intensive industries and promotes electricity consumption. The level of urbanization has a significant positive relationship with electricity consumption, which means that the higher the level of regional urbanization, the higher the regional electricity consumption. Rural residents consume less electricity for living and travelling than urban residents. Therefore, the increase in the urbanization rate leads to an increase in electricity consumption.

Table 2. Benchmark regression results.

Variables	(1) lnElec	(2) lnElec	(3) lnElec	(4) lnElec	(5) lnElec	(6) lnElec	(7) lnElec
Sprwal	0.0232 ***	0.0210 ***	0.0208 ***	0.0207 ***	0.0207 ***	0.0215 ***	0.0207 ***
	(0.0050)	(0.0046)	(0.0046)	(0.0046)	(0.0046)	(0.0045)	(0.0042)
lnPgdp		0.0917 ***	0.0903 ***	0.0880 ***	0.0841 ***	0.0791 ***	0.0731 ***
		(0.0145)	(0.0146)	(0.0146)	(0.0145)	(0.0144)	(0.0147)
Govern			−0.0396 *	−0.0570 ***	−0.0362	−0.0435 *	−0.0404 *
			(0.0205)	(0.0211)	(0.0230)	(0.0230)	(0.0227)
Educat				−0.0619	−0.0472	−0.0454	−0.0441
				(0.0501)	(0.0509)	(0.0499)	(0.0496)
Instru					−0.0094 **	−0.0085 **	−0.0077 **
					(0.0037)	(0.0037)	(0.0036)
Openne						0.2538 ***	0.2119 **
						(0.0926)	(0.0948)
Urbani							0.0008 **
							(0.0003)
_cons	22.5999 ***	21.6913 ***	21.7111 ***	21.7485 ***	21.7884 ***	21.8325 ***	21.8570 ***
	(0.0059)	(0.1441)	(0.1459)	(0.1460)	(0.1455)	(0.1435)	(0.1443)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	3396	3396	3396	3396	3396	3396	3396
R^2	0.9730	0.9756	0.9757	0.9757	0.9759	0.9761	0.9763

Note: *, **, and *** denote 10%, 5%, and 1% significance levels, respectively. Values in parentheses are standard errors.

5.3. Robustness and Endogeneity Tests

5.3.1. Replacing the Measurement of the Independent Variable

Urban sprawl is typically characterized by rapid land expansion leading to a decentralized distribution of population, which is reflected in low density and decentralization. Higher urban population densities may indicate a greater likelihood of agglomeration of economic activities and a lower tendency to urban sprawl. In contrast, in low population density areas, the spatial structure tends to be decentralized and the tendency of urban sprawl is higher [103]. This means that urban population density and the level of urban sprawl are roughly inversely quantitatively related [104]. Therefore, the logarithmic value of urban population density (lnDens) is used to replace the urban sprawl index in the benchmark regression as the independent variable. The results of the model estimation are shown in column (1) of Table 3, where the coefficient of urban population density is significantly negative. This means that higher population densities can reduce electricity consumption. And, it indicates that urban sprawl promotes electricity consumption.

Table 3. Robustness tests: changing the measurement of variables and removing policy-related disturbances.

Variables	(1) lnElec	(2) lnElec	(3) lnElec	(4) lnElec	(5) lnElec
lnDens	−0.0278 ***				
	(0.0065)				
Sprwal		0.1969 ***	0.0200 ***	0.0238 ***	0.0203 ***
		(0.0641)	(0.0047)	(0.0066)	(0.0046)
_cons	21.8717 ***	5.4305 ***	21.8421 ***	21.8728 ***	21.8224 ***
	(0.1454)	(1.8667)	(0.1568)	(0.1935)	(0.1659)
Controls	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes
N	3396	3297	3060	2437	2863
R^2	0.9762	0.7257	0.9744	0.9730	0.9737

Note: *** denote 1% significance levels. Values in parentheses are standard errors.

5.3.2. Replacing the Measurement of the Dependent Variable

Considering the possible bias of electricity consumption measured from lighting data, the regression is further conducted using the whole society's electricity consumption data published in the statistical yearbook as the dependent variable [105]. The regression results, as shown in column (2) of Table 3, show that the coefficient of urban sprawl is significantly positive at the 1% level, again indicating that the conclusion of the baseline regression is robust.

5.3.3. Removing Interference from Relevant Policies

Another challenge to the regression results is that in verifying the impact of urban sprawl on electricity consumption, it may be interfered with by policies such as New Energy Demonstration Cities, Low-Carbon Pilot Cities, and Broadband China. In order to exclude the interference of the above policies and ensure the accuracy of the benchmark regression, the samples of policy implementation are excluded from the regression, and the results are shown in columns (3)–(5) of Table 3, respectively. Compared to the baseline results, the significance level of the urban sprawl coefficient does not change after taking into account the relevant policy disturbances. This also indicates that the conclusion that urban sprawl increases electricity consumption remains robust.

5.3.4. Excluding Macro-Systemic Differences

(i) Incorporating multidimensional interaction fixed effects. Urban sprawl has different development trends in different regions. Therefore, this paper controls for the unobservable effects at the provincial level over time by controlling for the joint "province-year" fixed effects. As shown in column (1) of Table 4, the Sprawl coefficient is still positive at the 1% significance level. It remains consistent with the baseline regression results. (ii) Replacing the standard error clustering hierarchy. The baseline regression refers to the general practice of standard error clustering at the same level (city level) of the study object. However, this clustering approach ignores the fact that there are often strong correlations (e.g., infrastructure, environmental regulation intensity, etc.) among cities in the same province. We therefore re-clustered the standard errors to the province level and report the estimates as a robustness test in column (2) of Table 4. As can be seen from the results, there is no obvious change in the size or significance of the coefficients.

Table 4. Robustness tests: excluding macro-systematic differences and removing outliers.

Variables	(1) lnElec	(2) lnElec	(3) lnElec	(4) lnElec
Sprwal	0.0130 ***	0.0207 ***	0.0259 ***	0.0200 ***
	(0.0043)	(0.0045)	(0.0061)	(0.0044)
_cons	24.0708 ***	21.8570 ***	22.0697 ***	21.7217 ***
	(0.1924)	(0.2156)	(0.1807)	(0.1609)
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes
Pro#Year	Yes	No	No	No
N	3396	3396	3396	3036
R^2	0.9841	0.9763	0.9629	0.9751

Note: *** denote 1% significance levels. Values in parentheses are standard errors.

5.3.5. Removal of Outliers

(i) Excluding extreme value interference. In order to avoid possible outliers in the data from influencing the benchmark regression results, this paper applies a bilateral 1% shrinkage to all continuous variables. The results are shown in column (3) of Table 4, and the core explanatory variable urban sprawl remains consistent with the benchmark regression results. (ii) Excluding municipalities and provincial capital cities. On the one hand, municipalities directly under the central government and provincial capital cities may be affected by policy favoritism and may have a relatively large advantage in energy-saving technology and high-quality human capital compared with general prefecture-level cities. This makes the energy use efficiency of these cities stronger. On the other hand, the governments of municipalities and provincial capitals generally pay more attention to environmental issues. Tougher environmental constraints and more rational planning of the urban sprawl process may also lead firms to favor green technological innovation. Therefore, failure to exclude these factors may have some impact on the stability of our estimation results. The results in column (4) of Table 4 show that the results remain robust after excluding municipalities and provincial capitals.

5.3.6. Endogeneity Test

To mitigate the possible endogeneity problems of mutual causality and omission of unobservable variables in the baseline regression, this paper adopts the instrumental variable test to regress. Specifically, the relief degree of land surface is selected as an instrumental variable for urban sprawl [98]. The greater the relief degree of land surface, the more segregated it presents geographic features and the more dispersed population distribution. This implies that the possibility of population density and industrial agglomeration is lower. And the urban spatial pattern tends to develop in a more disorderly and decentralized spreading pattern. Therefore, the relief degree of land surface theoretically positively affects urban sprawl, and the relief degree of land surface does not directly affect urban power consumption. It meets the requirement of exogeneity. However, since the relief degree of land surface is a non-temporal variable, it is further constructed a cross-multiplier by the relief degree of land surface and lagged period of the urban sprawl index. It is ultimately used as an instrumental variable indicator (Tsrdls) of urban sprawl [106]. From the regression results in column (1) of Table 5 in the first stage, it can be seen that there is a significant positive correlation between the instrumental variable (Tsrdls) and urban sprawl (Sprwal). Also, the Cragg–Donald Wald F-statistic and Kleibergen–Paap Wald rk F-statistic, are both greater than the Stock–Yogo critical value of 16.38 under the Stock–Yogo weak ID test critical values (10%), thus ruling out the possibility of a weak instrumental variable. The regression results from the second stage column (2) show that urban sprawl significantly exacerbates urban electricity consumption. The above analysis shows that the baseline regression conclusions of this paper still hold after considering potential endogeneity issues using the instrumental variables approach.

Table 5. Instrumental variables test.

Variables	First Stage	Second Stage
	(1) Sprwal	**(2) lnElec**
Tsrdls	0.3923 *** (0.0411)	
Sprwal		0.0217 ** (0.0093)
Controls	Yes	Yes
Year	Yes	Yes
City	Yes	Yes
Observations	3113	3113
Cragg–Donald Wald F statistic	724.609	
Kleibergen–Paap Wald rk F statistic	91.278	
Stock–Yogo weak ID test critical values (10%)	16.38	

Note: ** and *** denote 5%, and 1% significance levels, respectively. Values in parentheses are standard errors.

5.4. Mechanism Testing

Based on the theoretical analysis, this paper further identifies and tests the mechanism by which urban sprawl affects urban electricity consumption through land resource allocation, private transportation and green technological innovation. The specific estimation results are shown in Table 6. From the results in column (2) of Table 6, it can be seen that the coefficient value of sprawl is significantly positive at the 1% level. It indicates that urban sprawl changes the way of land resource allocation, increases the proportion of industrial land, and indirectly promotes urban electricity consumption, verifying Hypothesis 2. Columns (3)–(4) of Table 6 show the regression results for private transportation. It can be seen that urban sprawl increases private transportation trips, and the number of private cars increases, which promotes energy consumption [107], testing Hypothesis 3. From the results in column (6) of Table 6, it can be seen that the coefficient of Sprwal is significantly negative at the 5% level. This indicates that urban sprawl inhibits urban green technological innovation, which is detrimental to the green transformation of the industry and indirectly promotes urban electricity consumption, validating Hypothesis 4.

Table 6. Mechanism test results.

Variables	(1) Landra	(2) Landra	(3) Ptrans	(4) Ptrans	(5) Pgpatt	(6) Pgpatt
Sprwal	0.0200 *** (0.0076)	0.0206 *** (0.0074)	0.0887 ** (0.0436)	0.0869 ** (0.0422)	−0.3316 * (0.1748)	−0.2816 ** (0.1429)
_cons	0.2193 *** (0.0083)	0.2829 (0.2131)	4.3972 *** (0.0475)	2.0753 (1.3583)	0.4735 *** (0.1493)	27.5717 *** (6.0903)
Controls	No	Yes	No	Yes	No	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes	Yes
N	3371	3371	2935	2935	3396	3396
R^2	0.0465	0.0505	0.9139	0.9163	0.2365	0.3470

Note: *, **, and *** denote 10%, 5%, and 1% significance levels, respectively. Values in parentheses are standard errors.

5.5. Heterogeneity Analysis

China is a vast country, with different spatial plans for different regions, different environmental goal constraints, and different bases for innovation. The stage of economic development also varies greatly, which may lead to a differentiation of the effects of urban sprawl on electricity consumption. Therefore, this paper focuses on the four dimensions of urban spatial structure, environmental regulation intensity, urban innovation base, and urban geographic location to analyze heterogeneity.

5.5.1. Heterogeneity Analysis of Urban Spatial Structure

Columns (2) and (4) of Table 7 report the heterogeneous effects of urban sprawl on electricity consumption at different levels of sprawl. The paper categorizes the sample cities into high and low sprawl groups according to whether the level of sprawl exceeds the national average for cities. Among them, the regression results for the high sprawl group are significantly positive, while the regression results for the low sprawl group are insignificant. This indicates that the higher the level of urban sprawl, the more significant the marginal incremental effect of urban sprawl on electricity consumption. The higher the level of urban sprawl in the region, the longer the spatial distance between enterprises, colleges and universities, research institutes, and other innovation subjects becomes, and the agglomeration economic effect of innovation factors is weakened. This is not conducive to the positive effect of agglomeration on innovation through risk diversification and knowledge spillover, and it hinders the realization of industrial green transformation and promotes electricity consumption. In addition, the higher the level of urban sprawl, the greater the dependence of residents on private cars, and the more obvious the promotion of electricity consumption.

Table 7. Heterogeneity of urban spatial structure.

Variables	High-Spread		Low-Spread	
	(1) lnElec	(2) lnElec	(3) lnElec	(4) lnElec
Sprwal	0.0201 ***	0.0177 ***	−0.0047	−0.0060
	(0.0052)	(0.0039)	(0.0122)	(0.0105)
_cons	22.5709 ***	21.7036 ***	22.6479 ***	22.0757 ***
	(0.0090)	(0.2299)	(0.0121)	(0.1656)
Controls	No	Yes	No	Yes
Year	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes
N	1254	1254	2142	2142
R^2	0.9689	0.9731	0.9761	0.9785

Note: *** denote 1% significance levels. Values in parentheses are standard errors.

5.5.2. Heterogeneity Analysis of Urban Environmental Regulation Intensity

This paper further examines whether there are differences in the impact of urban sprawl on electricity consumption across different urban environmental regulatory intensities. The strong environmental regulation group and the weak environmental regulation group are divided according to whether the urban environmental regulation intensity is greater than the national average for cities of environmental regulation intensity. As can be seen from columns (2) and (4) of Table 8, the regression results for the strong environmental regulation group are not significant, while urban sprawl has a significant contribution to electricity consumption in the urban phase of weaker environmental regulation. This suggests that higher environmental regulation strengthens the emission reduction concept and environmental regulation behavior of local governments, raises the environmental target constraints on local governments, and restricts land grants to high energy-consuming enterprises. In addition, it can also force high-pollution and high energy-consumption industries to accelerate the pace of green transformation. Environmental regulation is used to prompt enterprises to participate in technological innovation, especially in areas involving energy conservation and emission reduction, and to increase the innovation power of industrial green transformation. This has to some extent weakened the role of urban sprawl in promoting electricity consumption. When environmental regulations are weaker, localities face less environmental pressure and less incentive to reduce land concessions to energy-consuming enterprises and urban sprawl has a stronger effect on electricity consumption.

Table 8. Heterogeneity in urban environmental regulation.

Variables	Strong Environmental Regulation		Weak Environment Regulation	
	(1) lnElec	(2) lnElec	(3) lnElec	(4) lnElec
Sprwal	0.0226	0.0211	0.0237 ***	0.0205 ***
	(0.0171)	(0.0158)	(0.0051)	(0.0043)
_cons	22.3373 ***	22.0652 ***	22.6435 ***	21.8146 ***
	(0.0194)	(0.3288)	(0.0062)	(0.1545)
Controls	No	Yes	No	Yes
Year	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes
N	488	488	2908	2908
R^2	0.9713	0.9735	0.9729	0.9765

Note: *** denote 1% significance levels. Values in parentheses are standard errors.

5.5.3. Heterogeneity in the Level of Innovation Base

Differences in the green innovation base of cities may lead to differences in production efficiency, which in turn leads to the spread of cities with heterogeneous electricity consumption effects. In this paper, we use the total amount of green patents granted to measure the city innovation base. And the sample is divided into a high green innovation level group and a low green innovation level group based on the mean value of green patent grants. As shown in columns (2) and (4) of Table 9, the regression coefficients of urban sprawl are significantly positive at the 1% level for the low green innovation level group and insignificant for the high green innovation level group. It indicates that the effect of urban sprawl on electricity consumption shows very significant heterogeneity in the characteristics of the urban green innovation base. Green technological innovation is a key factor in improving energy efficiency, which helps industrial enterprises to clean up and decarbonize their production, thus reducing electricity consumption. The higher the level of urban innovation, the more it mitigates to some extent the contribution of urban sprawl to electricity consumption.

Table 9. Heterogeneity in the level of innovation base.

Variables	High Green Innovation Level		Low Green Innovation Level	
	(1) lnElec	(2) lnElec	(3) lnElec	(4) lnElec
Sprwal	0.0154	0.0045	0.0229 ***	0.0228 ***
	(0.0111)	(0.0098)	(0.0054)	(0.0046)
_cons	23.6332 ***	22.4690 ***	22.3423 ***	21.8181 ***
	(0.0118)	(0.4200)	(0.0066)	(0.1547)
Controls	No	Yes	No	Yes
Year	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes
N	683	683	2713	2713
R^2	0.9779	0.9847	0.9731	0.9754

Note: *** denote 1% significance levels. Values in parentheses are standard errors.

5.5.4. Heterogeneity of Geographic Location

Cities in different regions have certain differences in economic development and industrial structure. Therefore, the impact of urban sprawl on electricity consumption is also likely to be heterogeneous, and it is necessary to conduct a comparative analysis by region. Additionally, 283 cities at the prefecture level and above are categorized into three regions: east, central, and west. From the regression results in Table 10, it can be seen that, compared with the east and center, the more obvious the promotion effect of urban sprawl on electricity consumption is in the western region. The reason may be that, since the implementation of the Western Development Strategy in 2000, with the policy advantages and the absorption of a large number of foreign production factors, the size of the cities in the western region has increased rapidly. And, the National New Urbanization Pilot Work Program explicitly requires that new pilot cities should be tilted to the central and western regions. The cities in the central and west regions accounted for 57% of the total number of selected cities in 2014 and were as high as 61% in both 2015 and 2016. The phenomenon of urban sprawl is obvious, leading to a more serious mismatch of land resources and a significant rise in electricity consumption. However, the level of economic development of cities in the east and central regions is leading the country, which has produced a strong "siphon effect" on the resource elements of other regions, with a large number of foreign laborers, high-quality capital, and other agglomerations. Based on that fact, human capital and other characteristics of agglomeration ensure the innovation effect of human capital on the driving role of industrial green transformation. This, to a certain extent, weakens the negative effect of urban sprawl on electricity consumption.

Table 10. Heterogeneity of geographic location.

Variables	East	Central	West
	(1) lnElec	**(2) lnElec**	**(3) lnElec**
Sprwal	0.0083	0.0131	0.0332 ***
	(0.0053)	(0.0126)	(0.0069)
_cons	21.8188 ***	22.0268 ***	21.4169 ***
	(0.2533)	(0.2002)	(0.2489)
Controls	Yes	Yes	No
Year	Yes	Yes	Yes
City	Yes	Yes	Yes
N	1200	1200	996
R^2	0.9843	0.9734	0.9755

Note: *** denote 1% significance levels. Values in parentheses are standard errors.

5.6. Extensibility Analysis

5.6.1. Spatial Autocorrelation Analysis of Urban Sprawl and Electricity Consumption

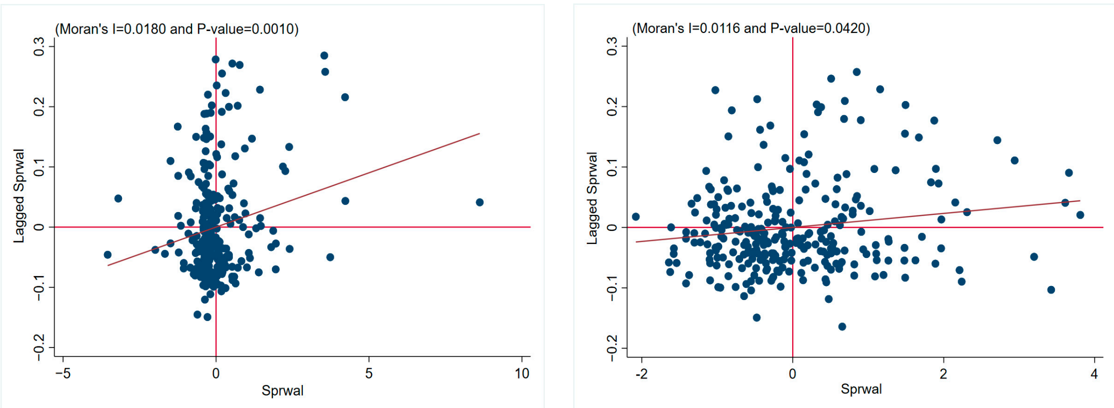
OLS does not take into account the effects of spatial interactions between cities. This may lead to biased results and conclusions that inherently lack spatial implications [108]. Therefore, the spatial relevance of urban sprawl is further considered to investigate whether there is a significant difference in the effect of urban sprawl on electricity consumption on its own and in neighboring cities. Before conducting the spatial econometric analysis, the existence of the spatial effects of urban sprawl and electricity consumption are examined separately. To this end, a spatial autocorrelation test was conducted using the global Moran's I index method, and the results are shown in Table 11. The global Moran's I value for urban sprawl are all positive and pass at least the 5% significance level test overall. There are individual cases of non-significance, but basically it can be assumed that there is spatial correlation of urban sprawl. The global Moran's I value for electricity consumption are concentrated at 0.109–0.113, and all pass the 1% significance level test, that is, it indicates that electricity consumption has strong spatial autocorrelation. This phenomenon may be attributed to the fact that there is an economic competition effect between cities, which makes the industrial structure tend to be homogeneous. This results in the increase of electricity consumption in the region, which significantly increases the electricity consumption of other cities. And, local governments may have formed vicious competition in land allocation, resulting in a significant positive spatial spillover effect of urban sprawl.

In order to better reflect the characteristics of spatial agglomeration, two representative years, 2009 and 2019, are selected to produce Moran's I index scatterplots of urban sprawl and electricity consumption. The results are shown in Figures 4 and 5. As can be seen in Figure 4, the local Moran's I index of urban sprawl is mostly clustered in the third quadrant, showing obvious Low-Low clustering characteristics in 2009. However, after a decade of development, the distribution of urban sprawl scatter points is more decentralized in 2019, and the low aggregation gradually moves to the first quadrant, tending to High-High aggregation. This indicates that the level of urban sprawl is increasing, but there are differences in the strategic orientation, development planning, and economic foundation of each city. This leads to obvious regional differences in the level of urban sprawl in China, and the spatial correlation of urban sprawl is weakened. As can be seen in Figure 5, the change in the scatter distribution of Moran's I index of urban electricity consumption between 2009 and 2019 is not obvious. The data points are more evenly scattered in the four quadrants, and the local Moran's I index is significantly positive at the 1% level. This suggests that urban electricity consumption is strongly influenced by neighboring regions, that is, the coexistence of "High-High", "High-Low", "Low-High", and "Low-Low". However, there are relatively more data points distributed in the first and third quadrants, and the phenomena of "High-High" and "Low-Low" aggregation are more obvious. This suggests that there is both spatial dependence and heterogeneity in urban electricity consumption. It is the result of a combination of the cities' industrial structure and ecological emphasis, and the implementation of the concept of synergistic regional governance.

Table 11. Global Moran's I value.

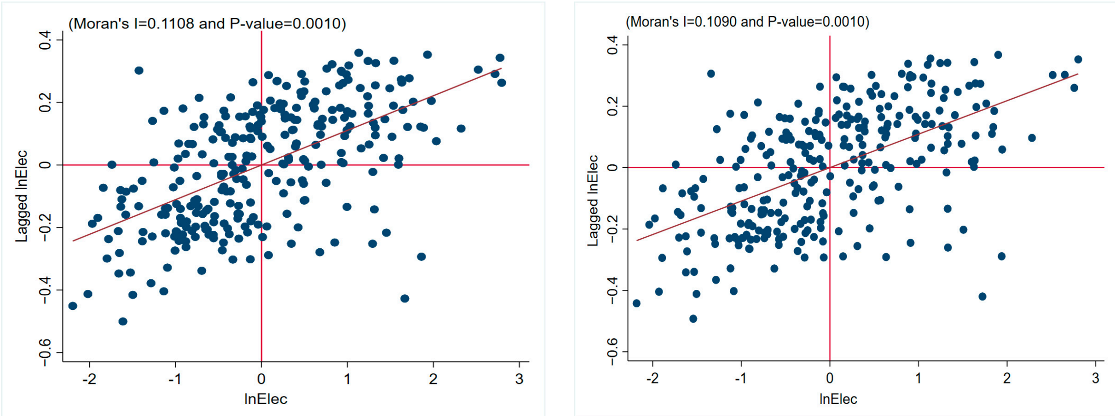
Year	lnElect			Sprwal		
	Moran's I	Z	sd(I)	Moran's I	Z	sd(I)
2008	0.111 ***	22.184	0.005	−0.000	0.607	0.005
2009	0.111 ***	22.189	0.005	0.018 ***	4.369	0.005
2010	0.112 ***	22.425	0.005	0.001	0.840	0.005
2011	0.113 ***	22.645	0.005	0.009 ***	2.550	0.005
2012	0.113 ***	22.648	0.005	0.007 **	2.112	0.005
2013	0.110 ***	22.025	0.005	0.005 **	1.736	0.005
2014	0.110 ***	22.024	0.005	0.005 **	1.713	0.005
2015	0.110 ***	21.946	0.005	0.006 **	1.822	0.005
2016	0.109 ***	21.911	0.005	0.007 **	2.015	0.005
2017	0.109 ***	21.893	0.005	0.012 ***	3.057	0.005
2018	0.109 ***	21.857	0.005	0.016 ***	3.825	0.005
2019	0.109 ***	21.842	0.005	0.012 ***	2.950	0.005

Note: **, and *** denote 5%, and 1% significance levels, respectively.



(**a**) (**b**)

Figure 4. Localized Moran scatter plot of urban Sprawl. (**a**) 2009; (**b**) 2019.



(**a**) (**b**)

Figure 5. Localized Moran scatter plot of electricity consumption. (**a**) 2009; (**b**) 2019.

5.6.2. Results of the Spatial Effects Test

Due to the existence of spatial correlations, this paper further analyzes them using spatial econometric models. Firstly, the inverse distance spatial weight matrix is used to estimate the spatial error model (SEM), spatial autoregressive model (SAR), and spatial Durbin model (SDM). The appropriate spatial econometric model was selected using the LM test, etc., and the specific results are shown in Table 12. The regression results show that the LM statistic and robust LM statistic of the spatial error model passed the 1% significance level test, but the LM statistic and robust LM statistic of the spatial lag model failed the significance test. In addition, based on the results of the test, the spatial error model with double fixation of time–area was chosen as a way to explain the spatial impact of urban sprawl on electricity consumption. From the estimation results of the spatial error model, the spatial coefficient λ of the spatial error term is 3.4318 and passes the 1% significance level test. It indicates that there is a significant spatial agglomeration phenomenon and spatial dependence on urban electricity consumption. That is, the electricity consumption of a city is not only related to its own factors but also affected by the neighboring cities, and the spatial correlation is mainly reflected in the random error term.

Table 12. Spatial measurement model estimation.

Variables	**SEM**	**SAR**	**SDM**
	(1) lnElec	**(2) lnElec**	**(3) lnElec**
Sprwal	0.0168 ***	0.0189 ***	0.0185 ***
	(0.0019)	(0.0020)	(0.0020)
λ	3.4318 ***		
	(0.0603)		
ρ		2.5635 ***	2.5983 ***
		(0.0361)	(0.0369)
W × Sprwal			0.0675 **
			(0.0324)
LM Test		1.247	
LM-error		1211.472 ***	
Robust LM-error		1212.660 ***	
LM-lag		0.676	
Robust LM-lag		1.864	
lrtest both ind,df(10)		395.21 ***	
lrtest both time,df(10)		23170.50 ***	
Controls	Yes	Yes	Yes
Year	Yes	Yes	Yes
City	Yes	Yes	Yes
N	3396	3396	3396
R^2	0.2893	0.0086	0.1244

Note: ** and *** denote 5%, and 1% significance levels. Values in parentheses are standard errors.

6. Discussion

This study confirms that urban sprawl exacerbates the impact of electricity consumption in China. Similarly, Spain faces rapid urban sprawl, with greater urban sprawl associated with higher electricity consumption [109]. Living in detached dwellings boosts electricity consumption, and urban sprawl may be an important driver of future surges in electricity consumption [110]. It is of great significance to grasp the interaction between urban spatial patterns and energy consumption, and then promote the construction of new urbanization and high-quality urban development. However, there are still some shortcomings in this paper. Firstly, this paper mainly utilizes statistical yearbook data to measure the urban sprawl index, while the statistical data "urban built-up area" may include some parts that do not belong to "cities" in the strict sense. This may have a certain impact on the results of urban sprawl measurement. Therefore, with the help of new data and methods, such as lighting data, extracting urban area and population data to measure urban sprawl, which is a breakthrough point in the future. Secondly, this paper describes and examines the mechanism of urban sprawl on electricity consumption from the aspects of land resource allocation, private transportation, and green technology innovation, as well as deepens the understanding of the relationship between urban sprawl and electricity consumption. But, the impact mechanisms of urban sprawl on electricity consumption is more complex. In the future, the impact mechanisms of urban sprawl on electricity consumption will be analyzed from more dimensions. Third, due to data limitations, this paper takes prefecture-level and above cities in China from 2008 to 2019 as research samples to explore the relationship between urban spatial patterns and energy consumption. The iteration of practice and strategic planning leaves the timeline of the study to be improved. Meanwhile, the promotion of urbanization with counties as important carriers is a new focus in China. Therefore, a more microscopic and detailed study on the relationship between spatial patterns and energy consumption in counties are possible further research.

7. Conclusions

This paper empirically examines the impact and mechanism of urban sprawl on electricity consumption based on the measurement of the urban sprawl index by processing the panel data of 283 prefectural-level and above cities in China from 2008 to 2019. Secondly, the heterogeneity of urban sprawl on electricity consumption is analyzed from four dimensions: urban spatial structure, environmental regulation intensity, urban innovation base, and urban geographic location. The SEM model is further used to investigate the impact of urban sprawl on electricity consumption, and the main conclusions are as follows: (1) In general, the levels of urban sprawl and urban electricity consumption show an upward trend. There are obvious differences between urban sprawl and electricity consumption in China. And, the spatial distribution of urban sprawl is relatively decentralized, while the cities with high electricity consumption levels are mostly concentrated in the eastern coastal areas. (2) Urban sprawl exacerbates electricity consumption. The conclusion still remains after the robustness test and the consideration of endogeneity issues. Urban sprawl exacerbates electricity consumption by changing the allocation of land resources, increasing the dependence on private transportation and inhibiting green technology innovation. (3) The effect of urban sprawl on electricity consumption is more pronounced in cities with high levels of sprawl, weak environmental regulations, and low levels of green innovation, as well as in west cities. (4) The Moran index shows that urban sprawl and electricity consumption both have a significant positive spatial correlation. The estimation of the SEM model shows that the electricity consumption of cities is not only related to their own regions but also influenced by the neighboring regions, and the spatial correlation is mainly reflected in the random error term.

Based on the above research conclusions, the following suggestions can be obtained. (1) Reasonable planning of urban spatial patterns, focusing on the improvement of energy utilization efficiency. In the process of new urbanization, we should comply with the reasonable demand of population density and economic growth and scientifically plan the urban development boundary. And, weighing the proportion of urban industrial land, residential land, and agricultural land. Correcting the short-sighted behavior of local governments in "seeking development with land" and reduce the degree of mismatch of urban land resources. Activating idle industrial land and optimize the spatial layout of industries; Promoting the advanced industrial structure in a gradual and orderly manner. And, paying attention to the integration of industry and city, the balance of business and residential development, and functional composites in the planning and construction of industrial parks. In addition, we will increase the compactness of urban spatial layout and reduce unnecessary commuting for seeking living services. Emphasis will be placed on the development of high-capacity green public transportation to reduce the proportion of private car trips. At the same time, promoting industrial specialization and diversified agglomeration and facilitates knowledge flow, matching, and sharing. (2) Based on regional development characteristics and advantages, differentiated territorial spatial planning should be introduced. Cities should strengthen the forcing effect of environmental regulation policies and continuously promote the improvement and innovation of environmental regulations. The demand for low-carbon development should be reflected in national spatial planning. With the help of stringent environmental regulation policy tools, the efficiency of land utilization can be improved. At the same time, it promotes intensive spatial layout and clustered industrial development mode and gives full play to the knowledge spillover effect to improve the cultivation of green innovation activities and help the green transformation of the industry. Urban sprawl in the eastern and central regions has not significantly exacerbated power consumption, and the optimal level of agglomeration and optimal city size should be maintained. In the western region, it is necessary to make full use of factor pooling, knowledge sharing, and technological spillover to promote the green development and transformation of cities and maintain a moderate spreading trend. (3) Regional alliances and establishing synergistic mechanisms for low-carbon development should be strengthened. Urban sprawl and electricity consumption have a positive spatial spillover effect. Therefore, sustainable urban development must abandon the "beggar-thy-neighbor" mode of thinking and break down urban administrative boundaries. Regional cooperation and establish a series of cooperative mechanisms should be strengthened, such as information sharing and joint law enforcement. The exchange of experience in land space planning between cities and the matching of measures to improve energy efficiency should be promoted, thus effectively mitigating the boosting effect of land sprawl on electricity consumption. We should deepen the reform of officials' performance appraisal system and continue to weaken the share of GDP growth rate in the performance appraisal of local officials. We should seek focus points for the emerging competitiveness of cities, reduce energy consumption and change the development model, and rationally promote the construction of new urbanization.

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