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Edited by
Agnieszka Szczepańska and Radosław Cellmer

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Article

Macro-Level Factors Shaping Residential Location Choices: Examining the Impacts of Density and Land-Use Mix

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Abstract: Many published papers have delved into the factors affecting the residential location choices of households using various logit models. Nonetheless, only a few pieces of literature have attempted to examine those associative attributes from a macroscopic view. Thus, this article investigates the factors that influence households' preference to reside in densely populated locations or regions with a wide variety of land-use types using ordered choice models (ORM). This study proposes three indicators that are reflective of residential areas, namely population density, housing density, and land-use mix index, based on prior research. Population density and housing density are modeled at census block and tract levels to explore households' sensitivity to different geographical scales. Regarding land use, this research classifies the diversity index into four categories: uniform, moderately diverse, more diverse, and the most diverse. Similarly, the study is predicated on 0.25-mile and 0.5-mile buffer zones. The findings are consistent with earlier research and highlight macro-level issues that influence residential location decisions. As for the residential preference for housing density, significant factors are the structure of households, the number of vehicles per household, and household income. Regarding the residential choices of population density, significant attributes refer to demographic characteristics, household income, and housing types. Concerning the residential choices based on land-use mix, the most influential factors turn out to be the interacting terms between demographics and housing-related index, household income, and housing-related indexes.

Keywords: residential choice; ordered choice model; population density; housing density; land-use mix

1. Introduction

The analysis of residential location choice is of great importance and interest in the explanation of urban growth and households' travel activity patterns [1]. Different urban forms, compactness or suburbanization, are essentially due to residents' preferences regarding where to live. Thus, a better understanding of the drivers behind households' choices benefits the policymaking on urban development and congestion-related mitigations. In other words, residence location modeling plays a pivotal role in the model systems of land use–transport interaction [2]. Accordingly, it is of utmost necessity to examine a whole range of important factors affecting where residents choose to live.

Much effort has been made to analyze the choices of residential locations using discrete choice modeling. Numerous factors affecting residential locations, such as demographic information, travel patterns, neighborhood characteristics, and spatial interactions between residential lands and workplaces, have been delved into for the past decades.

As an early explorer in this field, Lerman examined the relationships between residential locations and the travel patterns and socioeconomic characteristics of households. For the sake of explaining residential demand, Lerman designed a logit model consisting of households' combined choices, such as locality, commuting mode, car ownership, and so on [3,4]. His model was later improved and implemented, empirically and theoretically, by other scholars and governmental agencies. A crucial enhancement of Lerman's model is

the integration of accessibility represented by travel time and cost for working commute into the original one. Specifically, the expected maximum utility serves as a measurement of accessibility. This approach, though, was criticized for its inability to account for the correlation of people's trip decisions on a daily basis [3].

Accordingly, an activity-based travel model based on a daily activity schedule was introduced to better the residential choice simulations by Ben-Akiva and Bowman in 1995 [5]. They proposed an intergrade framework of residential, activity, and travel decisions. Their framework specifies three dynamic components during households' decision-making process in the considerations of residential locations—i.e., urban development (land use policies and real estate growth), household (mobility and lifestyle), and transport system performance. In other words, the activity-based choice model integrates the components of the utility related to a given residential location and the expected maximum utility among schedules available to household members. Nevertheless, this model inadequately addresses other important factors when people consider residential locality. For example, the degree of land-use mix surrounding residential locations plays a pivotal rule in households' decision-making. In addition, its daily-based feature weakens the model accuracy over a longer period of time.

Neighborhood characteristics are receiving much more attention in the analysis of residential location modeling [1,6]. While the concept of neighborhood is extensively studied among a variety of disciplines, there exists very little research about the explicit definition of spatial neighborhood. Additionally, traditional study units for land use and transport modeling, zip code areas, and census tract are criticized for the lack of theoretical justification of using these administrative boundaries. Instead of artificially fixed boundaries, a neighborhood is conceptualized as a multi-scale structure [6–9]. The traditional grouped alternative choice model for residential locations, though, fails to take into consideration the hierarchical neighborhood.

As a result, Guo and Bhat contended that the accessibility to public facilities serves as an alternative to describe neighborhood features, thereby identifying the spatial dimension of neighborhood at the operational level. Most importantly, "The concept of neighborhood and its definition are, therefore, central to residential location choice analysis" [1]. Hence, Guo and Bhat came up with the multi-scale logit model to analyze the residential locations of households, making possible the spatial representation of hierarchical neighborhood. Specifically, census units, circular units, and network bands serve as three representations of structural neighborhood. However, this definition fails to generate a universal form of multi-scale neighborhood, weakening its ability to apply this concept into distinct study areas.

Additionally, recent studies on lifestyle enriched the scope of the classic conceptualizations of residential choice [7,10–13]. Especially in the arena of knowledge cities, much research effort has been expended on what primarily contribute to the economic growth. Therefore, links have been established between knowledge workers and economic prosperity in European countries [14]. Regarding residential choice, cultural amenities and lifestyle are proven to play an essential role in the process of decision-making of knowledge workers [14–16]. Frenkel et al. empirically justified the importance of knowledge workers' lifestyle in the actual residential choice using a multiple nominal model and nested logit model. Specifically, they constructed eight groups of independent variables including lifestyle elements—i.e., culture and recreation, sport, and family activities—to estimate the probability of residential choice of knowledge workers [14]. Nevertheless, these studies primarily focus on the lifestyle patterns and residential preferences of knowledge workers, altogether ignoring other important demographic groups such as low-income persons and minorities.

The choice models of residential location are heavily criticized due to their limited ability to effectively represent spatial correlations among choice alternatives. The concept of spatial correlation, considered as the first law of geography, first emerged in the field of discrete choice model to enhance the traditional multinomial logit (MNL) model [17,18]. It

is evident that, likely, the property of independence from irrelevant alternatives (IIA) is violated when it comes to the alternatives featured by size and locational characteristics [19]. Accordingly, the nested logit (NL) model, which assumes a hierarchical structure of choice sets, was introduced to account for the alternative correlation. The NL model, however, suffers from its potential arbitrariness regarding the specification of each cluster or nest of alternatives [20]. More advanced choice models than MNL and NL models are worked out by several researchers, taking in considerations correlated components such as error terms and the autocorrelated element of utility [10,21–24]. A substantial improvement in the area of discrete choice analysis is the conceptualization of generalized extreme value (GEV). Under the framework of GEV, different choice alternatives are adaptably substitutable [25]. Based on this, Sener et al. developed the generalized spatially correlated logit model (GSCL) to account for diversely spatial autocorrelation [25].

There has been a rapidly increasing interest in the effort to explore the factors linked with residential location choices [13,26–29]. A growing body of literature has attempted to dig into how the whole spectrum of sociodemographic and additional attributes influence residential location choice [13,30,31]. Nevertheless, very few attempts have been done to investigate those associative attributes from a macroscopic view. Thus, this paper basically focuses on what are the crucial determinants of sociodemographic in households' propensity to live in highly populated areas or diversified land-use regions. In other words, the current article strives to delve into who chooses to live in areas of high population or housing density compared with those who do otherwise. In addition, much effort is placed on how different extents of land-use diversity influence households' residential preferences.

Recently, there has been a growing interest in understanding the factors that impact residential location choices. While there is a significant body of literature exploring the influence of sociodemographic and other attributes on this decision, few studies have taken a macroscopic approach to these associative attributes. This research seeks to address this gap by examining the crucial determinants of household propensity to live in highly populated or diversified land-use regions. Specifically, this study aims to investigate who is more likely to choose to live in densely populated areas compared to less populated areas, and to what extent land-use diversity influences residential preferences. By taking this unique approach, this paper contributes to the originality of research in this field.

2. Materials and Methods

2.1. Data Sources

The study area of this paper focuses on is the region of Miami–Fort Lauderdale–Pompano Beach (Core Based Statistical Area), which includes Broward, Palm Beach, and Miami Dade County, in Florida, the United States. The data considered in this study are twofold. First, our analysis is chiefly based on the 2017 National Household Travel Survey (NHTS) data which are designed and processed by Federal Highway Administration (FHA). Information regarding the travel behavior and sociodemographic of responding households is provided by the 2017 NHTS. The term 'households' used in this study denotes the civilian and non-institutionalized population, which is also the focus group of the NHTS. In other words, the population living in motels, hotels, and group quarters is excluded from the sampling process of the NHTS to ensure unbiased analysis results. Second, we also used the findings coming from the land-use parcel data created by the Florida Department of Revenue. In addition, these data were processed by the Institute of Transportation Engineers, University of Florida to accommodate current research. Information regarding land-use types and transit accessibility is offered by this data source.

These data were organized and cleaned through the following steps. First, an initial sample of 3980 households with detailed information regarding household sociodemographic and travel behavior was derived from the 2017 NHTS data. Second, the data related to land-use types and transit accessibility were incorporated into this original sample. Last but not the least, each variable included in the merged dataset was screened and inspected in the NCSS software to ensure the completeness of final data used in the modeling process.

In other words, missing data were excluded through data screening. Finally, a final sample of 3026 households was confirmed for this study (Table 1).

Table 1. Descriptive statistics of six types of choice alternatives.

	Choice Sets	Minimum	Mean	Maximum	Standard Deviation	Observations
Block level (1000/square mile)	Housing density index	2.60	3384.20	53,499.14	4752.22	3026
	Population density index	4.64	7268.73	99,411.00	8119.06	3026
Tract level (1000/square mile)	House density index	2.41	2889.06	38,555.15	3295.13	3026
	Population density index	6.93	5673.37	41,911.28	4297.53	3026
0.25-mile buffer area	Land-use mix index	0	0.29	0.89	0.19	3026
0.5-mile buffer area	Land-use mix index	0	0.43	0.93	0.16	3026

The analysis was conducted based on six types of choice sets—i.e., population density index and house density index at the block level or track level, and land use mix index at 0.25-mile or 0.5-mile buffer level. The consideration of identifying the choice sets at different spatial scale was aimed at exploring the impacts of spatially distinct neighborhoods on the individual residence choices. Table 2 provides the statistical descriptions for density-related indexes as well as land-use diversity indicators linked to each household. Additionally, Figure 1 offers an overview of frequency distributions of these indexes.

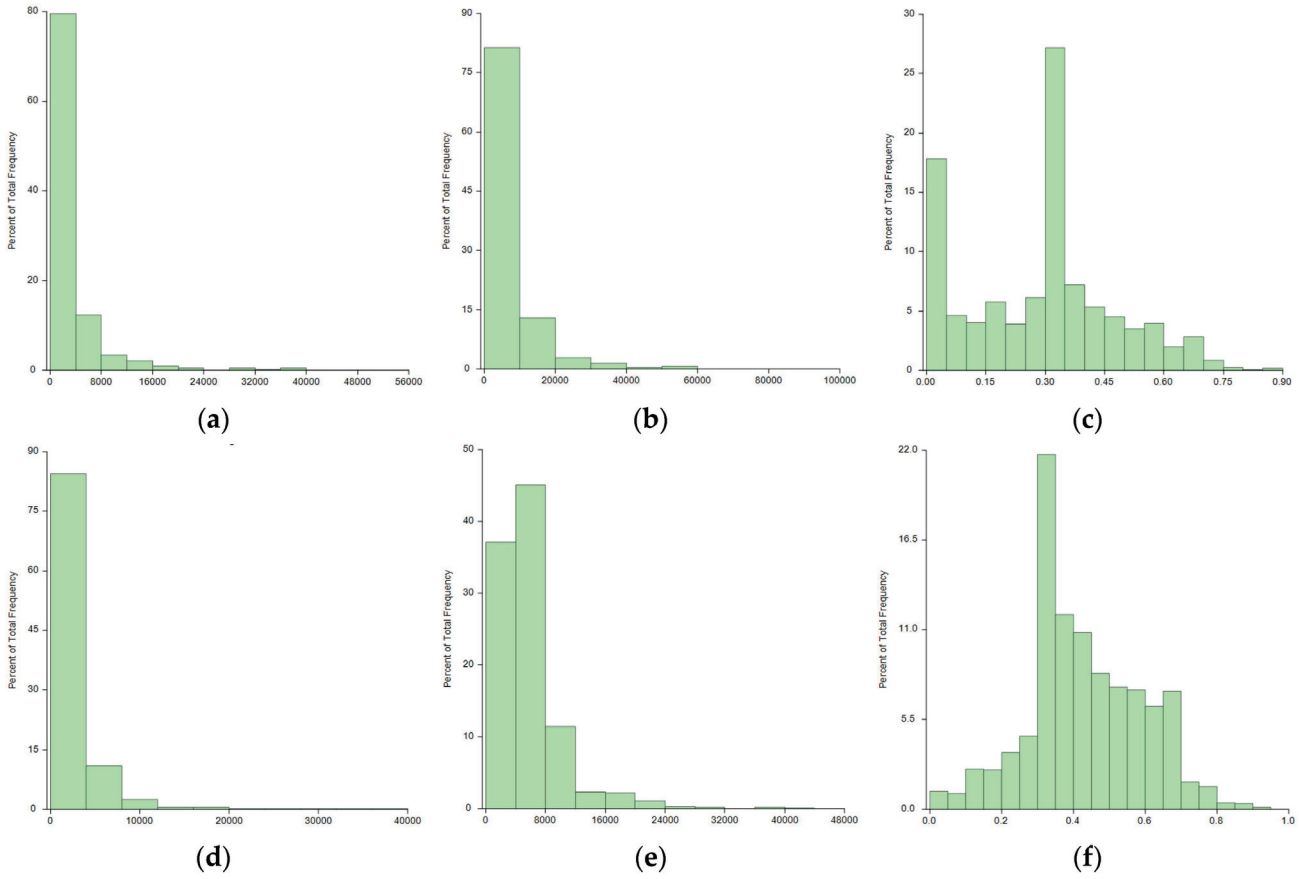

Figure 1. The histograms of six types of choice alternatives: (**a**) Net house density at block level; (**b**) net population density at block level; (**c**) land-use mix index within 0.25-mile buffer; (**d**) net house density at tract level; (**e**) net population density at tract level; (**f**) land-use mix index within 0.5-mile buffer.

Table 2. Categories of density and land-use mix related choice alternatives.

	Choice Sets	Least Dense		Densest	
Block level (1000/square mile)	Housing density index	(min, 1171.88)	(1171.89, 2141.69)	(2141.70, 3473.66)	(3473.67, max)
	Market share	756 (24.98%)	758 (25.05%)	759 (25.08%)	753 (24.88%)
	Population density index	(min, 2808.57)	(2810.58, 5300.21)	(5300.22, 8599.48)	(8599.49, max)
	Market share	757 (25.02%)	757 (25.02%)	756 (24.98%)	756 (24.98%)
Tract level (1000/square mile)	Housing density index	(min, 1404.80)	(1404.81, 2140.33)	(2140.34, 3197.09)	(3197.10, max)
	Market share	759 (25.08%)	757 (25.02%)	756 (24.98%)	754 (24.92%)
	Population density index	(min, 3014.76)	(3014.77, 4757.71)	(4757.72, 6924.86)	(6924.87, max)
	Market share	756 (24.98%)	759 (25.08%)	756 (24.98%)	755 (24.95%)
		Least diverse land-use		most diverse land-use	
0.25-mile buffer area	Land-use mix index	(min, 0.13)	(0.14, 0.33)	(0.34, 0.39)	(0.40, max)
	Market share	756 (24.98%)	1142 (37.74%)	374 (12.36%)	754 (24.92%)
0.5-mile buffer area	Land-use mix index	(min, 0.33)	(0.34, 0.41)	(0.42, 0.55)	(0.56, max)
	Market share	898 (29.68%)	618 (20.42%)	756 (24.98%)	754 (24.92%)

As for population and housing density indexes, 4 ordinal categories for each index were calculated and confirmed based on the process of data stratification. For instance, 4 choice options representing housing density index at census block level were generated using 3 quantiles of these data—i.e., 1171.88, 2141.69, and 3473.66. In other words, any households whose housing density index at census block level was equal to or less than 1171.88 thousand per square miles chose the first alternative—that is, the census blocks with the smallest density of housing units compared with the other three options. This same was true of the 3 additional density-related indexes.

Regarding the indicator of land-use diversity, we adopted the framework of land-use diversity designed by Guo (2007), while minor changes were made to accommodate our empirical analysis. In other words, we considered the measure of land-use mix defined by:

$$\text{LUXs} = 1 - \frac{\text{abs}(\text{Rs} - 0.25) + \text{abs}(\text{Cs} - 0.25) + \text{abs}(\text{Is} - 0.25) + \text{abs}(\text{Os} - 0.25)}{1.5} \quad (1)$$

where Rs, Cs, Is, and Os are the fractions of 0.25- or 5-mile buffer area that is residential, commercial, industrial, and other land-use types surrounding a specific household s. According to Guo and Bhat (2004), this land-use mix index ranges from 0 to 1, where 1 refers to a totally mixed land use and 0 shows that the land is purely pertinent to a single land use [32]. Similarly, using data stratification we identified 4 ordinal categories of land-use mix indexes (Table 2). We took the case of the land-use mix index within the 0.25-mile buffer area to a given household. The data were divided into four categories using 25%, 50%, and 75% quantiles—i.e., 0.13, 0.33, and 0.39, respectively. Accordingly, households whose land-use diversity index was within the 0.25-mile buffer equal or less than 0.13 were assumed to choose the alternative of the 0.25-mile area that was least diversified in land use. The same was true of the 0.5-mile land-use mix index.

Because of the correlation nature among similar choice alternatives in our study, we analyzed the residential choice using an ordered-response model (ORM). In fact, numerous published papers have proved the robustness of the ORM in modeling ordinal level dependent variables [32,33]. The ORM formulation was originally proposed by McKelvey and Zavonia in 1975 and adopted in our analysis.

For the sake of model specification, we consider the housing density at census block level, for example. The same conceptualization can be applied to five other ordinal-level dependent variables in this paper. In the case of the housing density index, the mechanism of ordinal-level responses assumes the existence of a potentially continuous propensity of housing density U_q^* for household q. This latent propensity is postulated to be a linear function of a vector of inherent and exogenous variables of the household q, x_q, and an error term ε_q that is independently and identically distributed. The latent propensity

U_q^* reflects the reported choice alternatives of housing density index, U_q, via 3 threshold bounds [32]. Simply stated, the propensity U_q^* is represented as:

$$\begin{array}{ll} U_q^* = \beta' x_q + \varepsilon_q,\ \varepsilon_q \sim N(0,1) & \\ U_q = 0 \text{ (not dense)} & \text{if } U_q^* \le 0 \\ U_q = 1 \text{ (somwhat dense)} & \text{if } 0 < U_q^* \le \mu_1 \\ U_q = 2 \text{ (very dense)} & \text{if } \mu_1 < U_q^* \le \mu_2 \\ U_q = 3 \text{ (the densest)} & \text{if } \mu_2 < U_q^* \end{array} \quad (2)$$

In the above equation, x_q includes all the explanatory variables plus a constant intercept. The error terms are normalized to follow a standard normal distribution with a mean of 0 and a variance of 1. Since the constant term is included in the model, the lowest threshold is confirmed to be 0 [33]. In addition, the μ's denote additional threshold bounds. Furthermore, the probability for a household q to live in a census block with a given housing density index that falls into an ordinal category k (k = 0, 1, 2, 3) is calculated based on Equation [2] as:

$$\begin{aligned} P[U_q = k] &= \Lambda(u_k - \beta' x_q) - \Lambda(u_{k-1} - \beta' x_q) \\ & u_{-1} = -\infty,\ u_0 = 0,\ u_3 = +\infty \end{aligned} \quad (3)$$

Last but not the least, a maximum likelihood procedure was conducted to obtain the best-fit vector of coefficient β' that was associated with explanatory variable x. This procedure was completed using the econometric software NLOGIT 5.0.

2.2. Description of Explanatory Variables

Given the data availability and explanatory variables suggested by Guo, Lerman and Frenkel et al. [1,3,14], we identified six categories of exogenous and endogenous attributes of households (Table 3). Next, each group of variables will be discussed briefly.

2.2.1. Demographics

Household demographics are mirrored by three variables—that is, the number of household members, the race of household respondents, and the family structures. The underlying logic for choosing these variables is that household size, ethnic status, and household structures (e.g., presence of children and retirees, etc.) have been found to be statistically significant in zone-based residential models [1,5]. In addition, the raw data were processed to accommodate the modeling process. Specifically, the categorical data were converted into dummy variables. For instance, there are 8 categories of race attributes—e.g., White, African American or Black, Asian, and American Indian or Alaskan Native, etc. Accordingly, the model can understand well the ethnicity of a given respondent on the basis of these dummy variables. For the sake of model construction, the base or reference dummy variable of household ethnicity is Rother—that is, the race of household respondent is any other race type. In addition, the same is true of the family structure attribute regarding data conversion.

2.2.2. Travel-Related Attributes

Travel-related attributes characterized three measures, including the number of vehicles, the category of number of household trips on travel days, and proximity to schools. First, the number of vehicles reflects households' travel mobility—that is, how easily an individual can make a trip from home to destinations. This may affect the residential location decisions. Second, the variable related to households' trips also mirrors the travel mobility of households. Third, whether a household is close to working places describes one aspect of its surrounding built environment, thereby potentially impacting the residential location considerations of households.

Table 3. Description of selected explanatory variables in the data set.

	Name	Description	Data Type
Demographics	hsize	Household size	Counts
		Race (selected)	
	White	The race of household respondent is White	Dummy
	Black	The race of household respondent is African American, Black	
	Asian	The race of household respondent is Asian	
	Indian	The race of household respondent is American Indian, Alaskan Native	
	Rother	The race of household respondent is any other race type	
		Structure of household (selected)	
	sadult	one adult, no children	Dummy
	sretire	one adult, retired, no children	
	sparyc	one adult, youngest child 0–5	
	madunc	2+ adult, no children	
	mretire	2+ adult, retired, no children	
	madyc	2+ adult, youngest child 0–5	
Travel attributes	hhveh	The number of vehicles in households	Counts
	cnht	Category of number of household trips on travel days	
	clwork	Proximity to work	Dummy
Employment and economic indicators	nworker	Number of workers	Counts
		Household income	
	hinc	High-income (total annual income is equal or greater than USD 60,000)	Dummy
	minc	Medium-income (total annual income is between USD 30,000 and USD 59,999)	
	linc	Low-income (total annual income is less than USD 30,000)	
	nadult	Number of adults at least 18 years old	Counts
Housing index	htenure	Housing units owned	Dummy
		The type of housing units	
	dsingle	The type of housing unit is detached single house	Dummy
	Duplex	The type of housing unit is duplex	
	Townh	The type of housing unit is rowhouse or townhouse	
	Apt	The type of housing unit is apartment or condominium	
	Mobhm	The type of housing unit is mobile home or trailer	
	Hothert	The type of housing unit is any other type	
Lifestyle factors	cschool	Close to school	
	cretail	Close to retail services	
	cfriend	Close to friends	
Transit	ctrans	Close to transit	

2.2.3. Employment and Economic Indicators

Three crucial measures of this group were considered based on earlier studies. The number of workers in a household embodies the employment status of family members. The variable of total annual household income serves as an indicator of households' economic characteristics, which has been proven to be decisive in determining the levels of car ownership of individuals [34]. Since car ownership is correlated with residential location decision [35], it is reasonable that there may exist a causal linkage between household income and residential location. The third measure is the number of adults at least 18 years old, which can be regarded as an index of the levels of the workforce represented in households.

As for data structuring, the variable of housing income is initially represented by 18 categories. This study creates 3 dummies according to these income categories—i.e., high-income households with total annual income equal or greater than USD 60,000, medium-income households with total annual income between USD 30,000 and USD 59,999, and low-income families with less than USD 30,000.

2.2.4. Housing-Related Index

The attributes of housing units themselves are, essentially, the reflection of residential locations. In other words, single-family houses are less likely to be located in downtown areas than apartments or condominium in that the land-use development of urban regions are more compact than that of suburban areas. Specifically, the housing-related index consists of two factors: housing tenure status and the type of housing units. Six dummies were generated to reflect the types of housing units.

2.2.5. Lifestyle Factors and Transit Accessibility

A number of measures—i.e., the proximity to schools, friends, and retail services—are used to depict the lifestyle of households. In other words, these attributes are potentially associated with the frequency of educational and recreational activities in households, thereby indirectly affecting residential location considerations. In addition, the dummy variable, proximity to transit, reflects the accessibility of transit services to a given household.

2.2.6. Interacting Terms

A variety of interactions among different groups of factors were explored in the modeling process to capture the effects of interacting terms on the response variables. Specifically, the interactions considered were primarily twofold. First, the economic indicators (e.g., low-income households, etc.) interact with transit and housing indexes such as housing tenure. Second, demographic characteristics such as household size interact with housing indexes.

3. Results

Three categories of models regarding housing, population, and land-use diversity index were estimated using the order-response logit technique. Furthermore, under each category two models were run to examine the impacts of the choice sets with different spatial scales on the estimated results. In addition, six groups of variables and various interacting terms across these groups (mentioned in the last section) were considered and explored in the empirical results. Through a systematic process of excluding statistically insignificant variables, the final results of each model and the direct effects of variables are presented and interpreted in the following sections. In addition, under each category the empirical analysis investigated the model sensitivity to different spatial scales of choice sets.

3.1. Model Results I (Housing Density at Census Block or Tract Level)

The parameter estimates concerning residential choice of housing density are presented in Tables 4 and 5. The effects of independent variables on the residential preferences concerning housing density are interpreted in the following paragraphs.

I. Effects of Demographics

Census block level. The effects of demographics suggest that the structure of households was an important factor in determining the propensity of households to live in areas with high housing density. Specifically, Table 4 indicates that single retired households with no children showed a higher propensity to live in census blocks with a large number of housing units per square mile than other types of households. This is probably due to the fact that a populated community can offer an atmosphere of family to those retired persons without children. In all likelihood, a large community provides better opportunities for these individuals to communicate with neighbors than a small one. This is somewhat

inconsistent with the findings of Bhat et al. [32], which indicate that the households with seniors tend to avoid high housing density developments. This inconsistence may partly result from different spatial scales of research objects used in this study and their empirical analysis. Here, we can focus on neighborhood level, or census block. However, at census block level, only the variable representing household structures, as a stand-alone factor, was statistically significant. As for interacting effects, the households with a large number of family members who lived in rowhouses or townhouses tended to live in areas with high housing density. The same was true of big families who own houses.

Census tract level. The effects of household structure on residential choice on housing density at census tract level were similar to the ones at block level—that is, singe retired households preferred those communities with a large quantity of housing units. The effects of race indicate that, at census tract level, American Indian or Alaskan Native families were less likely to reside in areas with high rate of housing density than Asian, Hispanic/Mexican, and White families, and households of other ethnic types. This was partially due to social gentrification issues. In other words, population clustering existed in the communities with similar racial background. Regarding interactions, big households living in apartments or condominiums displayed a higher propensity to live in housing-oriented areas than those dwelling in duplexes. Nonetheless, the variable of household size did not play a crucial role in the residential choice decisions regarding housing density either at census block or tract level.

II. Effects of Travel-Related Attributes

Census block level: It is expected that the level of vehicle ownership in household negatively impacts the likelihood for households to live in areas featuring high housing density developments. This is understandable in that the presence of cars equips the households with the ability to reside in suburbs that are typically more comfortable regarding environmental and living quality but have fewer housing units than urban areas. However, the proximity to work and the household trip variables turned out to be insignificant at census block level.

Census tract level: The effect of car ownership at census tract level was consistent with that at block level. In other words, vehicle ownership can be viewed as an essential element in the residential considerations regarding housing density. In addition, households who travelled more frequently preferred low housing density developments. It is worth noting that whether a household was close to workplaces hardly impacted the residential choice on housing density.

III. Effects of Employment and Economic Indicators

Census block level. The effects of economic indicators showed that high-income households shied away from areas featuring high housing density. However, at census block level, medium- and low-income households were indifferent to housing density. In addition, two terms of interaction between household-income and housing-related indexes were significant. First, low-income families living in detached single houses had lower propensity to live in the regions with a high concentration of housing units than others. Second, when owning their properties, low-income households tended to live in residential areas with high housing density. However, it is surprising to note that the employment indicators, and number of workers and adults (at least 18 years old) in a household barely had impacts on residential considerations concerning housing density.

Census tract level. The effects of household income implied a higher propensity to live in census tracts with large housing density among low-income households relative to medium- and high-income households. Furthermore, compared to medium-income households, high-income ones were less likely to choose areas with high housing density developments as their residences.

IV. Effects of Housing-Related Index

Census block level. Only the housing tenure was found to be significant. Hence, at census block level, there existed no residential choices on housing density among households if one only considered their housing unit types, such as single-family and multiple-family houses. Only when interacting with other variables did some factors concerning housing types impact the residential choices regarding housing density. The effect of housing tenure showed that households who rented tended to live in census blocks with high housing density.

Census tract level. Interestingly, at census tract level the effect of housing tenure disappeared. In other words, households who owned houses or rented them were indifferent to the housing density at census tract level. In addition, the variable of housing type became significant at this spatial scale. Specifically, households dwelling in rowhouses, or townhouses showed higher housing density propensity relative to those living in houses of other types—e.g., detached single houses, apartments, and mobile houses, etc. However, none of the variables in the group of lifestyle and transit accessibility was found to be statistically significant in these two models.

V. Model Fit and Threshold Parameters

The threshold parameters, without any meaningful indications, only served as a link between observed market shares of choices to the propensity for households to live in areas with high housing density. Log likelihood at convergence of two models turned out to be −4054.67 and −3933.88, respectively, whereas log likelihood for the constant-only model was −4194.91. Using such information, the robustness of these two models was confirmed by the likelihood ratio test, while the effects of factors on the dependent variable differed at different spatial scales.

Table 4. Ordered response model of residential choice of housing density at census block level.

Variables	Parameter	T Stat
Demographics with interactions		
Household size interacted with the type of housing unit of rowhouse or townhouse	0.22	8.43
Household size interacted with housing units owned	0.07	2.26
Structures of households (base is any other household type)		
One adult, retired, no children	0.45	4.02
Two or more adults, no children	0.36	3.87
One adult, no children	0.35	3.10
Two or more adults, retired, no children	0.27	3.06
Two or more adults, youngest child 0–5	0.20	1.84
Two or more adults, youngest child 6–15	0.17	1.71
Travel-related attributes		
The number of vehicles in a household	−0.07	−2.45
Employment and economic indicators with interactions		
High-income households (base is medium- and low-income households)	−0.29	−5.54
Low-income households interacted with the housing unit of detached single house	−0.30	−3.63
Low-income households interacted with housing units owned	0.26	3.46
Housing-related index		
Housing units owned	−0.19	−1.96
Number of cases	3026	
Log likelihood at convergence	−4054.67	
Log likelihood for constant-only model	−4194.91	
Mu(1)	0.70	
Mu(2)	1.43	

Table 5. Ordered response model of residential choice of housing density at census tract level.

Variables	Parameter	T Stat
Demographics with interactions		
Household size interacted with the type of housing unit of apartment or condominium	0.17	2.29
Household size interacted with the type of housing unit of duplex	0.13	4.70
Structures of households (base is any other household type)		
One adult, retired, no children	0.11	1.64
Race (base is any other ethnic type)		
American Indian, Alaskan Native	−0.64	−1.97
Asian	−0.42	−2.43
Hispanic/Mexican	−0.23	−1.63
White	−0.19	−3.28
Travel-related attributes		
The number of vehicles in a household	−0.06	−2.05
Category of number of household trips on travel days	−0.01	−2.07
Employment and economic indicators		
Household income (base is the low-income households)		
High-income households	−0.36	−6.53
Medium-income households	−0.10	−1.85
Number of adults at least 18 years old	0.06	1.63
Housing-related index		
The type of housing units (base is any other housing unit type)		
The type of housing unit is rowhouse or townhouse	0.80	15.36
Number of cases	3026	
Log likelihood at convergence	−3933.88	
Log likelihood for constant-only model	−4194.91	
Mu(1)	0.74	
Mu(2)	1.49	

3.2. Model Results II (Population Density at Census Block or Tract Level)

Tables 6 and 7 indicate the parameter estimates concerning residential choice of population density. The impacts of explanatory variables are discussed in the following sections.

I. Effects of Demographics

Census block level. Household structure played a pivotal role in affecting the households' propensity to reside in populated census blocks. Specifically, households with two and more adults and the youngest child between 0–5 years old showed the highest propensity to live in census blocks of high population density than those of any other types. What is more, multiple-adult families with the youngest child between 6–15 years old were more like to live in highly populated areas than those without children. This is partially due to that fact that big families characterized by a broad age range in the household members have diversified needs. For instance, households with an infant may opt to live in a community featuring good child service facilities such as baby-oriented grocery stores, children's hospitals, nurseries, and so on. Typically, these facilities are located in populated areas to accommodate the needs of the majority population. Hence, populated census blocks become the optimal residential locations for these families. As for the older families, the results show that retired households with two or more adults, but no children were more likely to live in populous census blocks than single-person households. Regarding race, the White households preferred census blocks with low population density more than households of other race types. This is probably because the White population is on average richer than other ethnic groups and capable of purchasing large housing units in less populated areas such as suburbs rather than downtown areas.

Table 6. Ordered response model of residential choice of population density at census block level.

Variables	Parameter	T Stat
Demographics		
Structures of households (base is any other household type)		
Two or more adults, youngest child 0–5	0.30	3.75
Two or more adults, youngest child 6–15	0.24	3.33
Two or more adults, retired, no children	0.21	3.94
Race (the base is any other ethnic type)		
White	−0.19	−3.59
Travel-related attributes		
The number of vehicles in a household	−0.06	−2.31
Category of number of household trips on travel days	−0.01	−2.31
Proximity to work	0.16	1.69
Employment and economic indicators		
Household income (the base is low-income households)		
High-income households	−0.41	−7.52
Medium-income households	−0.15	−2.76
Number of adults at least 18 years old	0.14	4.23
Housing-related index		
The type of housing units (the base in any other type)		
The type of housing unit is detached single house	−0.26	−5.70
Lifestyle factors and transit accessibility		
Proximity to friends	−0.19	−1.77
Number of cases	3026	
Log likelihood at convergence	−4089.05	
Log likelihood for constant-only model	−4194.93	
Mu(1)	0.70	
Mu(2)	1.430	

Table 7. Ordered response model of residential choice of housing density at census tract level.

Variables	Parameter	T Stat
Demographics with interactions		
Household size interacted with the type of housing unit of rowhouse or townhouse	0.12	4.98
Household size interacted with the type of housing unit of duplex	0.06	2.28
Structures of households (base is any other household type)		
One adult, youngest child 16–21	0.37	1.56
Two or more adults, youngest child 6–15	0.18	2.61
Race (base is any other ethnic type)		
Asian	−0.56	−3.24
White	−0.46	−8.28
Travel-related attributes		
Category of number of household trips on travel days	−0.01	−2.32
Employment and economic indicators with interactions		
High-income households (base is medium- and low-income households)	−0.31	−6.30
Number of adults at least 18 years old	0.09	3.25
Low-income households interacted with housing units owned	0.27	4.67
Housing-related index		
Housing units owned	−0.44	−5.95
Number of cases	3026	
Log likelihood at convergence	−4002.19	
Log likelihood for constant-only model	−4194.92	
Mu(1)	0.72	
Mu(2)	1.46	

Census tract level. It is interesting to note that single-person households with the youngest child between 16–21 years old showed higher likelihood to reside in densely-populated census tracts relative to those with two or more adults and the youngest child 6–15 years old and households of other structures. In addition, Asian households were found to be less likely to live in populated census tracts than White families and households of other types. Furthermore, compared to other ethnic groups, the White group did not choose to live in populous areas, which is consistent with the findings at census block level. As for interaction effects, the household size interacting with the type of housing units did impact households' propensity to live in populated census tracts.

II. Effects of Travel-Related Attributes

Census block level. All travel-related attributes were significant. Specifically, the negative coefficient indicated that households with high rates of car ownership tended to avoid living in populous census blocks. The household trips had similar effects to vehicle ownership on residential choice of population density. The variable of proximity to work implied that households who were close to work were more likely to live in populated census blocks.

Census tract level. Surprisingly, vehicle ownership and proximity to work were insignificant at census tract level. Only the measure of household trips on travel days was proven to be statistically influential upon residential choice concerning population density. Most importantly, the results at tract level regarding household trips were in accordance with those at block level—i.e., households with high frequency of trips tended to live in sparsely populated census blocks or tracts.

III. Effects of Employment and Economic Indicators

Census block level. The results indicate that high-income households had a lower propensity to live in census blocks with high population densities than medium- and low-income households. What is more, low-income households were most likely to live in densely populated blocks compared with high- and medium-income families. Additionally, an increase in the number of adults at least 18 years old in a household resulted in a similar effect on the household's propensity to reside in the most populated blocks.

Census tract level. The effect of high-income households at tract level was in line with the one at block level. However, medium- and low-income households were unconcerned about the population density at census tract level. Nevertheless, low-income households who owned properties showed higher likelihood of living in populated census tracts than high- and medium-income ones who rented. An increase in the number of adults at least 18 years old in a household resulted in a similar effect on the household's propensity to reside in the most populated tracts.

IV. Effects of Housing-Related Index

Census block level. The finding indicates that individuals whose houses were detached single houses were less like to inhabit a census block with a high rate of population density than those whose housing units were other types. However, the housing tenure variable had little explanatory power at block level.

Census tract level. At a sizable spatial scale, however, the housing unit types were no longer significant in terms of population-related residential choice, but the housing tenure did have obvious impacts at tract level. Specifically, a household owning a house tended to live in a sparsely populated census tract.

V. Effects of Lifestyle Factors and Transit Accessibility

One measure from this group was significant only at census block level. The results show that households who were close to their friends were more likely to inhabit census blocks with a small population density than those who were not.

VI. Model fit and threshold parameters

The log likelihood at convergence of two models turned out to be -4089.05 and -4002.19, respectively, whereas log likelihood for the constant-only model was -4194.9.

Based on the above information, the effectiveness of these two models is justified by the likelihood ratio test, while the effects of factors on the dependent variable differed at different spatial scales.

3.3. Model Results III (Land-Use Diversity Index at 0.25-Mile or 0.5-Mile)

Tables 8 and 9 display the parameter estimates concerning residential choice of land-use diversity. The following sections explain in detail the impacts of explanatory variables on the residential preferences of mixed land use.

Table 8. Ordered response model of residential choice of 0.25-mile land-use diversity.

Variables	Parameter	T Stat
Demographics with interactions		
Household size interacted with the housing unit owned	0.16	4.99
Household size interacted with the type of housing unit is detached single house	−0.15	−7.87
White (the base is any other ethnic type)	−0.16	−2.96
Employment and economic indicators		
High-income households (base is medium and low-income households)	−0.14	−3.33
Number of adults at least 18 years old	−0.09	−2.30
Housing-related index		
Housing units owned	−0.64	−7.20
Lifestyle and transit accessibility		
Proximity to friends	−0.19	−1.81
Number of cases	3026	
Log likelihood at convergence	−3901.85	
Log likelihood for constant-only model	−3991.07	
Mu(1)	1.03	
Mu(2)	1.40	

Table 9. Ordered response model of residential choice of 0.5-mile land-use diversity.

Variables	Parameter	T Stat
Demographics with interactions		
Household size interacted with the type of housing unit owned	0.11	4.07
Household size interacted with housing unit of detached single house	−0.09	−3.97
Race (the base is any other ethnic type)		
Asian	−0.36	−2.09
White	−0.17	−6.59
Structures of households (base is any other household type)		
One adult, youngest child 0–5	−0.70	−1.82
Employment and economic indicators		
Household income (the base is low-income households)		
High-income households	−0.34	−6.59
Medium-income households	−0.13	−2.45
Housing-related index		
Housing units owned	−0.53	−6.58
The type of housing unit is duplex (the base is any other type of housing units)	−0.19	−2.54
Number of cases	3026	
Log likelihood at convergence	−4091.20	
Log likelihood for constant-only model	−4168.91	
Mu(1)	0.56	
Mu(2)	1.25	

I. Effects of demographics

The 0.25-mile scale. First, the White households showed a higher propensity to dwell in an area with a single land-use type within a 0.25-mile buffer than households with any other racial background. This result is intuitively reasonable in that the White group may place more emphasis on individual space than other racial groups and attempt to avoid the potential issues resulting from mixed land use, such as noise and air pollution, crime issues, and so on. Second, the results of interacting terms suggest that a large household with an owned house was more likely to live in a land-use diversified area than others. Furthermore, a big family inhabiting a detached single house would avoid the regions with the developments of diverse land use.

The 0.5-mile scale. First, at this spatial scale, Asian families were more likely to reside in a region with a unique land-use type (probably residential land) than the White ones and households of other types. This is surprising, since in most Asian cities the land use within or surrounding a residential community is highly diversified. These results may be partially because, after coming to the United States, Asian households or their offspring may change their attitudes towards land use related to residence. What is more, the White households also shied away from diversified land use compared to other racial groups, such as American Indian and American Black, etc. The latter finding is in line with the results on the 0.25-mile scale. Third, the single-parent households with the youngest child between 0–5 years old attempted to keep their residences away from areas with mixed land use. The underlying logic is that the issues resulting from mixed land use, such as noise and security problems, may pose more threats to single-parent households with the presence of infants than households of other structural types.

II. Effects of Travel-Related Attributes

None of the travel-related attributes were statistically associated with households' propensity to reside in areas with diversified land-use structures. One probable reason may be that the scales of land-use diversity index were not substantial enough to make possible the potential effects of travel-related variables.

III. Effects of Employment and Economic Indicators

The 0.25-mile scale. The negative coefficients of these measures suggest that employment and economic indicators decreased the households' propensity to live in regions of diverse land use. Specifically, high-income households kept their houses away from mixed land use compared with medium- and low-income ones; medium- and low-income households were indifferent to the 0.25-mile land-use mix. Second, as the number of adults at least 18 years old in a household went up, a family was more likely to reside in an area with a uniform land use.

The 0.5-mile scale. The same was true of the 0.5-mile scale in terms of the effects of household income. In other words, when choosing residential locations, high-income families avoided those places of high rates of land-use diversity compared to medium- and low-income ones. Furthermore, low-income households were more likely to have residences in a highly diversified land-use area than medium-income ones.

IV. Effects of Housing-Related Index

The 0.25-mile scale. When it comes to housing units, the households owning properties preferred areas of single land use more than those renting. Nevertheless, the variable of housing unit type was not significant at the 0.25-mile scale.

The 0.5-mile scale. The same was true of housing tenure at the 0.5-mile scale. In addition, the outcomes indicated that households living in duplexes were more likely to reside in a block with a single land use than those dwelling in other types of housing units, like apartments or townhouses.

V. Effects of Lifestyle Factors and Transit Accessibility

Only one factor (proximity to friends) was significant at the 0.25-mile scale. The effect was that households who were close to friends showed lower propensity to live in a land-use diversified area. However, factors representing family activities and transit accessibility turned out to be insignificant.

VI. Model Fit and Threshold Parameters

The values of log likelihood at convergence of two models were −3901.85 and −3991.07, respectively, whereas the values of log likelihood for the constant-only model were −3991.07 and −4168.91, respectively. Based on the above information, the usefulness of these two models was demonstrated by the likelihood ratio test, while the effects of several factors on the dependent variable differed at different spatial scales.

4. Discussion

The purpose of this article was to investigate the factors that influence households' decisions to reside in populated areas or regions with mixed land use. To achieve this, the authors constructed six models, which led to several significant findings and contributions. The results of the study align with previous research and provide new insights into the macro-level factors that affect residential location choices. Regarding housing density, the household structure, number of vehicles, and income were found to be significant factors. Demographic characteristics, household income, and housing types were crucial in determining residential choices based on population density. For land-use mix, the most influential factors were the interaction between demographics and housing-related indexes, as well as household income and housing-related indexes.

However, several variables were found to be insignificant, such as travel-related attributes in the land-use diversity model. The implications of these findings for urban planning and community development are significant. The study suggests that vehicle dependence is a critical barrier to implementing compact and walk-friendly urban forms. As a result, policymakers must adopt measures to change households' attitudes towards private cars.

The study has some limitations, including issues with the representation of land-use diversity and the need for additional variables to increase the robustness of the models. Future research could explore other variables and redefine the land-use diversity index to compare the results with the current study. Overall, this study provides valuable insights into the factors affecting residential location choices and has important implications for urban planning and community development.

5. Conclusions

In conclusion, this study has provided significant insights into the factors that influence households' preferences to reside in populated areas or regions with mixed land use. The findings of the study have confirmed and extended previous research, shedding light on the crucial macro-level factors that determine residential location choices. The study found that household structure, number of vehicles, income, demographic characteristics, and housing types play important roles in shaping residential choices based on population density, housing density, and land-use mix.

Regarding residential choices based on land-use mix, the most influential factors are the interactions between demographics and housing-related indexes, household income, and housing-related indexes. Some variables were found to be insignificant; for example, in the land-use diversity model, travel-related attributes had little impact on the dependent variables. These findings have significant implications for urban planning and community development, such as the need to change households' attitudes towards private car travel.

The implications of these findings are essential for urban planning and community development. Compact and walk-friendly urban forms are critical for sustainable development, and the study suggests that vehicle dependence is a crucial barrier to implementing

these forms. Policymakers must adopt measures to change households' attitudes towards private cars and promote alternative modes of transportation.

Overall, this study contributes to the literature on residential location choices and provides valuable insights for policymakers and urban planners. By understanding the factors that influence households' decisions to reside in certain areas, policymakers can make informed decisions to promote sustainable and livable communities.

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Beyond Homeownership? Examining the Mediating Role of Housing Tenure on Young People's Subjective Well-Being

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Abstract: Young people around the world are facing similar housing challenges, trapped between a costly and unaffordable homeownership sector and an unstable (private) rental sector. China has opted to promote renting as an alternative to homeownership to alleviate the housing difficulties of young people in big cities. However, the influences of promoting rental housing on the subjective well-being of different groups have not been well understood. Therefore, this study examines the mediating role of housing tenure in the relationship between individual attributes and subjective well-being. The study is based on 1,149 questionnaires conducted on the housing situations of residents in Guangzhou, and 618 samples were extracted for analysis based on the purpose of this study. It is found that individual, marital status, (local/nonlocal) *hukou* status, and income level have significant indirect effects on subjective well-being, with housing tenure as the mediator. This study contributes to a deeper understanding of the influencing mechanisms of subjective well-being associated with housing tenure and human heterogeneity and specifies the key points for future research and policymaking.

Keywords: housing tenure; subjective well-being; young people; mediating effect; urban China

1. Introduction

Youth housing difficulties and the responding policy interventions are major contemporary global concerns [1]. The youth are facing very similar housing dilemmas internationally [1,2], e.g., declining affordability, insecurity, and poor quality of accommodation. Many young people are constrained to the private rental sector (PRS) or waiting for scarce opportunities for social housing. The 'normalized' pathway into a linear housing career with the promise of homeownership is disrupted and replaced by more chaotic pathways.

Over the past decades, the developed world has been moving towards 'homeowner societies' [3], but the sustainability of this trend is in doubt amidst widespread housing crises [4]. In the wake of the neoliberal turn, the 2007–2008 global financial crisis (GFC) and the COVID-19 pandemic, house prices in many jurisdictions have risen to unaffordable levels, with precarious employment and earnings [3,5]. Younger cohorts are finding it increasingly difficult to afford the down payment and/or mortgage loans. The value of housing as an asset also becomes uncertain, putting mortgaged homeowners at risk of negative equity. The PRS, to which a growing number of young people are being restricted, is characterized by insecure tenure and arbitrary rent increases, making it difficult for the younger generations to save money and accumulate wealth. Under such circumstances, the shift from a collective to an asset-based welfare system appears illusory. Certain countries (notably Britain) are witnessing young people turning into the 'generation rent' [6]. The rental sector, either public or private, is receiving increasing policy and social attention.

In China, young people in big cities are struggling to afford homeownership or being confined to the PRS or staying with their parents. In tackling the housing difficulties of young people, the Chinese government has started with the rental sector, intervening both in the market sector and the social sector. The housing rental market has been actively promoted since 2015, regulating the rental chaos and nurturing rental enterprises. The emerging Long-term Apartment Rental (LAR or *changzu gongyu*) is gradually gaining importance in the PRS. LARs also adopt the slogan in line with young people's aesthetic and consumption habits, e.g., safety, quality, service, shared public space and community interactive atmosphere.

Young people also enjoy greater access to the social housing sector, owing to the (welfare) developmental orientation of the (local) governments [7]. The public rental housing (PRH or *gonggong zulin zhufang*), Government-subsidized Rental Housing (GSRH or *baozhangxing zulin zhufang*), Shared Ownership Housing (SOH or *gongyou chanquan zhufang*) and Talent Housing (TH or *rencai zhufang*) are all targeted at a population that includes (talented) young people, e.g., [8,9].

With China's increasingly people-oriented policy orientation, policy development and relevant research are paying greater attention to the heterogeneity of different populations. As a public policy and urban planning increasingly concern themselves with the development of society as a whole, indicators beyond economic growth have come into focus, e.g., subjective well-being. Subjective well-being is also considered to be an appropriate indicator for assessing housing policies. Recent years have seen unaffordable housing expenditure posing a threat to residents' subjective well-being. Nonetheless, the impact of promoting rental housing as a longer-term alternative to homeownership remains under-researched. Besides, quantitative analysis of housing and well-being targeted at young people in urban China has been relatively scarce except, e.g., [10]. Therefore, this study aims to examine how personal attributes and housing tenure (rent/own) matter for subjective well-being.

This paper uses Guangzhou, a typical large Chinese city, as an empirical case. The mediating role of housing tenure in the relationship between individual attributes and subjective well-being has been examined. The data source is a questionnaire survey of Guangzhou residents conducted by the authors. It is found that individual marital (local/nonlocal) *hukou* (i.e., Household Registration System for particular rights) status and income level have indirect influences on subjective well-being, with housing tenure as the mediator. Educational attainment, surprisingly, has no significant effect on subjective well-being and a significant negative effect on young people's homeownership status. Suggestions for policymaking and further research are derived accordingly.

Based on these findings, we identify three individual attributes (local/nonlocal *hukou* status, marital status, and income level) that deserve attention in promoting renting. It is also recommended that the mechanisms by which housing tenure affects subjective well-being be further explored. This study contributes to a deeper understanding of the mechanisms influencing subjective well-being associated with housing tenure and human heterogeneity and thus specifying the key points for future research and policymaking. The development of housing sectors in China may provide empirical and theoretical knowledge of the increasing deviation of the global housing sector from the 'normalized' homeownership path. It is also suggested that further studies be conducted to examine other mediating effects, moderating effects (e.g., Wang et al., 2023) or incorporate spatial analysis (e.g., Gu et al., 2022).

2. Literature Review

2.1. Subjective Well-Being: The Influences of Individual Attributes and Housing Tenure

Increasing urbanization worldwide has made the provision of a better quality of life for city dwellers an important issue in urban planning [11]. Subjective well-being as a large-scale measure of social progress in public policy evaluation can be traced back to the 1960s [12,13]. In the 1990s, policy evaluation had moved beyond the traditional

cost-benefit analysis and employed a wider range of impact measures, with indicators such as subjective well-being [14]. Clapham [15] also argues that well-being would be an appropriate measure of the success of housing policies.

Since the second decade of the 21st century, China's policymaking has placed emphasis on the 'people-oriented' approach, stressing that the goal of urban policy is to enhance people's well-being [16]. Well-being has become a crucial criterion for evaluating urban planning, management and services [17]. In Chinese cities, homeownership status has been found to have a positive effect on people's subjective well-being [18–20]. Nonetheless, soaring and increasingly unaffordable house prices in Chinese cities have become a potential barrier to the improvement of residents' subjective well-being [20].

Similar to many young people worldwide [2], China's younger cohorts are getting confined to the rental sector or living with their parents/relatives. Policy interventions to address youth housing difficulties have predominantly focused on promoting renting, not sharing with roommates nor staying with parents, as an alternative to homeownership. China's private rental sector has long been in an underdeveloped state with little regulation and policy support, making it a temporary and unwilling choice for those who cannot afford homeownership [21]. China's earlier social rented sector also placed a lower priority on the housing needs of young people, leaving them largely excluded.

After 2015, China proposed 'accelerating the development of the rental housing market', 'encouraging both housing rentals and purchases (*zugou bingju*)', 'ensuring all people's access to housing (*zhuyou suoju*)' and 'equal rights for tenants and homeowners (*zugou tongquan*)'. Renting has been highlighted as a practical alternative to homeownership to alleviate the housing difficulties of urban residents, especially the younger cohorts. Enhancing the well-being of people with housing difficulties is one of the key objectives of China's housing policy [22].

Nonetheless, the impact of promoting renting for heterogeneous populations has been under-researched. In the existing literature, while personal attributes and housing tenure are often placed together as independent variables affecting subjective well-being, few studies have examined the more nuanced influencing mechanisms between these three aspects. In other words, it is difficult for established research to provide sufficient information on how housing tenure affects subjective well-being across different groups. For the study to be relevant to recent housing policy, the housing tenure studied in this paper is focused on and restricted to homeownership and renting.

Previous studies have discussed the relationships between personal attributes, housing tenure and subjective well-being. Individual socioeconomic and institutional attributes, e.g., income, age, sex, *hukou* status, educational attainment, and affiliation, have been found to be determinants of subjective well-being. Studies on the impact of affluence on subjective well-being have yielded mixed results [23]. Some studies point to rising affluence but declining happiness [24,25], while many other Western studies show that an increase in personal income leads to greater well-being [23]. Aside from income, subjective well-being is also significantly related to age (higher for the elderly) and sex (higher for women) [26]. Educational attainment was also found to have a positive effect on the happiness of Chinese people post-1980s [27]. The (change in) *hukou* status (obtaining citizenship and settling down in a small city) has been found to significantly improve people's well-being [27,28].

The relationship between the built environment (including housing) and subjective well-being has not been fully understood, despite certain attempts [11]. Agboola et al. [29], for instance, highlight the influence of neighborhood open space on residents' well-being. In terms of housing tenure, its impact on subjective well-being has been disputed. Unsurprisingly, a number of studies have found a significant positive effect of homeownership on subjective well-being [19,30,31]. However, there are some articles suggesting that housing tenure has been found to have no significant impact on the resident's mental aspects, e.g., [32]. Baker et al. [33], for instance, found that although residents' mental health scores differ across tenure, it was difficult to argue for an intrinsic link between tenure and mental health when population differences are taken into consideration. Under the

'people-oriented' policy development orientation, it is critical to identify how personal attributes and housing tenure matter for subjective well-being.

Considerable research has found that personal attributes have a significant impact on housing-related factors, e.g., [23,34,35]. The status of homeownership varies greatly among people with different socioeconomic and institutional conditions [35]. Age (the elderly) and education (the more educated) have positive influences on accessing homeownership. The higher the age and education level, the better the chance of homeownership. Institutional factors such as *hukou* status (urban as opposed to rural and local as opposed to nonlocal) contribute to greater access to homeownership (ibid.). In the study on young people, Niu and Zhao [10] found that demographic factors (e.g., older and married), market variables (e.g., household income and schooling years), and institutional elements (local and urban *hukou*) and affiliation (within state-owned enterprises) have significant positive effects on attaining owner-occupied housing.

In short, different personal attributes are found to have varying influences on housing tenure and subjective well-being. Housing tenure, especially when individual differences are considered, has been found to have mixed effects on subjective well-being. In addition, most of these articles focus on a wider age span rather than specifically on young people, a recent target group for China's housing policy. In the context of encouraging both housing rentals and purchases, substituting rental for the previously prioritized homeownership as a practical and timely way to address housing difficulties of young people may generate varying effects on the well-being of diverse groups. This paper highlights the importance of examining which personal attributes have an impact on subjective well-being and which of these influences have been mediated by the tenure of renting/ownership.

2.2. Youth Housing Arrangements in Urban China

This section provides an overview of the social housing sector and market housing sector in urban China and illustrates the practical significance/relevance of this research.

2.2.1. Social Housing Policies Targeting the Urban Youth

The Chinese housing system is divided into a *baozhang* (commonly translated as 'security' in Chinese official documents and media reports) system and a market system, as in the top-end of the housing planning system [7,36]. For the sake of consistency with international terminology, security housing is hereinafter referred to as social housing.

The social housing system mainly comprises GSRH, SOH and PRH. This new classification does not contain the previous cheap rental housing (CRH or *lianzu zhufang*) and economically comfortable housing (ECH or *jingji shiyong zhufang*) for details, please also refer to [37] which shows that they have been gradually discontinued.

PRH has a few variants, including $PRH_{(H)}$ tailored for low- and middle-income house poor urban households, $PRH_{(N)}$ for newly employed workers (young people aged between 18 and 35 years old), and $PRH_{(M)}$ for migrants.

GSRH was introduced in 2021, targeting young people and new migrants. Nonetheless, GSRH distinguishes it from PRH in the supply body. PRH has been predominantly provided and allocated by the state and other public institutions. The target group of PRH has mostly been low- and middle-income residents who have a local urban *hukou* and do not own a house. The provision mode of GSRH has gone beyond the typical characteristic of public housing (i.e., provided by the state). GSRH has been (designed to be) invested in and supplied by more diverse groups, including various (market) subjects, with the government offering incentives. It has a fairly generous barrier to entry, except that in the policy document, it is offered at below-market rents to young people and newcomers with housing difficulties.

SOH is set as a homeownership option for those unable to enter the private ownership sector (underfunded) and the PRH sector (income above access criteria). SOH is also intended to bridge the gap between GSRH and the homeownership market. The governments regard it as a homeownership alternative for young people after staying at

GSRH for a few years [7]. The SOH also aims to break away from the massive rent-seeking practices of the ECH, but the operation mode of the SOH has not yet been settled.

TH, although outside of the national social housing system (consisting only of the PRH, GSRH and SOH), is used by many local authorities to support the housing needs of talents. TH is not only provided for high-level talents but is also allocated by many companies (subletting TH from the local governments) to new employees. This is partly because the quality and location of TH may not meet the needs of executives while satisfying the expectation of many young people.

Considering the official specifications on the age of young people (Middle- and Long-term Youth Development Plan (2016–2025) defining young people as those aged between 14–35), this paper limits the young people studied to those aged 18–35. Only the adult group will be considered as matching the minimum qualifying age for applying for social housing.

2.2.2. New Development in Private Markets: The Rising Rental Sector

Since around 2015, overproduction in the real estate sector has become a prominent issue from time to time [38]. The instability of employment brought about by the GFC and the COVID-19 pandemic has deterred young people from carrying a mortgage loan to purchase a house. Urbanization and population growth have been decelerated, especially in provinces and cities with a net outflow of population. Renting has been seen as a market of potential as growth momentum in the property market wanes [39].

Since 2015, the private rental market has been promoted by the central governments to provide decent and affordable rental housing to young people. The emerging LAR has been advocated to supplement the formerly 'small-scale petty landlordism' that housing units are possessed and managed by individual landlords [40] (p.661), towards institutionalization and platformization with sizeable real estate enterprises, Internet companies, institutional investors as the dominant market players. The government has proposed a two-pronged strategy to increase the supply of rental housing: (1) special designation (*danlie jihua*) of land transfer for newly-built rental housing, (2) renovate or convert existing property stock into rental units. The rental units produced could also be sources for social rental housing, particularly the GSRH (and TH) and private rental housing.

2.3. Limitations of Extant Research

To reiterate, this paper seeks to discover which personal attributes have influences on subjective well-being via housing tenure (rent/own). Much research has analyzed individual attributes and housing tenure as independent variables influencing subjective well-being, either separately or jointly, with individual attributes frequently as control variables. While this allows for an examination of the effect of housing tenure and/or personal attributes on subjective well-being, few studies have been able to provide a rather integrated analysis. In other words, past analyses could hardly answer the question of which groups are likely to be affected in terms of subjective well-being when rentals are promoted as a longer-term alternative to homeownership.

3. Materials and Methods

3.1. Study Area

Chinese youth is confronted with housing difficulties similar to that of the youth in many other districts, e.g., North America, Europe, and East Asia. Youth housing challenges are highlighted in large cities with a continuous influx of people. According to the 2020 China Census by County Data, Guangzhou is one of the seven megacities with an urban population of more than 10 million (the other six are Beijing, Shanghai, Shenzhen, Chongqing, Tianjin and Chengdu) [41]. Besides, Guangzhou differs from the capital and municipalities that may have special policies and authority, and its status as a provincial capital may provide more reference for other big cities. Guangzhou's housing policy is also largely in line with the national housing policy developments. Specifically, Guangzhou has served as a pilot city for a number of housing policies, e.g., national youth

development pilot city, one of the first batches of pilot cities for central financial support for the development of the rental market, and a pilot city for the use of collective land for construction of rental housing. During the 14th Five-Year Plan period, Guangzhou plans to raise 660,000 units of social housing (including 600,000 GSRH, 30,000 SOH and 30,000 PRH) and supply 650,000 units of private homeownership housing. The supply structure of social housing and market housing is close to 1:1, which makes it a possible place to analyze the housing tenure of rent and own. For the sake of representativeness and generalisability, Guangzhou (Figure 1) was chosen for the case study.

The survey samples cover young residents (aged between 18 and 35 years old) in 11 districts of Guangzhou. There is a wide range of housing types for young people, covering both owned and rented housing in the public and private sectors. In Guangzhou, the private sector includes private ownership and private rental. The PRS includes petty private rental (or with real estate brokers) and the emerging LAR. The social housing sector includes PRH (comprising $PRH_{(H)}$, $PRH_{(N)}$ and $PRH_{(M)}$), SOH, and also TH, which is not in the social system but supplied by the public institutions. These housing sectors are basically consistent with the national housing arrangements.

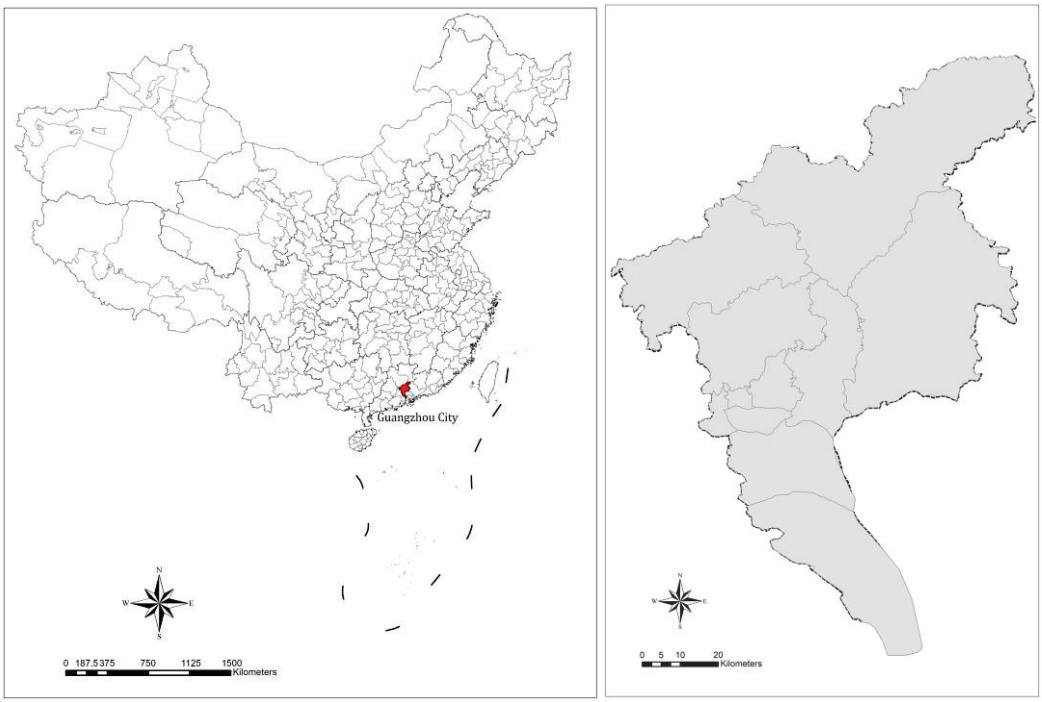

Figure 1. Study Area: geographical location of Guangzhou City in People's Republic of China (**left**) and district delineation of Guangzhou City (**right**) (drawn by the first author).

3.2. Data and Methods

The data were obtained from the questionnaires on the housing situations of Guangzhou residents with 1149 questionnaires distributed and a total of 1065 valid samples collected, with an effective rate of 92.7%.

Conducting a face-to-face investigation on a large scale has become a challenge due to the strict community regulation under the COVID-19 pandemic in mainland China. The questionnaire was first conducted online based on the random sampling method. The questionnaire was designed to target only residents in Guangzhou. The possible bias of the online questionnaire towards a younger sample also fits in with the unit of analysis of this research (i.e., young individuals). A stratified random sampling technique has been employed, designed to cover all districts and housing types (in different types of neighborhoods) in the city, and face-to-face questionnaires were administered to supplement the online questionnaires. Nonetheless, the number/proportion of each housing type for

young people in each district is difficult to obtain from open sources. The stratified sampling of the survey allows for type coverage and does not fully guarantee that the sample size of each housing type matches the proportional relationship of the overall sample.

Among the valid questionnaires, 744 questionnaires were collected from respondents aged 18–35. For the purpose of the study (focusing on housing tenure of renting and homeownership), further exclusion was made of residence in the parental home, workplace and public space, as well as questionnaires that could not identify urban/rural *hukou* status (one of the independent variables), generating a sample of 618 for final analysis.

This article aims to examine the role of housing tenure in the relationships between personal attributes and subjective well-being. In fact, a variety of statistical approaches could have been adopted to test the interrelationship between housing tenure, individual attributes and subjective well-being. For instance, the moderating effect of housing tenure could be tested to see if it shapes the relationship between individual attributes and subjective well-being. Multilevel regression modeling may also be applied (e.g., [42]). This paper, however, attempts to examine the mediating role of housing tenure. Specifically, the analysis is about how individual attributes affect subjective well-being by influencing housing tenure. An examination of the mediation models may provide information on which populations require more policy attention and academic scrutiny. Subsequent studies may go further to analyze other mediating effects and moderating effects or incorporate spatial analysis (e.g., [43]) to deepen understanding.

Independent variables of the empirical study include individual socioeconomic and institutional attributes. The mediator is housing tenure. For the dependent variable, subjective well-being, we use a standard well-being question: 'How happy do you feel now?' on a five-point scale [10]. Table 1 illustrates the measurement and descriptive statistics of the variables.

It was expected that all the independent factors (except sex, which would have a significant negative effect) would have significant positive effects on the dependent variable; all the independent factors would have significant positive effects on the mediator, and the mediator would have a significant positive impact on the dependent variable.

Since the independent variables involved dichotomous variables (e.g., *hukou* and marital status, sex, and age), a stepwise method is used for mediation analysis [44,45]. The corresponding steps are (i) testing the coefficient c of Equation (1) ($H_0 : c = 0$); (ii) testing the coefficient a of Equation (2) ($H_0 : a = 0$), and the coefficient b of Equation (3) ($H_0 : b = 0$). If coefficient c is found significant, and coefficients a and b are both significant, then the indirect effect is significant. The test of full mediation needs to add one step, i.e., (iii) testing if the coefficient c' is insignificant [44]. These steps are also known as the 'test of joint significance' [46]. IBM SPSS Statistics 25 was used for model estimation.

Since the mediating variable is dichotomous, Equation (2) uses logistic regression instead of linear regression [44,47,48]. The scale unity of the effect is the key challenge for binary mediating variables/dependent variables in mediating effect analysis. As indicated by Iacobucci [49], in linear regression, a t-test is used to test the significance of regression coefficient a. The statistic for the test is $t = a/SE(a)$. When the sample size increases to more than 30 degrees of freedom, the t-test can be viewed as a Z-test, written as $Z_a = a/SE(a)$. In the logistic regression, the significance of the regression coefficient b is tested by Wald's $\chi 2$ test. The statistic for the test is $\chi 2 = (b/SE(b))^2$. The square root of the test statistic is $b/SE(b)$, which is a t-test statistic. When the sample size increases to more than 30 degrees of freedom, it can be written as $Z_b = b/SE(b)$. Therefore, after converting the regression coefficients a and b into Z_a and Z_b, Z_a and Z_b are of the same scale, and the significance test of the indirect effect is to testify the significance of $Z_a \times Z_b$ [50].

We follow the method proposed by MacKinnon and Kox [51] to test the significance of $Z_a \times Z_b$ based on the distribution of the product. Asymmetric confidence intervals were obtained using the RMediation Package [52] in R software (R 4.2.2), and the indirect effect is significant if the confidence interval does not include zero [50]. Feinberg [53] also suggests the use of bootstrapping or Bayesian approaches to test for the significance of $Z_a \times Z_b$.

However, the commonly used statistical software does not allow for direct confidence intervals for the bootstrapping or Bayesian methods [50].

Table 1. Measurement and Descriptive Statistics for Variables.

	Number	Percentage (%)	Homeownership		Subjective Well-Being	
			Number	Percentage (%)	Mean	SD
Independent Variables						
Age						
1: 30–35 years old	202	32.686	109	53.96	3.728	0.972
0: 18–29 years old	416	67.314	76	18.269	3.435	0.9
Sex						
1: Male	277	44.822	83	29.964	3.534	0.919
0: Female	341	55.178	102	29.912	3.527	0.954
Education						
1: Secondary education and below	30	4.854	7	23.333	3.433	1.165
2: Undergraduate (short-cycle courses)	81	13.107	28	34.568	3.346	1.185
3: Undergraduate (Normal Courses)	297	48.058	100	33.67	3.606	0.876
4: Postgraduate (Master)	184	29.773	43	23.37	3.533	0.836
5: Postgraduate (Doctoral)	26	4.207	7	26.923	3.346	1.018
Annual disposable personal income						
1: 40,000 yuan and below	105	16.99	25	23.81	3.162	1.057
2: 40,001–150,000 yuan	320	51.78	80	25	3.506	0.867
3: 150,001–250,000 yuan	133	21.521	44	33.083	3.639	0.882
4: 250,001–500,000 yuan	46	7.443	27	58.696	3.935	0.904
5: Over 500,000 yuan	14	2.265	9	64.286	4.5	0.65
Marital status						
1: Married	203	32.848	111	54.68	3.872	0.886
0: Otherwise	415	67.152	74	17.831	3.364	0.912
Affiliation						
1: Governments or state-owned enterprises	295	47.734	96	32.542	3.569	0.897
0: Otherwise	323	52.265	89	27.554	3.495	0.966
***Hukou*$_a$ status**						
1: Local	421	68.123	158	37.53	3.695	0.914
0: Nonlocal	197	31.878	27	13.706	3.315	0.917
***Hukou*$_b$ status**						
1: Urban	421	68.123	149	35.392	3.572	0.919
0: Rural	197	31.877	36	18.274	3.442	0.96
Mediator						
Housing Tenure						
1: Homeownership	433	70.065			3.881	0.858
0: Renting	185	29.935			3.381	0.926
Dependent Variable						
Subjective Well-being						
1: Extremely unhappy	20	3.236				
2: Unhappy	42	6.796				
3: Average	236	38.188				
4: Happy	230	37.217				
5: Extremely happy	90	14.563				

Further, to measure the magnitude of the indirect effect, the standard deviation of the regression coefficient of Equation (2) was calculated using Equation (5), where S_k is the standard deviation of the kth independent variable; S is the standard deviation of the distribution function of the logistic random variable ($\frac{\pi}{\sqrt{3}}$ = 1.8138).

The independent variables that are consistently significant in the test of joint significance are, respectively, used as the independent variables in the indirect effect analysis,

and the remaining (original) independent variables are used as the control variables, as demonstrated in Figure 2.

$$Y' = i_1 + cX_j + \varepsilon_1 \quad (1)$$

$$M = i_2 + aX_j + \varepsilon_2 \quad (2)$$

$$Y'' = i_3 + c'X_j + bM + \varepsilon_3 \quad (3)$$

$$M = LogitP(M = 1|X) = ln\frac{P(M = 1|X)}{P(M = 0|X)} \quad (4)$$

$$\beta'_k = \beta_k\left(\frac{S_k}{S}\right) = \beta_k S_k / \left(\frac{\pi}{\sqrt{3}}\right) \quad (5)$$

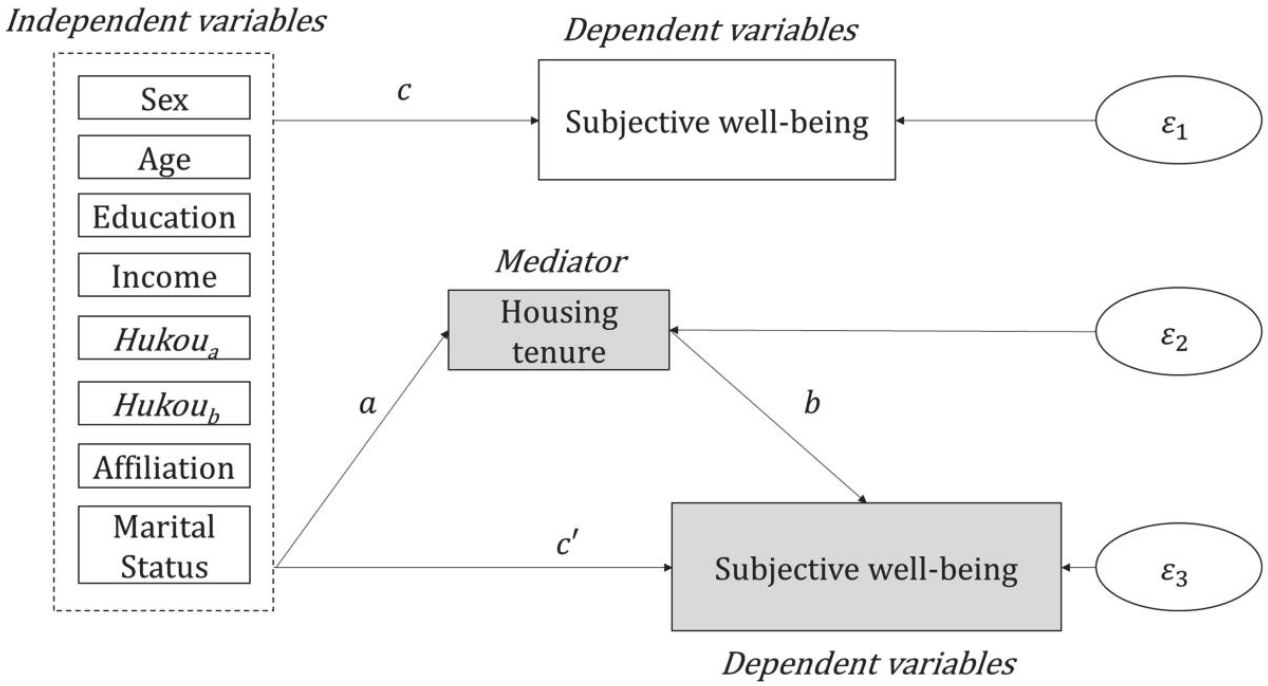

Figure 2. Theoretical Framework for Empirical Testing. Note. The a, b, c, c', ε_1, ε_2, ε_3 are consistent with the connotations of the corresponding terms in Equations (1)–(3).

4. The Mediating Role of Housing Tenure in the Relationships between Individual Attributes and Subjective Well-Being

4.1. Test of Joint Significance

The test of joint significance is used to extract the independent variables involving indirect effects. It can be seen from Table 2 that annual disposable personal income, $hukou_a$ and marital status are found significant in the tests of joint significance. Therefore, this paper takes these three variables as independent variables respectively to detect the indirect effects involving the influences of housing tenure. The remaining independent variables are used as control variables for theoretical enrichment.

Table 2. Test of Joint Significance.

	Subjective Well-Being		Housing Tenure		Subjective Well-Being	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Independent Variables						
Age (0: 18–29 years old; 1: 30–35 years old)	−0.106	0.091	0.732 ***	0.240	−0.138	0.092
Sex (0: Female; 1: Male)	−0.096	0.073	−0.144	0.216	−0.091	0.072
Education	−0.014	0.045	−0.280 ***	0.136	−0.005	0.045
Marital status (0: otherwise; 1: married)	0.439 ***	0.089	1.249 ***	0.243	0.388 ***	0.091
Annual disposable personal income	0.226 ***	0.043	0.320 ***	0.122	0.215 ***	0.043
Affiliation (0: otherwise; 1: governments/SOEs)	−0.072	0.077	−0.121	0.223	−0.068	0.077
$Hukou_a$ (0: otherwise; 1: local)	0.337 ***	0.083	1.900 ***	0.273	0.274 ***	0.086
$Hukou_b$ (0: Rural; 1: Urban)	−0.085	0.088	0.172	0.281	−0.088	0.088
Mediator						
Housing tenure (0: rental; 1: ownership)					0.223 **	0.090
Constant	2.897 ***	0.153	−2.772 ***	0.476	2.888 ***	0.152
N	618		618		618	
(Pseudo) R^2	0.136		0.268		0.144	
−2 Loglikelihood			561.58			

Note. *** $p < 0.01$, ** $p < 0.05$.

4.2. Examining the Mediating Role of Housing Tenure: Identifying Key Individual Attributes

This part analyses the indirect effect of housing tenure in three models (Model 1, 2, and 3), with annual disposable personal income, marital status, and $hukou_a$ as the independent variable, respectively, and subjective well-being as the dependent variable.

4.2.1. The Mediating Role of Housing Tenure: Income as the Independent Variable

In Model 1, annual disposable personal income is expected to have significant positive effects on homeownership and subjective well-being, and homeownership is expected to significantly and positively affect subjective well-being. As expected, the annual disposable personal income has significant positive effects on both housing tenure and subjective well-being (Figure 3). Based on the distribution of the product, the asymmetric confidence interval (95%) is between 0.007 and 0.165, without crossing zero, indicating that the indirect effect of housing tenure is significant. The standardized indirect effect size in the path of 'Income→Housing Tenure→Subjective Well-being' is 0.159 × 0.109 = 0.017, with the indirect effect accounting for 7.56% of the total effect (0.017 + 0.208 = 0.225).

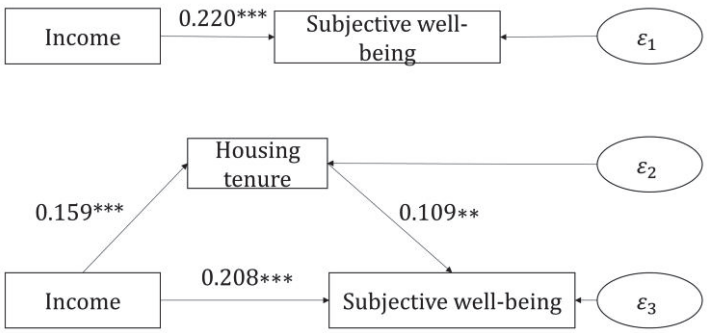

Figure 3. The standardized regression coefficient of Model 1 (annual disposable personal income as the independent variable). Note. *** $p < 0.01$, ** $p < 0.05$.

4.2.2. The Mediating Role of Housing Tenure: $Hukou_a$ as the Independent Variable

In Model 2, young people with local *hukou* are expected to have significant positive effects on homeownership and subjective well-being, and homeownership is expected to significantly and positively affect subjective well-being. In Figure 4, $Hukou_a$ (i.e., with/without

local *hukou*) harbors significant positive effects on both housing tenure and subjective well-being. Based on the distribution of the product, the asymmetric confidence interval (95%) is between 0.086 and 0.805, without crossing zero, indicating that the indirect effect of housing tenure is significant. The standardized indirect effect size in the path of '$Hukou_a$→Housing Tenure→Subjective Well-being' is 0.520 × 0.109 = 0.057, with the indirect effect accounting for 27.92% of the total effect (0.057 + 0.146 = 0.203).

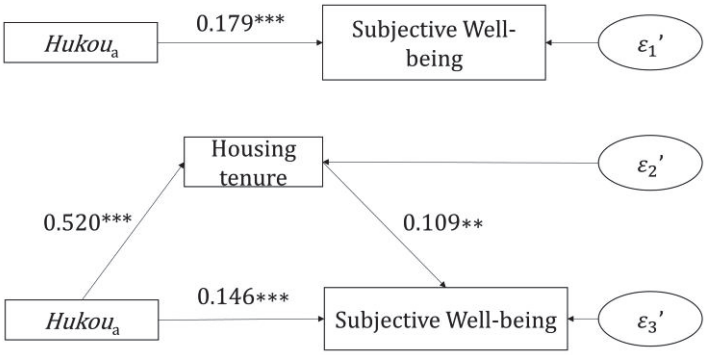

Figure 4. The standardized regression coefficient of Model 2 ($hukou_a$ as the independent variable). Note. *** $p < 0.01$, ** $p < 0.05$.

4.2.3. The Mediating Role of Housing Tenure: Marital Status as the Independent Variable

In Model 3, married cohorts are expected to have significant positive effects on homeownership and subjective well-being, and homeownership is expected to significantly and positively affect subjective well-being. As Figure 5 indicates, marital status significantly and positively influences both housing tenure and subjective well-being. Based on the distribution of the product, the asymmetric confidence interval (95%) is between 0.054 and 0.551, without crossing zero, indicating that the indirect effect of housing tenure is significant. The standardized indirect effect size in the path of 'Marital Status→Housing Tenure→Subjective Well-being' is 0.323 × 0.109 = 0.035, with the indirect effect accounting for 15.22% of the total effect (0.035 + 0.195 = 0.230).

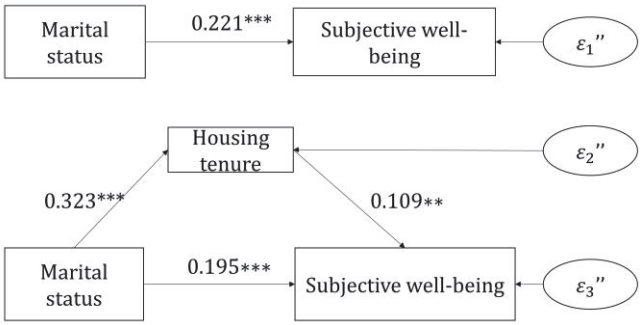

Figure 5. The standardized regression coefficient of Model 3 (marital status as the independent variable). Note. *** $p < 0.01$, ** $p < 0.05$.

4.3. Further Analysis of How Subjective Well-Being Differs across Groups and Housing Tenure

This section is intended to provide a more nuanced analysis by presenting the differences in subjective well-being between different categories of the independent variables (i.e., annual disposable personal income, marital status, and (non)local *hukou* status) under renting and homeownership (Figure 6). There are significant differences in subjective well-being between owning and renting for people at different income levels. The lower the income group, the higher the subjective well-being of buying a house than that of renting. This may be due to purchasing a house allowing for a more secure life for the lower-income group. In terms of the higher income group, otherwise, homeownership may not be such an improvement in their quality of life. Therefore, promoting renting should examine the

possible influencing mechanisms of the subjective well-being of different income groups, especially the lower income segments.

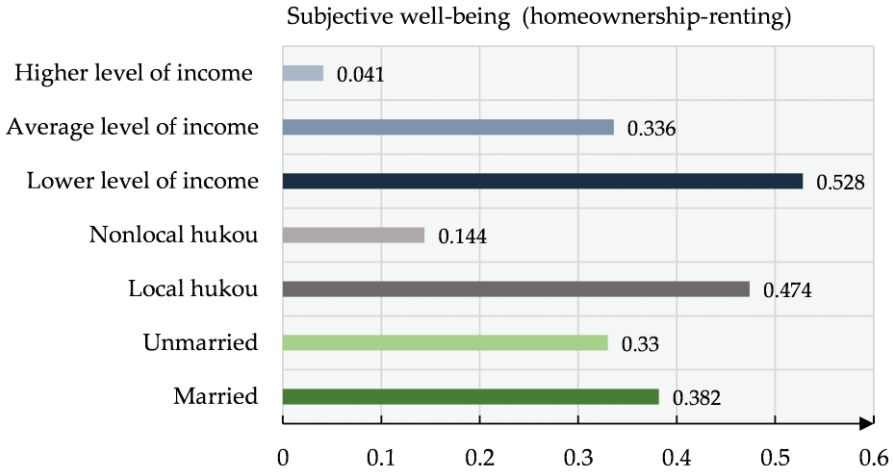

Figure 6. Differences in subjective well-being between homeownership and renting for different groups.

Compared with residents with local *hukou*, the gap in subjective well-being between buying and renting (happier with homeownership) is smaller for nonlocal residents. This may be attributed to the fact that non-residents are faced with more institutional barriers than local residents. We further examine the difference in subjective well-being between local/nonlocal household residents in buying and renting a home at different income levels (Figure 7). Findings are rather unexpected in terms of the nonlocal residents. For the higher-income nonlocal residents, the renters are found to be happier than the homeowners. This points to the need to further examine the influencing mechanisms of subjective well-being of nonlocal young people.

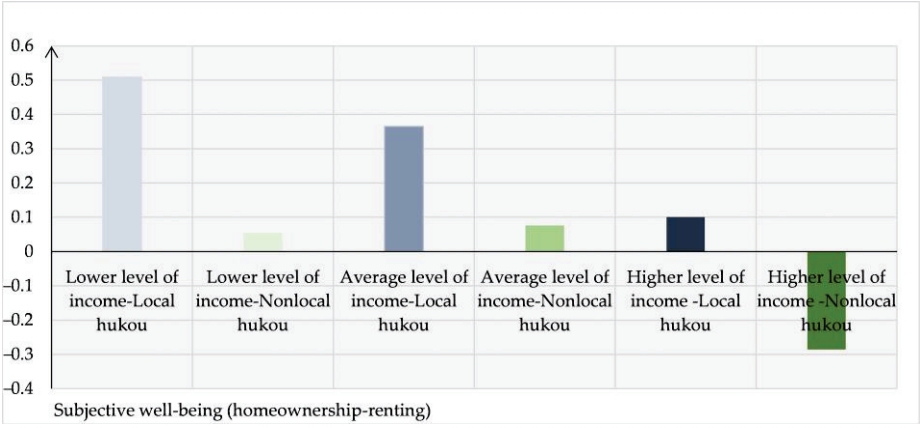

Figure 7. Differences in subjective well-being between homeownership and renting for (non)local groups at different income levels.

For both the married and unmarried groups, homeownership scores higher than renting in terms of subjective well-being. However, homeownership still matters more for the married than the unmarried ones. It may be that the (potentially) improved educational opportunities that homeownership brings to the children of the homeowners contribute to their less burdensome and more enjoyable life.

In the previous section, we identify three key variables, marital status, local/nonlocal *hukou* status and income level, and found that housing tenure plays a role in their relationships with subjective well-being. In this section, we further compare the differences in

subjective well-being between different categories of these variables for renting and home purchasing. We found that the gap in subjective well-being between buying and renting is greater for the lower-income, local and married groups than for the higher-income, nonlocal and unmarried groups. The mechanisms of how housing tenure (rent/own) in these groups further affects subjective well-being are particularly worthy of further exploration.

4.4. Summary of Findings

Among the young residents, marital status (0.221, standardization coefficient), annual disposable personal income (0.220, standardization coefficient), and local *hukou* in Guangzhou (0.179, standardization coefficient) are found to have significant positive effects on subjective well-being.

At odds with the hypotheses, the effect of age on subjective well-being has been found to be insignificant. This may be due to the samples being divided only into two groups (18–29 and 30–35 years old). Relatively close age ranges may also not demonstrate significant differences in subjective well-being. The effect of sex on subjective well-being is also found to be insignificant. In previous studies, women have been found to have higher levels of subjective well-being [26]. However, young Chinese women have been increasingly under pressure from employment, marriage and fertility, which may have a negative impact on their subjective well-being [54].

The effect of $hukou_b$ (urban/rural) on subjective well-being has been found to be insignificant, possibly due to the increase in living standards and well-being brought about by the rising economic value of rural *hukou* status (especially in the central areas in big cities) in recent years. The type of occupation (governments/state-owned enterprises or otherwise) poses no significant effect as well. Also, educational attainment does not have a significant effect on subjective well-being, which may be related to the increase in the number of people with higher educational attainment but facing considerable employment pressure in recent years. It has been widely reported that young people are struggling to enter graduate school or find a decent and stable jobs (especially in the civil service sector) [55–57]. Moreover, due to the high house prices and rents in big cities, even well-educated young people have found it difficult to enjoy an affordable but good quality of life, which may affect their subjective well-being.

As for the influences of individual attributes on the housing tenure, those with local *hukou* (0.520, standardization coefficient), higher annual disposable personal income (0.159, standardization coefficient) and a married status (0.470, standardization coefficient) would have a significantly higher probability of buying a house. Young people with local *hukou* status may have easier access to hardly affordable homeownership. The access and cost of education for children may be linked to homeownership. As a result, those getting married may also consider buying a house if they can afford it financially. Personal income has an impact on the purchase of housing, but not as much. After all, the income generated by a regular salaried job is relatively limited compared to the high down payment and mortgage. The wages of a double-income family may provide important financial support for mortgage repayments.

Apart from these three variables, age and educational level also have significant effects on housing tenure. Not surprisingly, 30–35-year-olds are more likely to own a house than younger ones (18–29), with possibly greater wealth accumulation. However, surprisingly, educational attainment has a significant negative effect on homeownership, unlike the previous findings of the positive impact of human capital under housing market mechanisms [35]. This may be related to the restriction of the study to the youth population. The prolonged education of young people allows them to enter the labor market at a later stage. Employment has also become more precarious, and young people need to devote much time and energy to struggling with their careers. At the same time, returns can be erratic and meager. It also points to the current plight of young people, who may not be able to match their expectations of (economic) reward with higher levels of education also see [58].

As for the indirect effect of local/nonlocal *hukou* on subjective well-being, almost 30% (27.92%) of the influence could have been explained by the influence of housing tenure. When income levels were further considered, it was found that among nonlocal residents with higher incomes, tenants are happier than homeowners. This is indicative of the complexity of nonlocal residents and that further mechanisms require inspection.

The indirect effect of housing tenure on the relationship between marital status and subjective well-being accounts for 15.22% of the total effect. The subjective well-being of both married and unmarried groups is higher in the state of homeownership than in renting. However, this gap is higher for the married group than for the unmarried cohort.

The indirect effect of housing tenure on the relationship between income and subjective well-being is modest (7.56%). This indicates that an increase in income may increase subjective well-being in many ways other than buying a house. Nevertheless, there are significant differences in the subjective well-being of different income groups between renting and homeownership. The lower the income, the higher the subjective well-being in the state of homeownership than in renting.

5. Discussion and Conclusions

With the housing policy promoting renting as an alternative to homeownership, it is necessary to examine how this may affect different groups of people. Based on the increasing importance of subjective well-being in public policy and urban planning, this paper uses it as an indicator to assess the (potential) policy impact. The research question has been framed as to which individual attributes have indirect effects on subjective well-being that are mediated by housing tenure (rent/own). In the existing literature, while individual attributes and housing tenure are often placed together as independent variables affecting subjective well-being, few studies have examined the more nuanced influencing mechanisms between these three variables. This study, therefore, possesses theoretical and practical implications, contributing to an in-depth understanding of the mechanisms influencing subjective well-being associated with housing and human heterogeneity, as well as directions for housing policymaking and further studies.

We found that annual disposable personal income, marital status, and local/nonlocal *hukou* status possess significant indirect effects on subjective well-being mediated by housing tenure (rent/own). Other individual variables have been found to have no significant direct/indirect effects on subjective well-being, although age and educational level have been found to be significantly influencing housing tenure. The more detailed model results and the accompanying policy recommendations and research directions are discussed below.

Firstly, in terms of the influence of income level on subjective well-being, only a modest part of the effect has been found to be explained by housing tenure. This suggests that income can enhance subjective well-being through many other mechanisms other than purchasing a house. However, housing expenses exert considerable pressure on young people. Housing mortgage is the main component of household debt in China, with 75.9% of households using debt to purchase housing [59]. People emptying six wallets (young couples' and their parents') for a down payment and being left with a mortgage loan for decades is commonplace. If young residents spend a disproportionate amount of their income on housing, it actually reduces their ability to obtain an increase in subjective well-being through other possible mechanisms. Further analysis found that the lower-income group, as compared to the higher-income groups, has a higher increase in subjective well-being in the homeowner segment than the renters. This suggests the necessity of examining the influencing mechanisms of housing tenure on subjective well-being when promoting renting as a longer-term alternative to homeownership, especially for lower-income groups.

Secondly, housing tenure contributes to the indirect impact of marriage on subjective well-being to some extent. The reasons may refer to previous findings that renting groups are stuck in a state of prolonged drift, leading to depression [60]. For the married group, homeownership may contribute to their subjective well-being by bringing stability and positive emotions to their lives. Thus, when promoting renting, especially to young

married couples, it is important to examine the mechanisms through which homeownership enhances their subjective well-being. The influencing mechanism may be in multiple dimensions, such as economic, psychological or institutional. Improvements in these aspects may make the promotion of renting to a wider group more compelling.

Thirdly, housing tenure plays a considerable role in the indirect effect of local/nonlocal *hukou* on subjective well-being. For those with local *hukou*, the gap in subjective well-being between homeownership and renting is greater than for those with nonlocal *hukou*. This also suggests that for local *hukou* residents, promoting renting may have a greater negative impact on their subjective well-being improvement. The mechanisms by which the housing tenure of local *hukou* residents affects their subjective well-being need further examination. The subjective well-being of nonlocal residents reveals more complexity. For instance, the subjective well-being of the higher-income group is higher among those who rent than those who own. The current emphasis in China's rental housing policy is particularly on targeting new citizens (i.e., those without local *hukou* or who obtained local *hukou* for less than three years). The intricacies within the nonlocal population and the mechanisms by which renting/owning affects their subjective well-being deserve further inspection.

These findings reflect the influences of specific socioeconomic and institutional contexts in China. However, the recent changes in China and the situation facing young people are also relevant elsewhere in the world. Since China's economic reforms and accession to the World Trade Organisation, the plight of young people has increasingly resonated with global trends. Young people are subjected to the woes of a fading traditional welfare system and rampant leveraging and speculation in the housing market. Depreciating diplomas, prolonged education and highly competitive labor markets are restricting young people's purchasing power and making it difficult for them to earn an affordable and decent living. Relevant findings of China's large cities may therefore be of relevance to other parts of the world.

For the three personal attributes identified in this paper as having significant indirect effects on subjective well-being (housing tenure as the mediator), the effects of income and marriage are potentially more generalizable, as these are variables that youth around the world are concerned with. As for the $hukou_a$ status, the findings may also be relevant if it is understood as local/nonlocal status rather than the 'hukou' as a uniquely Chinese institution. Previous studies have suggested that the institutional influence of the post-reform era has been attenuated [34]. This paper also finds that the effect of $hukou_b$ (urban/rural) is insignificant. In this case, the local/nonlocal *'hukou'* difference may be interpreted as a local/nonlocal distinction. However, the generalisability of the findings needs to be limited, as the institutional barriers accompanying the *hukou* system still substantially exist, despite their gradual erosion.

This paper analyses the mediating role of housing tenure using the frequently used test of joint significance, which is applied to models where the independent variables are dichotomous variables [44,50]. As the mediating variable is a categorical variable, testing the significance of the indirect effect requires scale unification. In this paper, the distribution of the product test is taken, and the results can be run with R software. Although tests for indirect effects can be performed using Bootstrap or Bayesian methods [53], they are difficult to calculate directly with commonly used statistical software, and their effects are not yet well examined [50]. In addition, as cross-sectional rather than (hard-to-get) longitudinal data were used, this study remains a preliminary analysis (also see [42]). Follow-up studies could deepen the exploration of causal relationships. In addition, the impact of a more detailed classification of housing tenure and housing quality on the subjective well-being of different groups could be further analyzed. The moderating role of housing tenure may also be examined. Analyses conducted, or with indicators, at different spatial scales (e.g., provinces, cities, districts, and communities) could be developed in subsequent studies (e.g., [42,43]). Given the focus and space constraint of this paper, the subsequent research may require another space.

Findings from China may provide experience for countries with similar youth housing challenges. It is recommended that more comparative analyses be carried out on a global basis. Limited by the data obtained, further studies can explore more potential influencing mechanisms of subjective well-being, e.g., sense of belonging, welfare system, cultural elements, and influences of parents (and/or partners), with more nuanced population classifications. Moreover, indirect effects can be explored with more housing tenure types. After all, buying a house with or without a mortgage loan may have different effects on subjective well-being. Social rental and market rental may also generate different influences. Given the limited data available and the still nascent development of GSRH and SOH, the study of subdivision of housing tenure may be further developed when new housing types become more available to the residents for a more nuanced and holistic analysis.

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Article

Why Did the "Missing Middle" Miss the Train? An Actors-In-Systems Exploration of Barriers to Intensified Family Housing in Waterloo Region, Canada

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Abstract: (1) Background: Missing Middle (MM) housing may be critical to address decreasing housing affordability and to achieve critical density in transit-oriented neighborhoods; however, its production is in decline. We report on a case study of housing development around a new light-rail transit line in the Region of Waterloo, Canada, investigating the puzzle of how a residential building boom coincided with decreasing housing affordability. (2) Methods: Following participatory co-creation and communication of background research characterizing housing demand with stakeholder partners, we created a data narrative arguing that MM housing was desired by residents and profitable for developers and then used it to guide semi-structured interviews with planners and real estate industry stakeholders. Based on these interviews, we developed a qualitative system map and causal loop diagrams that demonstrate interactions between key actors (residents, brokers, planners, developers, and investors) as mediated by boundedly rational real estate demand expectations. (3) Results: Our interviews identify multi-faceted barriers, beyond demand perception, to MM housing development. Systems analysis illustrates how high-density, small-unit high-rise development can become locked in, concurrently locking out MM housing. (4) Conclusions: Our research identifies barriers to MM housing supply by articulating the systemic feedbacks between the planning and land/housing market realms and reveals key leverage points, empowering planners to develop policies that catalyze hoped-for housing market supply responses to increase housing affordability. Based on these findings, we suggest targeted interventions: multi-unit base residential zoning, MM site plan typologies, non-profit and co-op financing, unit-mix requirements, pre-build MM condo purchase by municipalities or non-profits, and MM demonstration projects.

Keywords: Missing Middle; housing suitability; latent demand; systems mapping; complex systems; land and housing markets; land-use planning

1. Introduction

In 2019, the Region of Waterloo (RoW) launched the ION light-rail transit (LRT) network. The ION was implemented with two stated goals—to move people and to intensify land use. Land-use intensification goals succeeded, with CAD 3.2 billion in new building investments in the Central Transit Corridor (the CTC, the area approximately 800 m around transit stops) between 2011 and 2020, materializing primarily in the form of high-rise residential developments [1]. Recent statistics show a 41% increase in building permits from 2020 to 2021, with 70% of new residential units comprising infill development [2].

At the same time, housing in the RoW has become increasingly less affordable across all income levels. Figure 1 illustrates the steep upturns (and moderate downturns) of local housing prices over the last 10 years. Mirroring national trends, the RoW experienced a steep increase in single-family home prices from 2016 to 2018, driven mainly by migrating Toronto-area buyers [3]. The pandemic strengthened these trends, with year-over-year single-family home gains of 33% [4,5], the second highest in Canada [6], representing

loan-to-income levels similar to those of London, U.K. The Kitchener–Waterloo Community Foundation also reports increasing rents, growing scarcity of affordable rentals, and housing supply lagging population growth [6].

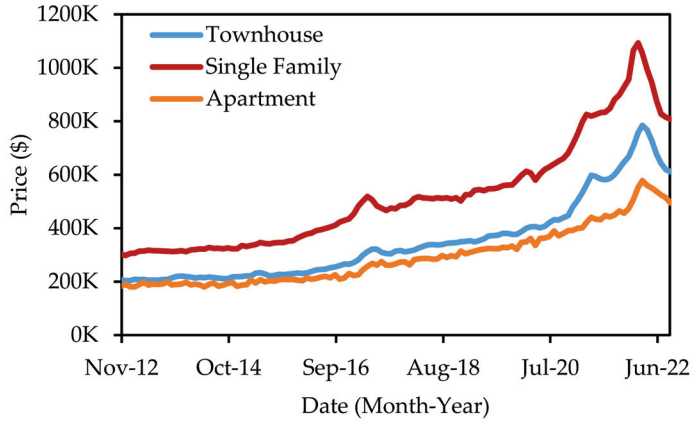

Figure 1. Benchmark housing prices for Kitchener–Waterloo between November 2012 and October 2022. "Benchmark housing prices" are a "typical" home based on the features of homes that have been bought and sold." [4].

How can a residential construction boom and housing affordability crisis co-exist? The prevalent narratives to explain the steep decline in housing affordability throughout the province of Ontario focus on population growth, coupled with insufficient housing supply to meet that growth. While some approaches arguing for supply limitations focus on estimating future households and providing each with a housing unit [7–9], others focus on the supply needed to restore historical levels of housing affordability [10]. All approaches to date, however, base their analyses on average household sizes and, separately, their possible dispersion into the fairly narrow housing type definitions aggregated from Census categories [11], basing their analysis only on the total number of units or by categorizing housing types into single-family, low-rise intensified (four stories or lower), or high-rise (five stories or higher). Through this lens, with steep increases in the number of housing units, housing supply should not be driving unaffordability in the RoW.

In reality, household sizes are diverse, as are the types of built forms that can house them. Generic "housing supply" may not meet the demand for suitable housing if the built form does not provide the right number of bedrooms. The Canadian Mortgage and Housing Corporation (CMHC) defines "housing suitability" in terms of the match between the number and status of household members and the number of bedrooms in a unit [12]. While concepts of suitability can be culturally mediated [13], this definition suffices given our focus on family-sized housing. Locally, the 2021 Canadian Census [14] indicates that while only 0.2% of couples without children were unsuitably housed, unsuitable housing increased for couples with children (7.2%), one-parent families (10.4%), and "other" households, a category including multi-family and roommate households (24.6%), with households in two-bedroom units most likely to fall in the "unsuitable" category. These data suggest that a scarcity of suitable housing for larger households with low-to-moderate incomes is a possible explanation for the housing price run-up, whereby households not able to find suitable housing in the marketplace are pushed into either too-small, too-far-away, or too-expensive housing, inflating housing prices in the non-MM categories. These dynamics may work against transit-oriented development (TOD) and intensification goals if a lack of suitable housing near jobs results in longer commutes [15]. Such unsuitably housed households comprise latent demand for more suitable housing forms—so-called "Missing Middle" (MM) housing.

We therefore hypothesize that the lack of supply of MM housing in the RoW is a key explanatory factor that resolves the puzzle of increasing supply and decreasing affordability. Such lack of MM housing supply is an acknowledged issue throughout North America. The

term "Missing Middle" describes the medium-density housing types that are increasingly scarce in new residential construction [16,17]. This family-sized (three or more bedrooms) housing includes ownership and rental townhomes, duplexes and triplexes, and low- to mid-rise apartment buildings [17] and may also include secondary suites and dwellings such as laneway suites and tiny homes [16,18,19].

This paper reports the results of qualitative exploratory research around potential barriers and solutions to MM housing supply in the RoW, employing a complex systems lens to our analysis of planning and market contexts [20,21]. Our objective is to apply systems-thinking methods to demonstrate that complex housing market dynamics may have "locked in" "tall and sprawl" development patterns [22] and "locked out" MM housing supply, creating a supply gap in suitable housing for low-and-moderate-income family-sized households. To address this objective, our research proceeded in four stages of participatory research with stakeholder colleagues in the planning, real estate, and housing-development fields. In Stage 1, we co-developed and reported the results of qualitative and quantitative surveys and interviews with residents (renters and home buyers), developers, and realtors. In Stage 2, we collaboratively constructed a data narrative arguing that MM housing was scarce in the RoW. Stage 3 used this data narrative to guide qualitative discussions with developers and marketing stakeholders. Based on these interviews, in Stage 4, we developed and analyzed a qualitative system map and causal loop diagrams presenting our hypothesized dynamics and suggested systems interventions, which comprise the major research findings of this paper.

Section 2 of this article provides literature background on MM housing and the developers' decision-making context. Section 3 describes the methods employed at each stage. Section 4 summarizes the information shared with stakeholders and feedback received in Stages 1–3. Section 5 presents the systems diagrams and analysis. In Section 6, we identify potential planning and fiscal policy levers that have the potential to increase local MM housing supply (Stage 4).

2. Literature Background

2.1. How and Why Is "Missing Middle" Housing Missing?

Missing Middle housing supply is in decline across North America. In the United States, MM housing production (defined as a building with 2–4 units) has been in steady decline since 1982 [23]. In Canada, the construction of MM housing types has declined significantly since the 1950s [24], when municipalities began enacting restrictive zoning by-laws favoring single-family homes [16,25,26]. In an analysis of building start data, MM supply gaps have been recently identified within Ontario's main population center (the Greater Golden Horseshoe (GGH)) [27], although parts of the RoW were highlighted in leading MM supply throughout the GGH.

Simultaneously, increased demand for urban living among family-sized households is increasing demand for MM housing [28,29]. However, limited supply has made urban MM housing unaffordable for middle-income families [30,31], forcing a choice between a small urban apartment or a single-family detached house in the suburbs.

Despite the high demand for MM housing and many municipalities relaxing their zoning by-laws to facilitate infill and greater diversity in housing types permitted, developers are reluctant to build medium-density family housing, citing issues of limited land supply [32], planning red tape (e.g., restrictive zoning, building code, and parking requirements), and high development costs [18,33–35]. As a result, developers prefer to build on either side of the spectrum, creating a housing market characterized by "tall and sprawl" development [22].

2.2. Developer Decisions in a Planning and Market Context

Developers' decisions about when, where, and how to develop lands are shaped through interactions with investors, brokers, sellers, buyers, potential and actual residents, and municipal planners [36–42]. Figure 2 demonstrates these complex and multi-faceted

influences on developers' decision-making. To assess where to build and what to build, potential profit for a particular development site and building design are measured through a "pro forma". These potential profits are influenced by the planning context, including zoning constraints, the anticipated time to completion, development charges, affordability requirements, and unit size mix (the proportion of units with one, two, three, and more bedrooms). If developers' strategic responses to planning requirements are not considered, policies might not create correct and feasible incentives [43]. For instance, when unevenly applied, inclusionary zoning rules (mandating a proportion of affordable units) can lead to a net reduction in affordable housing by diverting some of the developments to the closest unregulated alternatives [44]. In Toronto and elsewhere, requirements for two- and three-bedroom units without specifying minimum unit sizes may create units with sufficient bedrooms but insufficient living area for the household size [45].

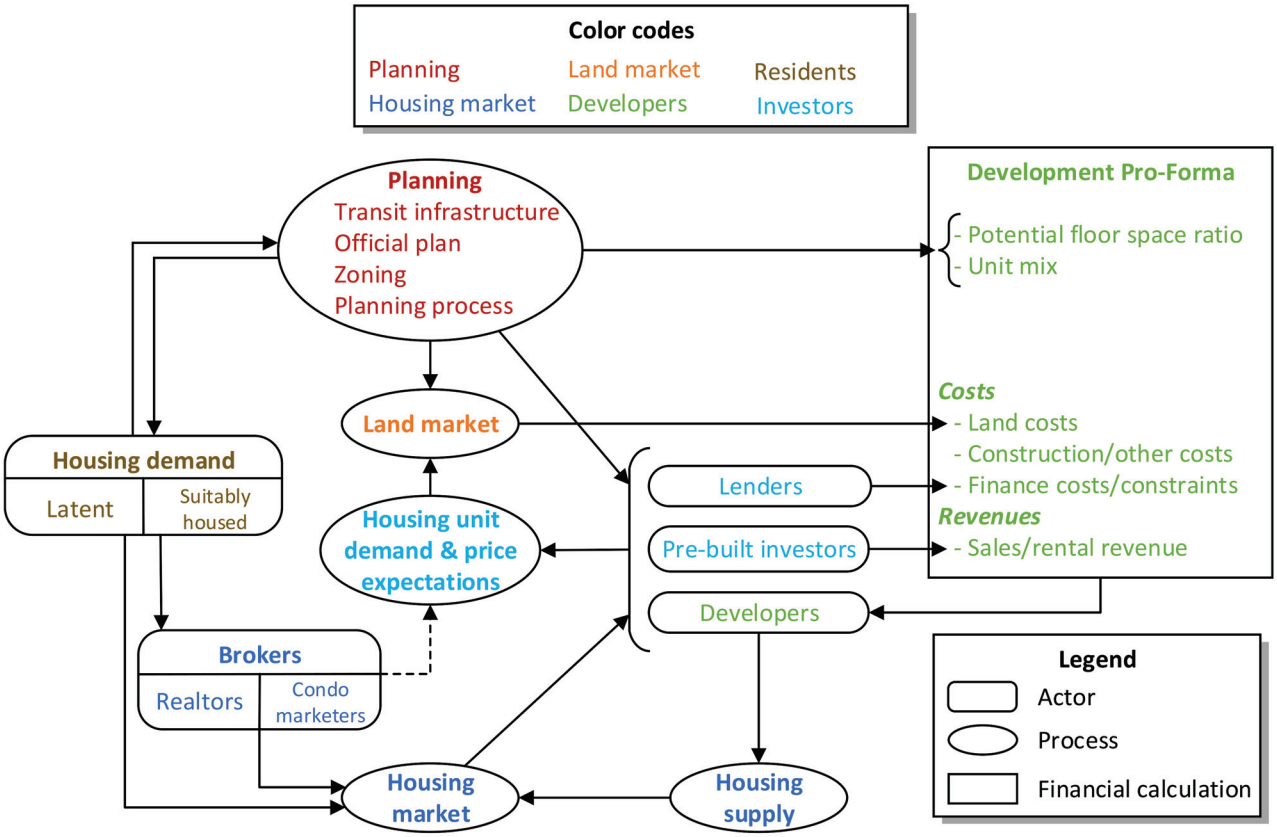

Figure 2. Qualitative systems map representing developers' decision-making context: actors, processes, and calculations by shape, and actor realm by color; dashed line represents incomplete information flow. (Supplementary Materials Video S1).

On the cost side, profitability is further influenced by building and investment costs and constraints. Construction costs depend on the type of build, with high-rise costs per unit area being up to 2.5 times those of low-rise builds [46]. Developers, lenders, and pre-build investors (who advance purchase condos) rely on their expectations about housing demand—how many units will sell or rent at particular prices. Developer finance options include equity finance (own capital), lender finance, or a hybrid model, where lenders require matches through pre-sales to investors or future residents. Larger projects require a combination of capital sources, which require reliable partners [47,48]. Financial lenders can include banks, real estate trusts, and non-profit lenders [49]. For any lender, assessment of higher project risk or lower expected return means higher interest rates and lower loan-to-value ratios [50]. Investors who pre-purchase units also incur the risk of lower sales values or delayed sales once construction is complete [51,52]. Thus, owner–investors'

beliefs and preferences can guide or limit developers' decisions [53]. This cost-and-finance side discussion highlights the importance of the expectations of end-user demand from not only developers but also the investors who finance builds.

While the development pro forma is a widely used tool, literature debates whether developer decision making fits economic models of expected profit maximization under the widely acknowledged risk that characterizes land and housing markets. While some authors qualitatively characterize developers as profit-seeking, risk-taking, and innovative [41,54], other studies find evidence of "boundedly rational" decision behavior, including satisficing (the tendency to select the closest satisfactory solution), loss aversion (weighing losses more than gains), and weighing relative rather than absolute wealth shifts (prospect theory) [55]. Mohamed [56] argues that this satisficing behavior is due in part to the project complexity reflected in Figure 2, potentially explaining uneven housing supply (scarcity of three-bedroom infill relative to greenfield builds) [57].

3. Methods

3.1. Historical Supporting Research

Findings from our previous case study research, reported below, have been shared with the stakeholders involved in this study through public, private, and one-on-one briefings. Numerous surveys and interviews have helped us gain an understanding of the system's actors and their motivations—the "who" in our system. Most surveys were developed in collaboration with stakeholder partners, whose feedback cross-validated and assisted in the interpretation of quantitative and qualitative survey results. DeFields [58] conducted a hybrid mail/internet response spatially stratified random sample via postal mail of 1272 households with private yards in Kitchener–Waterloo, analyzing 206 complete responses. Pi [59] created a rental database through a web-scrape of all Kijiji rental postings (19,544) from 5 weeks in late summer 2015, invited a spatially stratified sample of 2912 residents to respond via postal mail, and analyzed a total of 290 responses. Tran [60] conducted key informant semi-structured interviews with 18 local development firms, out of 40 local development firms identified by municipal partners. Cook [61] conducted five semi-structured focus group interviews with a total of 27 local realtors, recruited using maximum variation purposeful sampling methods through the local realtor association and realtor agencies. Huang [62] conducted a mail/internet hybrid response survey of all residents identified by Canada Post as likely home buyers or sellers from June 2015 to April 2017 (5185), receiving responses from 357 home buyers (all complete survey questions and additional method details are contained in each reference).

3.2. Data Narrative

Data narratives [63], a series of descriptive statistics connected by structured arguments, are used in Ontario to support both local planning and the development of provincial policy [1,6–9,64]. Planners, developers, and policymakers also often use a single statistic to justify policies and beliefs. Such data narratives reflect the state of a dynamic system, potentially showing correlations consistent with underlying hypothesized dynamics. However, they do not demonstrate or prove causality, reflecting the "what", but not the "why".

Based on the widespread use and acceptance of data narratives, in order to investigate local perceptions related to MM housing scarcity, we worked with local housing economists (staff from CMHC) and the Kitchener–Waterloo Association of Realtors from Fall 2020 through to Spring 2021 to build a data narrative that presented evidence for the local scarcity of three-bedroom apartment units, especially in the core areas (downtowns) within the CTC. We argued that it was a puzzle—and potentially a market failure—that three-bedroom units were not being constructed. We presented four kinds of evidence: (1) underlying demand for MM housing; (2) income and demographic trends favoring MM housing as being the preferred and/or feasible alternative for many residents; (3) lack of current supply of MM housing; and (4) potential profitability of constructing MM housing.

3.3. Semi-Structured Interviews

We used our data narrative as a template to facilitate discussions with 7 local developers and representatives of a condominium marketing firm during the summer and fall of 2021. We employed semi-structured interviews to increase our understanding of the system under study; identify key actors and their roles; test existing hypotheses; identify potential hypotheses and research questions; understand the beliefs, perspectives, and lived experiences of actors; and develop our qualitative systems representation [65–67].

3.4. Systems Analysis

Dynamical systems representation and analysis is growing in popularity and application [68]. Dynamical systems link stocks and flows through hypothetical or empirical causal relationships. Stocks are entities that accumulate or deplete over time, and flows are the rates at which the stocks change. Using examples from our case study, this approach describes a system in terms of stocks (planning regulation, housing, information, and finance), flows (policy change, housing supply, demand perceptions, and housing finance and sales), and the processes that connect them (plan and policy development, housing development, information exchange and belief formation, and land and housing markets).

Forrester [69] asserts that a systems lens can "sharpen clarity of thought and provide a basis for improved communication", "reveal the interrelatedness of physical and social systems", and "unify knowledge" (p. 187). Ghosh [70] emphasizes that systems knowledge can aid in both understanding and intervening in systems through understanding systems interactions and complexity, including identifying and managing unintended consequences. Page [71] emphasizes the role of systems dynamics models in identifying causal dynamics, including positive and negative feedback loops. We employ systems dynamics modeling, in the form of a qualitative systems map and corresponding qualitative causal loop diagrams (Section 5), with these purposes in mind. In short, we use systems dynamics analysis to formally represent causal hypotheses, illustrating the "why". Similar approaches have been taken by Olaya [72], Kubanza et al. [73], Macmillan et al. [74], Luna-Yeyes and Anderson [75], Guest et al. [76], Saryazdi et al. [77], and Shoar and Payan [78]. We select these methods as suitable for this study among the broad range of qualitative systems dynamics modeling methods that can be used to reason about systems and explore hypotheses, including Boolean networks [79], cross-impact balances [80], simulation modeling [81–83], agent-based modeling [84,85], and analytical optimization [86]. We use the results from our semi-structured interviews as evidence (Section 4.4) to identify actors and their roles, understand the flows of information, and identify causal feedbacks and sources of path-dependence in our case-study system.

4. Knowledge Exchange with Partners

4.1. Local Trends and Economic Context

Trends noted in the literature review (Section 2) are also observed in our local case study. Our previous research on local developers [60] showed that they relied primarily on their own past experience in making decisions and that many developers were taking a "wait and see" attitude towards investments in the CTC. Subsequent to that research, the success of key early builds has led to a cascade of high-rise, small-unit development applications and builds along the LRT corridor, supporting a highly risk-averse, boundedly rational decision-making model for local developers. However, MM builds remain largely absent. In the RoW, while townhome builds are tracking up in the suburbs [24], the overall gap in MM housing supply has been noted by CMHC, the realtors' associations, and local politicians [87,88]. Our previous research finds evidence for latent demand for urban MM housing—renters and buyers who could not find affordable housing with bedrooms and greenspace they were seeking [58,59,61,89]. Evidence of this latent demand has sparked some policy changes designed to increase MM housing, including a City of Kitchener Zoning By-law Amendment increasing the number of units allowed on any

residential parcel [90] and specific MM housing goals in the most recent RoW Official Plan Amendment [88].

We offer some additional context on housing demographics and basic economics concepts to fill in gaps for planning and housing market readers and give context to our data narrative. Locally, while multi-unit housing builds can be purpose-built rentals or for the condominium market, residents often move between ownership and rental at various life stages, and these transitions are mediated by housing availability and affordability. An understanding of the housing options available to various groups, and the extent to which these types are substitutable for particular resident classes, is essential in order to understand housing demand and the extent to which it is elastic (when many substitutes exist, increases in prices will cause large drops in quantity) or inelastic (when the housing is essential and substitutes are absent, a small increase in prices will cause little change in quantity) [91]. In principle, such understanding could contribute to more accurate expectations formation for end-user demand (uptake and willingness-to-pay) for developer and investor actors; however, we have not yet seen this topic addressed in the literature.

On the rental side, residents might choose a too-small rental (two bedrooms or fewer, defined as unsuitable housing) or, if available, a three-bedroom unit or small rental house, leased as a purpose-built rental or an investor-owned condo. Home purchases are available only to those with sufficient income, investment capital, and qualifying credit. On the purchase side, residents may choose to purchase a too-small condo or townhome (unsuitable housing), purchase a three-bedroom MM unit if available, purchase a larger home between two households or for a multi-generational household, or purchase a single-family home. When assessing the demand for MM rental or condo builds, developers and marketers (anecdotally) do consider other options available to their potential residents. Thus, a clear understanding of the choices available to potential residents in the market is critical to understand the elasticity of or, for better or worse, the extent of captive demand. For instance, while some potential residents may have the means to buy a two-bedroom condo if rents for a three-bedroom apartment are too high, those without the financial capacity to buy may only have a choice between relatively expensive two- and three-bedroom rentals.

A "scarce" resource in economics is generally defined as a situation where more of that resource will increase the economic payoffs to one or more actors [92,93]. In principle, that actor should be willing to pay up to the additional value added for them of another unit of the resource. For instance, if a three-bedroom apartment is scarce on the demand side, there will be at least one resident who is willing to pay more for a third bedroom. A potential profit opportunity exists for housing suppliers (i.e., developers) if the resident's willingness to pay for that additional bedroom exceeds the developer's costs of production for it. As MM housing is by nature multi-unit, developers need signals that sufficient numbers of potential residents are all willing and able to pay a sufficient premium for the third bedroom, and further, that other more attractive substitutes do not exist in the market.

4.2. Previous MM Housing Demand Evidence

Evidence of underlying demand for MM housing was produced through collaborative research and shared previously with municipalities, real estate professionals, and developers. We summarize the take-home points communicated, emphasizing that the research was shared when current. While these trends likely persist, surveys would need to be repeated to confirm findings.

Responses from a survey of households with private yards [58] demonstrated a willingness of higher-income couples with children and retirement-age single-family-home residents to move to MM housing types. However, these groups desired private greenspace or, to compensate for no private greenspace, a nice view, proximity to a park or forest, a porch or balcony, proximity to an urban center, and/or a sense of privacy.

A 2016 survey of local renters [59] found evidence of demand for the urban amenities generally associated with MM housing. When rating the importance of neighborhood characteristics in their rental decisions, 80% rated "ease of walking" important to very

important, and around 60% rated land-use mix "important to very important", whereas around 60% rated "density of housing" neutral to not at all important, indicating openness to denser MM housing. While most respondents stated that their ideal housing type was lower density than their current housing, renters in the youngest (students) and oldest (retirees) categories generally preferred apartments to houses. Evidence for MM housing was most clearly seen in reported gaps between renters' current and ideal number of bedrooms. For instance, while 17% of respondents currently occupied three-bedroom units, 31% listed three-bedroom as their ideal. Further, whereas 7% of residents lived in four-bedroom units, 17% rated these as ideal. Across all categories, 47% rated a home size of 1000–1500 square feet (ideal for a small three-bedroom) as their ideal home size. Echoing the survey of DeFields [58], while 43% of renters ideally wished for a small or medium yard, 49% ideally wanted no outdoor space or a patio/deck/balcony only. Couples and lone-parent families, not surprisingly, preferred yards, whereas singles, students, and seniors preferred a deck, patio, or balcony. While rents have accelerated locally since this survey, many respondents reported that their ideal rent was higher than their current rent, indicating latent demand for unit size, quality, and access to open space in local rental markets.

Huang et al. [89] applied latent-class analysis to a survey of local buyers and sellers between 2016 and 2018 to identify unmet demand for TOD. They found that while young professionals and seniors were the most common buyer groups in the TOD areas, and families most common in the suburbs, many younger families would have preferred to buy in the TOD areas but could not find units with sufficient dwelling space and access to greenspace to meet their needs.

In summary, ten years of local research supports the potential demand for MM housing, especially in areas served by transit. It suggests that "suitable" housing in our case context requires both sufficient bedrooms and sufficient greenspace access. Concurrent with common wisdom and other research, some of this demand comes from younger and downsizing households, but some also comes from family households seeking access to TOD amenities and an urban lifestyle.

4.3. Data Narrative: Empirical Evidence of the Scarcity of Three-Bedroom Units

Below we summarize the main points of our longer data narrative, developed and shared with stakeholders in 2021. We began our data narrative by arguing for the then-current scarcity and potential profitability through these "take-home" points:

1. Although there is clear scarcity of rentals with three or more bedrooms, they are not being constructed as part of new builds, most acutely not in Kitchener Central.
2. With benchmark single-family homes selling for more than CAD 800,000, rents for units with three or more bedrooms should be very high, as so many family households cannot afford to buy a single-family home.
3. There is very clear evidence from market research for strong demand for rentals with three or more bedrooms, not only for families with children living in the home, but also for downsizers.
4. One explanatory hypothesis is that developer decisions are mostly shaped by investor demand, rather than that of potential residents. We need to ask both actors what barriers exist for the supply of three-bedroom units.

In addition to the background research summarized above, we provided evidence of strong, potentially inelastic demand for three-bedroom apartments. On the rental side, Figure 3 shows that when rental units turn over or new units come on the market, rents for three-bedroom units are 40% higher than those for existing three-bedroom units, indicating an accelerating willingness to pay for these units.

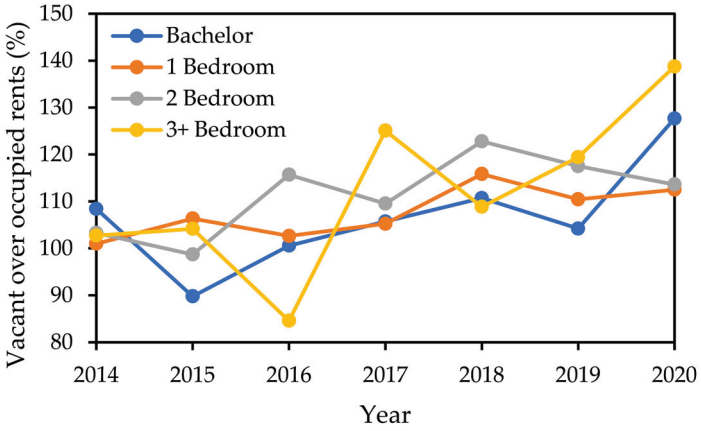

Figure 3. Premium of vacant rents over occupied rents by year in the Kitchener–Waterloo–Cambridge CMA [94].

We also argued that on the sales side, three-bedroom apartments had become a substitute for three-bedroom townhomes and single-family homes, likely due to the accelerating prices of the single-family options. As Figure 4 shows, a fall in days-on-market and growth in average price and trends for three-bedroom condos across the RoW mirrored the exponential changes seen in the RoW's largest cities of Kitchener and Waterloo (the location of the new LRT line) for townhomes and single-family homes. These trends are consistent with three-bedroom condos being substitutes for other three-bedroom products, or within the same sub-market.

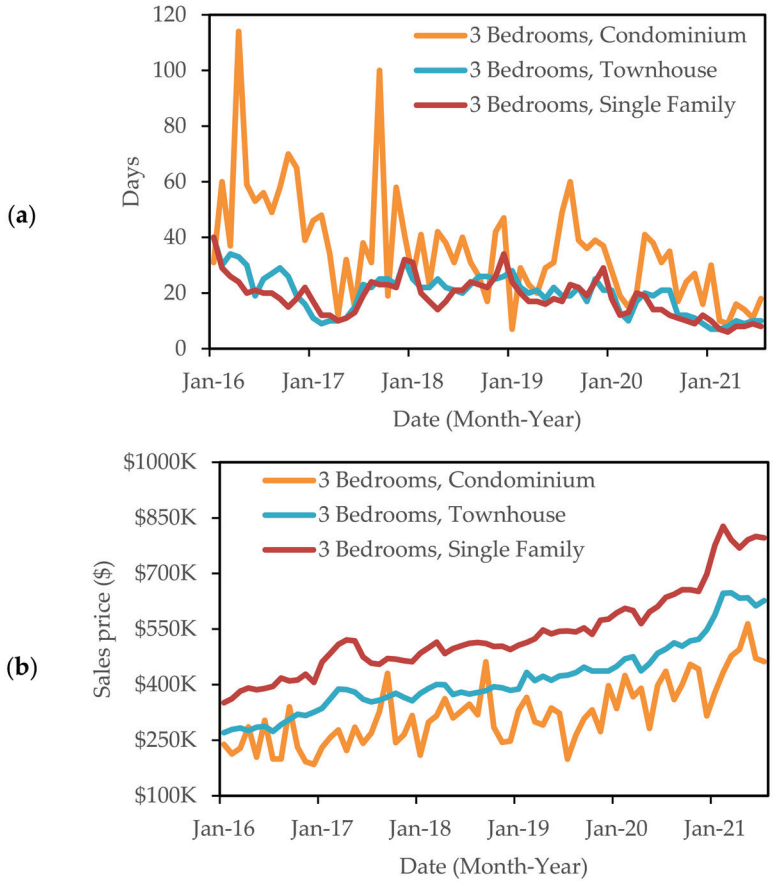

Figure 4. (**a**) Average days on market and (**b**) average sales prices of properties in the housing market of the Waterloo Region [4].

From Figure 1, we also see that the benchmark sales prices of apartments (all sizes) did not show the same exponential growth trends. As discussed earlier, the majority of apartments in this area are one- or two-bedroom. The accelerating price trends for three-bedroom apartments were not seen for apartments as a whole, indicating that one- and two-bedroom apartments are not substitutes for three-bedroom units in these markets.

We next presented evidence of income and demographic trends favoring MM housing. Our analysis assumes that younger and lower-income households have a higher propensity to choose MM housing, including apartments. Looking at the best available demographic information at that time (the 2016 Canadian Census), we argued there should be very high demand for rental units with three or more bedrooms in the RoW. Based on the 2016 Census, the youth population (0–19) comprises 28% of the RoW's population, and young adults (20–34) comprise 22%. Together, these stats imply that the RoW's population is younger than that of the Greater Toronto Area and provincial averages. The proportion and share of 20–34-year-olds living in medium- and high-density housing in the RoW was 53% in 2016, growing since 2011. The average number of persons per unit was projected to increase over the next decade and to remain higher than provincial averages. The average household size in 2016 was 2.6 persons. Only 24.59% of households were one-person, with 33.26% being two-person, 16.58% being three-person, 16.26% being four-person, and 9.32% being five or more persons. If even a proportion of the roughly 45% of households with three persons or more were seeking apartments, there was little to no supply to support the demand [64,95]. In 2019, the average income of renters was CAD 59,700 (down from CAD 68,600 in 2018). The average income of owners was CAD 122,600 (down from CAD 133,800 in 2018). These statistics demonstrate a likely gap for higher-middle-income renters, especially as the income threshold to purchase a home went up dramatically in 2020–2021 [96,97].

In short, these statistics demonstrated likely future demand for three-bedroom apartments due to a high and increasing cohort of younger, lower-income residents, who already have a high and growing propensity to live in higher-density housing (supported also by our previous research).

We presented extensive evidence that MM housing is not currently being supplied in the RoW. On the rental side, CMHC [98] reported that for the Kitchener-Cambridge-Waterloo (KCW) Census Metropolitan Area (CMA), rentals with three or more bedrooms represented only 8% of the existing supply. There was a particular scarcity of purpose-built rental units, with purpose-built rental apartments and row-home rentals comprising a small percentage (9.2%) of total apartment/row rental units. Further, the purpose-built rental stock was aging: 60% of purpose-built rentals in KCW CMA were built before the 1960s; for units with three or more bedrooms, the figure was 62%. Thus, what meager stock was available was mostly lower quality. On the condo rental side, while around 30% of condo units were rented out, there were too few rental condo units with three or more bedrooms to report. Therefore, average rents were also not reported. (This finding likely relates to the low number of condo builds and to investor preferences, discussed below.) This scarcity was not resulting in more new rental supply; rentals with three or more bedrooms also represented only 8% of new rentals. For purpose-built rentals, the supply was even lower. Table 1 shows that in 2020, units with three or more bedrooms were only 6.0% of the new purpose-built rental supply, despite the market scarcity of three-bedroom units.

Table 1. Rental apartment unit supply [94].

Year	Bachelor	1 BR	2 BR	3+ BR
2015	2.6%	32.0%	60.5%	4.8%
2020	2.3%	31.4%	60.3%	6.0%
Net increase in units between 2015 and 2020	61	1971	4097	759

The deficit of three-bedroom rentals was even more acute in the Kitchener downtown core (defined by CMHC as "Kitchener Central"—the location of the majority of high-tech firms and future home to the new intercity train station). In Kitchener Central, there were only 145 rental units with three or more bedrooms in 2020. These represent only 8.3% of all rentals with three or more bedrooms in Kitchener in 2020. The vacancy rate for units with three or more bedrooms in Kitchener Central in 2020 was 0%. The turnover rate was 2.6%. No new units with three or more bedrooms were constructed in Kitchener Central between 2018 and 2020 [98].

On the sales side, at the time of the memo's authorship, Realtor.ca (the national housing listing website) listed only three three-bedroom condos for sale [99]. In short, while demand for three-bedroom MM units was clear, current and future supply was absent, especially in the downtown cores.

Although we did not develop full pro formas to calculate the potential profitability of MM housing, we did present evidence that the product had potential profitability. On the rental side, in October 2020, average rents were CAD 863 (bachelor), CAD 1076 (one-bedroom), CAD 1295 (two-bedroom), and CAD 1435 (three or more bedrooms) [98]. While this represents a diminishing willingness to pay for an additional bedroom (CAD 213 for one, CAD 219 for two, and CAD 140 for three), a three-bedroom unit should have a lower per-square-foot construction cost, as the fixed costs of a kitchen, one bathroom, and potentially one parking space are distributed over more area. Further as seen earlier in Figure 3, rent premia for new three-bedroom units are substantially higher than those for one- and two-bedroom units, indicating higher market potential for rent than shown in the 2020 data. Specific to Kitchener Central, the average rent for three or more bedrooms in Kitchener Central was CAD 1627, 4.6% higher than the rest of the KWC CMA. (Note that this is for older housing stock as there were no new builds, and rent growth for these units was not reported due to their low numbers.) On the sales side, while the authors did not have access to all sales data, in June 2021, a 1500 sq. ft. three-bedroom, two-bathroom condo in the Waterloo downtown core sold for CAD 745,000, comparable to the three-bedroom single-family home sales price. We argued that at an estimated price point of about CAD 600,000, construction of three-bedroom condo units should have been profitable. While construction costs are only a portion of final unit costs, assuming a size of 1500 square feet (deemed ideal by a majority of the respondents to our 2016 rental survey) and using construction costs from the Altus Group [46], construction costs for three-bedroom condo units should range from CAD 202,500 to CAD 300,000 per unit.

We tempered our arguments in favor of the potential profitability of three-bedroom apartments by noting that our previous research emphasized that Kitchener–Waterloo apartments are not providing the bundle of attributes (unit size and greenspace access) that buyers need [30,58–61]. In short, apartments can solve the unit size problem, but unless they also provide access to small private or high-quality public open spaces, they are unlikely to appeal to MM buyers.

4.4. Results of Discussions with Real Estate Industry Stakeholders

Our discussions of the data narrative with developers revealed nuanced evidence. While they have access to similar information, developers express a diversity of beliefs and strategies, with some seeing demand for MM housing and beginning to actively experiment with new supply, and others remaining unconvinced of this market in the RoW.

Our initial hypothesis was that a gap between perceived and actual demand for three-bedroom apartments was the major barrier to their supply. Locally, historical discussions with some municipal staff and developers have reflected a deep skepticism about the market for and feasibility of MM housing. The commonly heard expression has been "the demand is not there". Some of this skepticism continued among developers in our recent discussions. A commonly expressed belief is that three-bedroom units would be too expensive for potential buyers. This rhetoric contradicts the acknowledged point that per-unit costs for three-bedroom units are lower than those for smaller units, as three-

bedroom units need only one kitchen, often one parking place, and potentially no more bathrooms. Implicitly, developers express skepticism that renters or buyers would pay the premium required for the three-bedroom units, based on the belief that more attractive substitutes exist in the market. For instance, developers assume that if the price point of a three-bedroom downtown condo is comparable to that of a three-bedroom suburban townhome, all local buyers would choose the suburban townhome. Thus, evidence of latent market demand may not be sufficient to convince developers of profitability; rather, a critical mass of successful examples would be needed. The situation is confounded by the fact that most of the few three-bedroom apartments that have been constructed in the downtown cores are in high-rises, with no immediate access to private or public greenspace. It is not a surprise to the authors that demand for such units would be weak, given our previous research.

However, our discussions revealed a set of much more nuanced and complex barriers to MM housing supply, which were created and mediated through interactions between the investment, development, and planning realms. Our initial mental model of the market dynamics focused mainly on demand-side actors (renter and buyer households, acknowledging their diverse cohorts), developer actors, and developers' perceptions. We needed to modify our mental model to better articulate the dual nature of land and housing markets (as a use good, for living in, and an investment good, for asset value) and thus to also include diverse investor actors—construction finance and individual condo pre-purchase investors.

Discussions revealed additional profitability constraints to the supply of MM housing, especially in transit areas where land values reflect possible profits from small-unit high-rise housing. Again, we needed to modify our conceptual models and narrative to include the dynamics behind land-value uplift. Land-value uplift occurs when a new investment (in our case, the ION) creates increases in expected and then realized land values due to improved accessibility and expected TOD [100].

Our discussion with developers also emphasized project risk as a central constraint to supply decisions. Beyond the uncertainty of direct resident demand, developers stressed the importance of other sources of market uncertainty, emphasizing the important role that construction cost volatility plays in the decision to develop, postpone, or cancel a project. Looking at broader market trends, developers also reported tracking unit uptake and delaying development when uptake decreased.

Discussions shed light on the important, and often constraining, role that project finance played. Locally, developers reported lender requirements for highly specific existing demand evidence, requirements to pre-sell 60–80% of units to obtain additional financing, and a minimum 10–15% return on their investments. For large-scale high-rise, small condominium builds, developers can partner with large investors, but they need to demonstrate substantial pre-sale (up to 80% of units), need to demonstrate potential project returns (internal rate of return) of 10% or higher, and need to provide highly specific evidence of demand and previous success of the potential build in the local market. Evidence of latent demand [89] will not suffice—the unit type needs to have been previously sold in the local market.

Condo brokers and developers report that there is often a gap of at least 3 years between pre-sales and taking possession of units. Discussions with realtors and a local condo marketing firm revealed how this gap might limit pre-sales of three-bedroom units. Buyers looking for such family-sized units often have immediate needs (for example, an expanding family). Beyond this, especially in volatile housing markets, buyers might not want to give up the option value of purchasing a single-family home, which has features such as private greenspace and sufficient living space that most family households desire. Resident buyers also tend to look towards realtors and Realtor.ca for potential homes, and condo units do not appear on these sites until units are almost ready for occupancy. In short, there are substantive barriers to residents participating in pre-sales of family-sized units.

While no developer suggested this barrier, it is possible to conclude that investors purchasing condos would not prefer three-bedroom units for several reasons. First, they would often be rented to households with children, and investors might perceive that units with children receive more wear and tear. Second, a small family could remain in a three-bedroom unit indefinitely—as a young couple, with 1–2 children, and as downsizers. When regulations limit rent increases, turnover is the only opportunity for investors to substantively raise rents. Further, in volatile real estate markets, such as Ontario's current falling market as shown in Figure 1, investors have an incentive to keep condo units empty, as it increases their ability to liquidate (In Ontario, buyers need to honor an existing lease in a purchased unit in most circumstances.). Again, investors therefore benefit from short leases and frequent turnover.

Finally, land-value uplift from increases in the allowed density of housing builds (up-zoning), or anticipated up-zoning approvals, clearly limits what can be built. From our previous research, discussions with greenfield developers and discussions with realtors, it is clear that products such as low-rise stacked townhomes with small private yards and balconies are viable, and increasingly popular, new housing models. They further have the advantage that builds can be staged so that initial units can be quickly completed, providing revenues to finance the next build. However, developers report that land in intensified areas, where small high-rise condos have succeeded, is too expensive for low-rise projects to be viable, even though construction costs per square foot are substantively lower for low-rise builds. Thus, seemingly counterintuitively, real zoning limits to low-rise height may contribute to the development of more affordable housing.

While zoning is frequently asserted to be a barrier to housing supply in Ontario, our discussions focused only peripherally on zoning. Station-area planning in the local cities envisioned generous up-zoning along the transit corridor, and in anticipation of this up-zoning, rates of approval of Official Plan and Zoning By-law Amendment applications have been high, with approvals granting zoning higher than planned densities [101]. Some developers, however, expressed a preference for building as-of-right, rather than going through the additional time and financial cost of amendment applications.

5. Qualitative Systems Mapping of Development, Investment, and Planning Interactions

Based on our literature review and stakeholder conversations, we formalized our system understanding through a qualitative systems diagram (Figure 2) [68]. The diagram shows the key actors (residents demanding housing for rental or sale, real estate brokers, developers, and financial actors: lenders who finance construction and investors who pre-purchase condos). It also shows their main interaction environments: the planning realm, land markets, and housing markets. Interaction environments are limited by the actor's roles. Residents seeking housing participate in housing markets, interacting with brokers and, to some extent, with planners. Realtor brokers interact directly with residents and planners, but less frequently have direct interactions with developers. Condo brokers interact with some residents, but primarily with developers and pre-build investors. Developers interact with lenders, pre-build investors, and planners. Within this system, Figure 2 highlights the important role of housing unit demand and price expectations, and it shows how development costs are impacted by key actors and processes.

Based on Figure 2, we developed a causal loop diagram (Figure 5) to hypothesize how these complex processes may lead to a self-reinforcing lock-in of high-density, small-unit-size condo builds in the RoW. At the regional level, the planned LRT promised to improve accessibility and bring TOD amenities. The RoW's stated intensification goals, along with station-area plans, signaled a permissive planning for high-density development, reflected in the developer's pro forma as higher potential floor space ratios. Together, these planning changes created latent demand from potential residents seeking improved accessibility and TOD amenities. Planning changes also led investors (lenders and pre-build investors) and developers to anticipate this latent demand—although given their bounded rationality, they may or may not have correctly perceived such demand. These perceptions led to a

favorable assessment of the profitability of high-rise developments, which motivated them to invest in new high-rise builds, thereby contributing to housing supply and increasing high-rise, small-unit housing stock. New residents whose demand was correctly perceived then located in downtown cores through rental and housing market interactions. These successful housing market outcomes positively reinforce the planning priority for high-rise development (reinforcing loop 1). The positive price expectations for high-rise builds by the housing investors led to an increased willingness to pay for properties where additional high-rise development would be feasible. These dynamics created an expectation that profitable high-rise development was possible on any parcel in the downtown cores, leading to land-value uplift in the land markets. As long as there was investor or resident uptake of housing units (real or expected), this dynamic created a self-reinforcing lock-in of the high-rise development model (reinforcing loop 2).

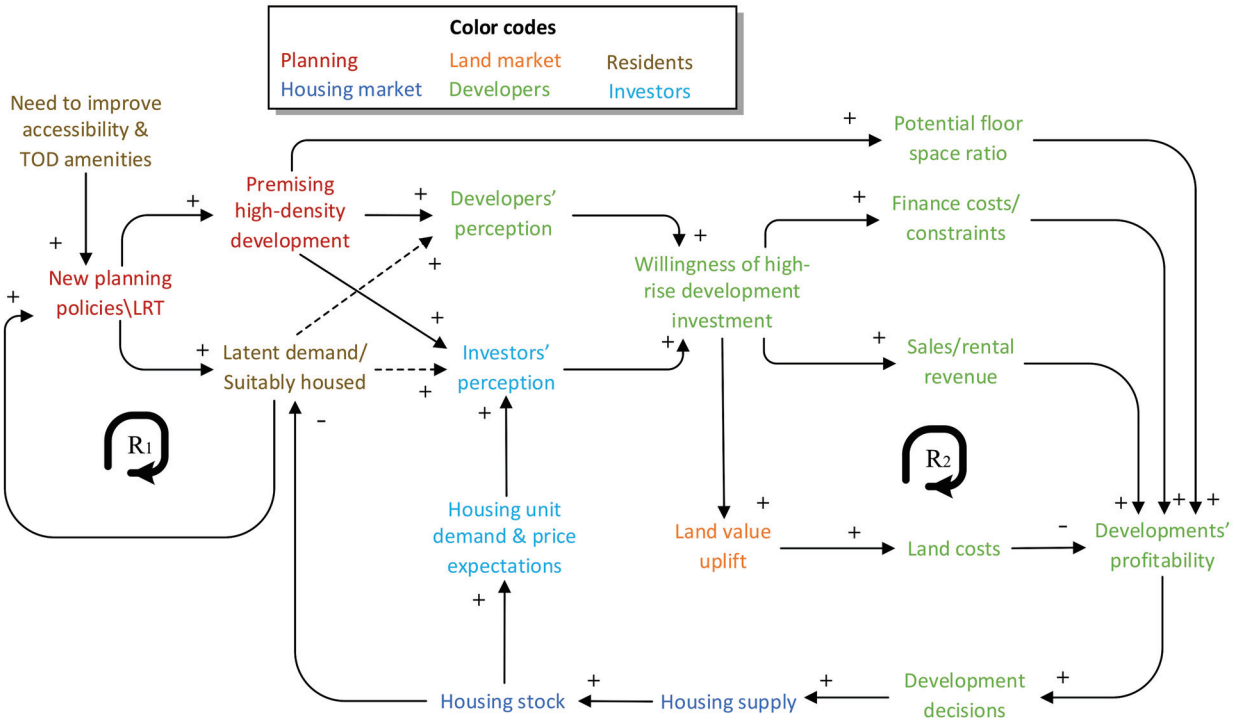

Figure 5. Qualitative causal loop diagram characterizing the underlying dynamics of high-rise development decisions.

Those whose needs were not met (family-sized households) remained in latent demand. Locally, planners have begun to perceive this latent MM housing demand and have responded by creating a more permissive residential parcel zoning in Kitchener and targeting MM housing in the RoW's most recent Official Plan update. However, we argue that the planner's attempts to increase MM housing supply are likely to fail, because multiple dynamic factors "lock out" MM housing in our downtown cores, as well as any areas where developers anticipate that high-rise builds would be approved. We illustrate this "broken" balancing loop in Figure 6. While the new planning interventions signal a priority for MM development, developers and investors may not perceive the latent demand for MM housing. MM housing also has a reduced floor space ratio relative to high-rise builds, meaning fewer units built on costly land (due to land-value uplift that prices land by the potential profitability of high-rise builds). Without strong evidence of existing demand and profitability, lenders will not provide construction financing, and pre-build investors will not purchase units. With no MM supply of the product, latent demand will not be revealed, locking out new MM housing supply. These dynamics directly reflect the narratives put forth in conversations with our developer partners—in the downtown cores, MM builds

are no longer cost-feasible. Therefore, the planning priorities will not be realized without other interventions.

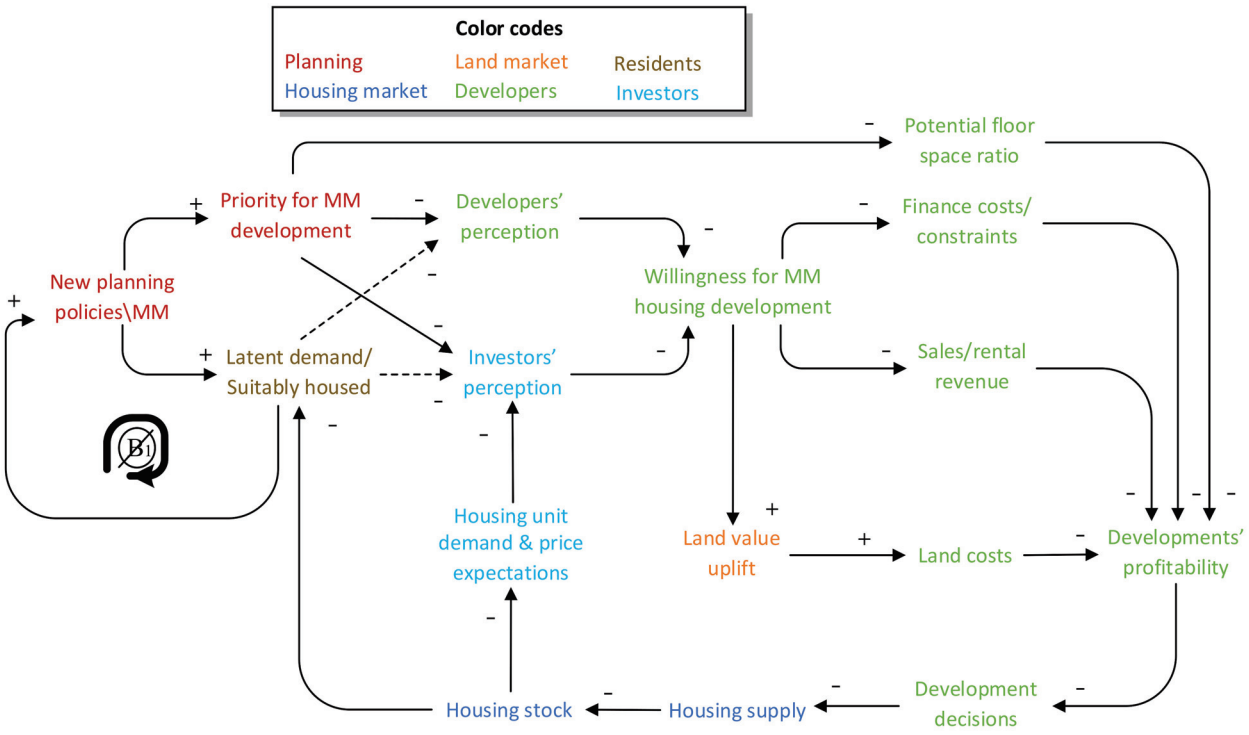

Figure 6. Qualitative causal loop diagram characterizing the underlying dynamics of MM housing development decisions.

6. Conclusions and Implications for Planning

6.1. Concluding Recommendation for Planning and Housing Markets

Our discussions and analysis suggest particular planning and policy responses, some already acknowledged, and some novel. While a full review of factors impacting the supply and success of MM housing is beyond the scope of this paper, recommendations arising from our analysis include the following:

- In areas targeted for MM housing that would otherwise be under pressure for land-value uplift reflecting potential high-rise development, limit this uplift by enforcing low-rise zoning (i.e., refusing development applications for higher height and density). This suggestion may contradict the belief by some planning and economic actors that markets allocate land to its highest and best social use. They do not, as land and housing markets incorrectly and incompletely incorporate external and public good values [102]. We also remind the reader of the dual market for housing as both a use and investment good. Investors will push land allocation to its profit-maximizing use as an investment good, not a use good. Thus, planning and zoning have important roles to play in correcting market failures. Planning interventions may have the capacity to create successful "balancing loops" if they limit land-value uplift.
- Simplify the planning and approvals process by modifying single-family zoning to allow multiple units on all residential parcels "as-of-right" (i.e., without submitting an Official Planning or Zoning By-law Amendment application). This widely supported planning measure has been implemented in various jurisdictions around North America to differing extents, including Kitchener (duplex plus two additional units) [90]; Minneapolis (three units) [103]; Grand Rapids, MI (four units) [104,105]; Portland (multiplexes) [106]; California (four units) [107]; and to geographically limited extents in Atlanta, GA [104], and Saint Paul, MN [17].

- Simplify the planning and approvals process by creating easily approved standardized MM typologies. Our future research in the RoW is focused on this goal. In the RoW, site plan applications are currently required for residential builds of three units or more, but not for duplexes, incentivizing duplex builds over higher-density MM. While existing examples of this approach are scarce, the City of Edmonton held a contest to create MM architectural typologies [108]. Moreover, Saint Paul, Minnesota, facilitated the housing permission by including MM housing types such as duplexes, triplexes, townhomes, small-scale multifamily, and accessory dwelling units [109].
- Provide non-profit finance to create reasonably affordable MM builds, allowing for support by broad evidence of potential demand. For example, a joint project between the City of Minneapolis and the Minnesota Housing and Land Bank Twin Cities provides MM finance of up to USD 70,000 to USD 95,000 per affordable unit, with higher subsidies for larger units [17,110]. The State of Michigan has provided no-interest construction and rehabilitation loans for MM homes for moderate-income residents [111].
- Create programs to facilitate co-op builds, where three or more households collaborate to finance, design, and build an MM housing build, as undertaken by the City of Vancouver in low-density neighborhoods targeted for MM housing [22]. The Government of Canada has also initiated a new Co-operative Housing Development Program to expand co-op housing in Vancouver and across Canada to stimulate a new generation of co-op housing [112].
- Acknowledging the potential bias by condo investors against renting to families with children, implement planning requirements for unit mix (including three-bedroom units), minimum sizes (1200–1500 square feet), and adequate provision of on-site private and proximate public greenspace and playgrounds. Unit-mix requirements and recommendations have been implemented in Grand Rapids, MI [104]; Montreal [113,114]; and Toronto [115].
- Facilitate non-profit or municipal pre-purchase of three-bedroom condo units to bridge the gap between end-user resident demand and the financing need for condo pre-sales. We have not found previous examples of this "bridging broker" role for non-profit or municipal entities.
- Facilitate MM demonstration projects to demonstrate financial feasibility and market uptake, reducing uncertainty for both the for-profit and non-profit housing supply sectors. Ideally, these demonstration projects should be co-designed with end-users to ensure their market viability. Such demonstrations may be particularly important given the finding by the authors of [23] that new MM builds are more likely in neighborhoods with existing MM housing.

6.2. Recapping our Complex Systems Lens

This paper has demonstrated how a complex systems lens, supported by qualitative systems mapping, can help to identify the potential and limitations of the planning process to address housing market challenges. Planning plays direct and indirect roles. Major planning investments and up-zoning can create path-dependent change, not only by incentivizing new populations to seek residence in an area, but also by creating expectations of new demand by developers and investors. These changes can create positive feedback loops that lock in certain kinds of development—where there is strong evidence of existing demand—and lock out novel housing types—where demand evidence is weaker, or the new products are "priced out" through land-value uplift. Our narrative emphasizes how market interactions between heterogeneous resident, planning, developer, and investor actors in the planning and land/housing market realms create reinforcing feedbacks.

Our systems view also has allowed us to identify potential solutions—some of which may need to be implemented concurrently—that might spark supply of MM housing in our study area. While some have been implemented elsewhere, others appear to be novel. We argue that our systems analysis allows us to move beyond the data narratives most often

used to drive policy locally, without major investments in data and quantitative modeling. Thus, a systems analysis approach can facilitate improved policy design by incorporating an understanding of system dependencies and feedbacks. Such analysis thus has the potential to create policies that avoid misaligned incentives and unintended consequences.

Finally, we wish to emphasize that systems analysis need not be quantitative to accomplish its main goals of understanding systems and the implications of their causal mechanisms and identifying potentially effective interventions. The work that we have presented can be effectively communicated verbally, through a qualitative systems map, and through causal loop diagrams. In participatory research, there may be benefit to taking the simplest and most universally understood means of communicating systems dynamics. Basic systems diagrams can then be used to support the development of quantitative models [84].

6.3. Limitations and Future Work

This research describes an expectations-driven positive feedback loop, which accelerated planning approvals, high-rise housing supply, and land-value uplift. While such market dynamics have been observed throughout history and characterized as "bubbles" [116], market fundamentals such as limits to rents, increasing land prices, and even out-migration should create balancing mechanisms, limiting the persistence of the feedback loop. Locally, housing supply has slowed, but this has been due to external increases in construction costs and rising interest rates, rather than balancing due to market saturation [117].

While our case study shared generalizable features with other planning and housing market regimes across North America, local planning regulations and market conditions create particular constraints and opportunities for our location. More generally, even though some of our proposed solutions have been implanted elsewhere, their longer-term impacts in the real world are not yet completely understood. In frequently shifting policy and planning environments, it can be challenging to assess the empirical impact of interventions. Future research with our planning, development industry, and resident partners locally should, however, allow us to develop and test the interventions proposed here and assess how effectively they can harness planning and finance tools to better incentivize MM housing builds.

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Poorer Regions Consume More Undeveloped but Less High-Quality Land Than Wealthier Regions—A Case Study

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Abstract: Despite the efforts of developed countries to protect undeveloped land, development continues to expand beyond urban boundaries. High-quality land needed for food production is often consumed. This study aims to verify possible causes of undeveloped land and high-quality land consumption within regions (NUTS3) using a new approach to building growth monitoring. It investigates residential (RBs) and commercial buildings (retail and industrial buildings, RIBs). The development between 2006 and 2016 in the Czech Republic, a country in Central Europe, is used as a case study. Population growth and gross domestic product per capita (GDP) within regions are considered two potential causes of land consumption; this hypothesis is verified using a linear regression model. Only GDP showed statistically significant results. It correlated negatively with RBs and RBs + RIBs built on undeveloped land and positively with RBs + RIBs and either RBs or RIBs built on high-quality land. Based on the results, we recommend that land protection policies be differentiated according to regional specifics to be more effective. Regions with lower GDPs should obtain more support in protecting undeveloped land against residential development. The protection of high-quality land should be emphasized by supporting residential and commercial development on brownfield sites in regions with higher GDPs.

Keywords: Czech Republic; land consumption; land protection; high-quality land; residential building; commercial building

1. Introduction

A need for the protection of land against new development has been recognised in many parts of the world, and the land consumed by new buildings is a significant cause of diversity decline in the world [1]. In the European Union (EU), land protection against urbanisation is perceived as one of the most pressing environmental protection themes [2]. In 2013, the EU established a target of having no land consumed by new development in the EU by 2050 [3], which became known by a short slogan, "no net land take by 2050". However, not much progress on the EU level was recorded as of 2020 [4]; it seems the goal is not being achieved (EEA, 2020). This paper aims to contribute to the debate on how policy can better protect the land in order to achieve this target.

The European Environment Agency [5] monitors the land take, defining it as the 'change of the amount of agriculture, forest and other semi-natural and natural land taken by urban and other artificial land development.' The soil being covered by development results in a loss of biodiversity, which is linked to the physical shrinking of biotopes, and the soil's capacity to regulate the water cycle is heavily compromised [6]. At the same time, the planet's population is increasing, and new migrants may advance the European population in the future [7], increasing the demand for land for living and farming. As land and soil are non-renewable resources, the solution seems to be an efficient use of land, preferably using vacant, so-called brownfield sites, and those with a lower soil quality.

Both the Organization for Economic Co-operation and Development (OECD) and the EU support a compact city policy and the protection of open, undeveloped land [8,9]. Special attention should be given to high-quality agricultural land, which should primarily be used for cultivation [10].

The EU established the target, and the national governments are expected to formulate planning objectives. Some countries, such as Luxembourg, Austria, and Germany, have set national objectives [11]. Some countries, such as Germany, declare that the national objectives are insufficient for their application [12]. There are two reasons for this. Firstly, there are differences between regions and municipalities, so the objectives should be formulated relative to those differences. Germany, for instance, related the objectives to the number of inhabitants within an area (ibid). The second reason regards policy delivery. Regional or local authorities, not the national government, are responsible for delivering planning policies in the EU [6]. As such, some regions should formulate planning policies for dealing with regionally specific demography and land use [13]. In addition, the European Commission [14] highlights the crucial role of regional and local authorities, specifically in addressing soil sealing. Therefore, an evaluation of the factors that might affect growth on undeveloped and high-quality land should be performed on the regional level, using European NUTS3 units (Nomenclature of Units for Territorial Statistics), which are uniform for the EU.

The two main drivers of land consumption in the EU are population growth and economic development [1]. However, the EU target does not distinguish between types of land use [10], i.e., residential and commercial [11]. However, different land uses are affected by different drivers. Moreover, the various drivers may differently affect the new development on both undeveloped and high-quality land; therefore, building on undeveloped versus high-quality land might differ for attractive and economically strong regions. Regional attractiveness can be expressed by population growth and gross domestic product growth (GDP).

We aimed to verify the relationship between residential buildings (RBs) and retail and industrial buildings (RIBs) on undeveloped land and high-quality land and population growth and GDP. Specifically, we estimated the connection between (i) the consumed undeveloped land with RBs, RIBs, and RBs + RIBs, respectively, and the population growths and GDPs in the NUTS3 regions, and (ii) the consumed high-quality land with RBs, RIBs, and RBs + RIBs, respectively, and the population growths and GDPs in the NUTS3 regions (iii). Moreover, we aimed to present a new method for monitoring growth on undeveloped land compared to growth on built-up land.

As a case study, we use the Czech Republic, a developed country located in the centre of Europe, a representant of a post-socialistic country. Here, as well as in Slovakia, Hungary, Slovenia, the Baltic States, and, to a certain extent, Poland [14], land consumption began only in the late 1990s. The development further continued after the expansion of the EU in 2004, when the newly joined countries obtained many subsidies aiming to equalise economic and social conditions in EU countries and their regions [15]. In the Czech Republic, within 20 years of 1989 (the year of the Velvet Revolution), more than 30% of inhabitants had moved outside of the cities [16], which was described in Bičík and Jeleček [17] and Sýkora and Stanilov [14] in detail. Despite a slower pace of building since the economic crisis of 2008 [14], the growth in regions with large cities has remained strong in the Czech Republic [18]. Built-up areas often grow at the expense of agricultural areas [17,19,20]. In the last three decades, a drastic reduction in agricultural activities was recorded, especially in post-socialistic countries [21]. In the Czech Republic, there is no specific national or regional policy objective for limiting growth on undeveloped land in order to fulfil the EU target. However, a strict requirement to protect high-quality agricultural land against new development was launched in 2006 (Construction Act No. 500/2006).

We hypothesised that population growth would positively correlate with the buildings' growth on both undeveloped and high-quality land, and we hypothesised that GDP would negatively correlate with the buildings' growth on both undeveloped and high-quality land.

2. Materials and Methods

Data about the growth of RBs and RIBs between 2006 and 2016 on undeveloped and high-quality agricultural land in 14 regions of the Czech Republic were created. Data about population growth and GDP for the same time period and the same regions were calculated in order to test the hypotheses.

Research manuscripts reporting large datasets that are deposited in a publicly available database were used. The accession numbers have not yet been obtained at the time of submission; they will be provided during review.

2.1. Study Area

The Czech Republic is administratively divided into 14 regions (see Figure 1), corresponding with European NUTS3 units (Nomenclature of Units for Territorial Statistics). There is, nevertheless, some irregularity in the regional division. The region of the City of Prague (Prague region) is both a region and a municipality, resulting in a lack of undeveloped and notably high-quality land in this region. Therefore, we considered 14 regions for the analysis of undeveloped land and only 13 regions for the analysis of high-quality land, excluding the Prague region. According to the Regional Development Strategy [22], there are three metropolises in the Czech Republic; in addition to Prague, they are Brno (in the South Moravia region) and Ostrava (in the Moravia-Silesia region). We refer to the metropolitan regions for interpreting some phenomena in regional development.

Figure 1. The map of the study area. Borders of NUTS3 regions in the Czech Republic (source: Register of Territorial Identification, Addresses and Real Estate, https://www.cuzk.cz/ruian/, accessed on 10 October 2022).

2.2. Processing Data on Building Growth

We used the data about buildings that obtained a building descriptive number, collected yearly in the Register of Census Districts and Buildings by the Czech Statistical

Office. This enables more precise analysis compared with the alternative of using data about erected buildings obtained via remote sensing (see the Discussion Section). The data contain information about the area dimensions of the buildings, the way they are used (commercial or residential purposes), and their location. They are in the form of georeferenced points. Such data need to be transformed using a GIS (Geographical Information System). The methodology is summarised in Figure 2.

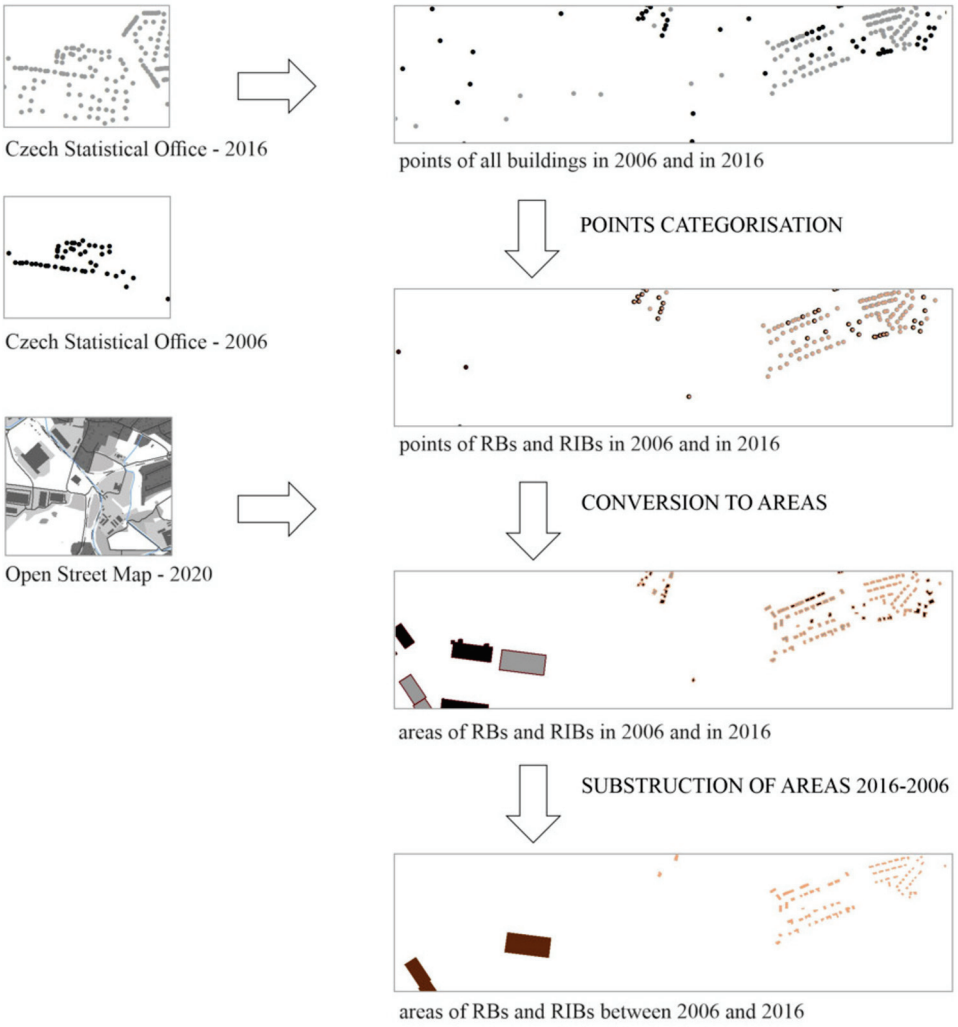


Figure 2. Data processing scheme of the building growth between 2006 and 2016.

The used data consist of two sets. The first dataset includes all existing buildings built up until 2006, while the second includes those built up until 2016. Only the Residential Buildings (RBs) and Retail and Industrial Buildings (RIBs) were chosen and joined into one map ("points categorisation"). The RBs consist of the buildings with the following attribute values: *construction with residential use* (code 03), *construction with prevailing residential use* (code 06), and *construction which, by its form, corresponds to a single-family dwelling* (code 07). The RIBs include buildings with the following attribute values: *industrial factories and warehouses* (code 01); *factories with shops and other salerooms, retail spaces, shopping malls, and the like* (code 10); and *factories designed for industry, handicraft, and other production or services of a production nature, and the warehousing of products, staff, and materials* (code 12). Code 01 accounts for 19%, code 10 for 23%, and code 12 for 58% of all the RIBs. If there was no building code in the dataset for the year 2006, the missing code was replaced by the one from the 2016 dataset, assuming that the building's use was not changed over time.

We used the Open Street Map (OSM) to convert points of buildings into areas of buildings by intersecting the building data with the OSM, which includes polygons (areas) of all existing buildings in the year of the map's creation. We used the OSM from 2020 to ensure both 2006 and 2016 buildings were included. The advantage of the OSM is that it is available worldwide and is of sufficient quality. Finally, the building growth was obtained by simply subtracting the area of buildings in 2006 from that of 2016.

The building growth can be divided according to territorial units. In this article, we use the NUTS3 regions. In the Czech Republic, they are freely available from the digital vector geographic database of the RÚIAN (Register of Territorial Identification, Addresses, and Real Estate, https://www.cuzk.cz/ruian/, accessed on 10 October 2022).

2.3. Defining Building Growth on Undeveloped Land

We assume the unbuilt area is simply land that does not contain any buildings. There are two possible vector data sources available to identify the land without buildings: Urban Atlas and Corine Land Cover (CLC). Urban Atlas is more precise than CLC [23]; however, it does not cover the entire area of the Czech Republic or the entire EU. We, therefore, use CLC in this study to allow for this methodology to be used in other European countries as well. CLC monitors the land use in 1990, 2000, 2006, 2012, and 2018. We used the dataset of 2006; the analysis can, however, be conducted analogically in the other monitored years.

Undeveloped land (i.e., land without buildings) contains the following CLC layers (including the layer code in brackets): *Arable land* (2.1), *Permanent crops* (2.2), *Pastures* (2.3), *Heterogeneous agricultural areas* (2.4), *Forests* (3.1), *Scrub and/or herbaceous vegetation associations* (3.2), *Open spaces with little or no vegetation* (3.3), *Inland wetlands* (4.1), and *Inland waters* (5.1). It needs to be noted that undeveloped land also contains water and wetlands, where no buildings are constructed.

Finally, the building growth data (Figure 2) were intersected with the undeveloped land layers to define only the buildings built between 2006 and 2016 on undeveloped land.

2.4. Defining Building Growth on High-quality Agricultural Land

In order to define high-quality land, we used the Czech database of agricultural land based on the Act for Protection of Agricultural Land (Act No. 334/1992, using a plot) as an alternative to the European Soil Database (using a raster of 1km x 1km). The Act (§1 No. 334/1992) defines agricultural land as agriculturally cultivated land, i.e., "arable land, hops, vineyards, gardens, orchards, permanent grassland". The database is based on a complex and detailed land classification and is regularly updated. Agricultural land is classified into five soil protection classes according to soil quality. In line with the Construction Act (Act No. 500/2006), which protects high-quality soil against new constructions, we used the first two classes with the highest soil protection (Act No. 334/1992) as the high-quality land for the analyses. It must be noted that the agricultural land is monitored regardless of its location (built-up or undeveloped land). Nevertheless, only a minor part of it is located within the built-up land (typically gardens and orchards).

Finally, the building growth data (Figure 2) were intersected with the high-quality land within the agricultural land database to define only the buildings built between 2006 and 2016 on high-quality land.

2.5. Analyses

First of all, we needed to calculate comparative values. The GDP variable was calculated as GDP per capita. The buildings' growth on undeveloped land was calculated as a percentage of the buildings' growth anywhere, i.e., RBs growth on undeveloped land is the percentage of RBs growth on undeveloped and built-up land in the region (anywhere), while RIBs growth on undeveloped land is the percentage of RIBs growth anywhere, and RBs + RIBs growth on undeveloped land is the percentage of RBs + RIBs anywhere. Analogically, the buildings' growth on high-quality land was calculated as a percentage of the buildings' growth anywhere.

A simple linear regression analysis was performed with MS Excel data analysis and used to describe the relationship between population growth, GDP growth per capita (independent variables), and undeveloped land consumption and high-quality land consumption (dependent variables). The data were verified by a normality check. As a result, all the variables, except for the RBs and RIBs growth on undeveloped land, were log-transformed before the analyses.

3. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. Conditions in the Study Area

The results are presented in Table 1. The first two columns show what proportion of land is occupied by undeveloped land and high-quality land in each region. We can see a marked difference between the lands' proportions. While the average percentage of undeveloped land is 90% (SD 12), the average proportion of high-quality land is 24% (SD 8). The difference is even more significant if we keep in mind that this is only the City of Prague (46.4%), with prevalently built-up land, which decreases the average values. In short, the results show that it is high-quality land that is much more limited, and this applies in all regions within the Czech Republic.

Table 1. Population growths, GDP per capita growths, and residential (RBs) and commercial (RIBs) buildings' growth on undeveloped land and on high-quality land in the Czech Republic between 2006 and 2016.

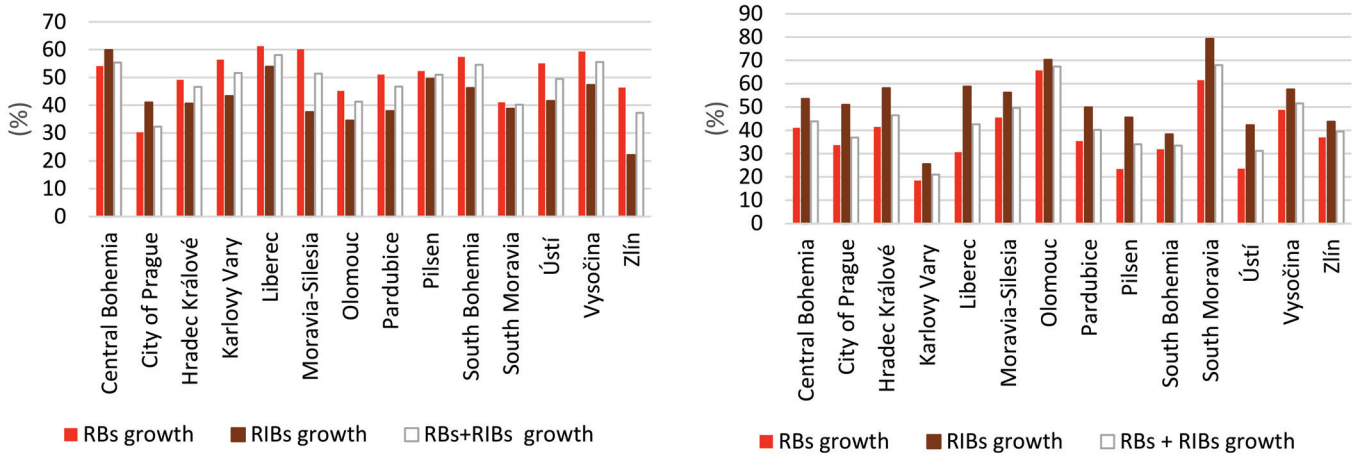
	Undeveloped Land in 2006	**High-Quality Land in 2006**	**Population Growth**	**GDP per Capita Growth**	**RBs Growth**	**RIBs Growth**	**RBs + RIBs Growth**	**RBs Growth**	**RIBs Growth**	**RBs + RIBs Growth**
					On undeveloped land			On high-quality land		
	*	*	**		[1]	[2]	[3]	[1]	[2]	[3]
Region	%	%	%	Euro	%	%	%	%	%	%
Central Bohemia	93.3	28.7	14.6	5241.2	54.1	59.8	55.4	41.1	53.5	43.9
City of Prague	46.4	35.3	7.3	13,970.6	30.3	41.0	32.3	33.6	50.9	36.9
Hradec Králové	93.3	30.8	0.6	4867.6	49.1	40.6	46.6	41.4	58.0	46.4
Karlovy Vary	94.9	11.4	−2.1	2473.5	56.4	43.3	51.6	18.4	25.5	21.0
Liberec	93.8	18.0	2.5	3421.0	61.2	53.8	58.1	30.6	58.7	42.6
Moravia-Silesia	90.4	24.4	−3.0	4211.6	60.1	37.5	51.4	45.5	56.1	49.6
Olomouc	93.4	30.8	−0.7	4544.7	45.1	34.5	41.3	65.7	70.3	67.3
Pardubice	93.3	26.5	2.0	4270.0	51.0	37.9	46.7	35.4	49.8	40.2
Pilsen	96.4	10.8	4.6	4942.6	52.3	49.6	51.0	23.4	45.5	34.0
South Bohemia	96.6	18.1	1.6	3332.5	57.4	46.2	54.5	31.8	38.3	33.5
South Moravia	92.8	39.8	4.0	5543.0	41.1	38.8	40.2	61.5	79.2	68.0
Ústí	91.4	21.2	0.0	3110.3	55.0	41.5	49.5	23.6	42.2	31.2
Vysočina	96.1	28.3	−0.3	4251.1	59.3	47.3	55.5	48.8	57.5	51.6
Zlín	92.8	17.3	−0.9	5284.3	46.4	22.1	37.2	37.0	43.7	39.5

* 100%: regional area. ** 100%: population in 2006. [1] 100%: RBs growth. [2] 100%: RIBs growth. [3] 100%: RBs + RIBs growth.

The population and GDP per capita grew over the ten years under review. While GDP per capita increased in every region, the population increased in only 53% of the regions. Again, the Prague region and its surrounding region (Central Bohemia) were shown to be the most attractive regions for the economy and new inhabitants, followed by the second metropolitan region, the South Moravia region (see Table 1). However, GDP growth does not go hand in hand with population growth by a long sight (e.g., see the Olomouc, Zlín, or Vysočina regions). The least attractive region in terms of population decline (not GDP) was the third metropolitan region, the Moravia-Silesia region.

The buildings' growth on undeveloped land and high-quality land are displayed in Figure 3, where the values are arranged alphabetically by region. The graphs clearly show

more variability in the growth on high-quality land (43 ± 13%) than on undeveloped land (47 ± 7%). Another marked difference regards the use of the buildings. While RBs are more often built on undeveloped land (RBs: 51 ± 8%; RIBs: 42 ± 9%), RIBs are more often built on high-quality land (RIBs: 53 ± 13%; RBs: 41 ± 8%). Such difference is particularly notable in the Moravia-Silesia or Zlín regions (for growth on undeveloped land) and in the Liberec or Pilsen regions (for growth on high-quality land). The South Moravia region has, markedly, the highest proportion of RIBs on high-quality land.



(**a**) Growth on undeveloped land. (**b**) Growth on high-quality land.

Figure 3. Percentages of buildings (RBs, RIBs, and RBs + RIBs) built on undeveloped land (**a**) and high-quality land (**b**) in the Czech Republic between 2006 and 2016. 100% = buildings built anywhere.

3.2. Relationship between Population Growth/GDP Growth and Buildings' Growth on Undeveloped/High-quality Land

The regression analysis was performed to explain the relationship between population growth and the percentages of the buildings' growth on undeveloped land and high-quality land, respectively. The analysis did not significantly ($p = 0.05$) explain any of the relations. However, on $p \leq 0.1$ (specifically, $p = 0.06$), the RIBs growth on undeveloped land was positively correlated with the population growth. The model, however, explained 27% of the data variability.

The other regression analysis was performed to explain the relationship between the GDP growth per capita and buildings' growth on undeveloped land and high-quality land, respectively. We compared only 13 regions in the high-quality land model, excluding Prague's region, since Prague contains an abundance of quality soils, and these soils are, unlike in other regions, primarily located in the built-up land (Table 1). This model (displayed in Figure 4) explained most of the relations with statistical significance. The model explains approximately 50% of the data variability in the relationship between GDP and all (RBs + RIBs) buildings built on undeveloped land or high-quality land, and between 45 and 74% of the data variability in the relationships between GDP and RBs built on undeveloped and high-quality land, and RIBs built on high-quality land (Figure 4). However, the relationship between GDP and the buildings' growth on undeveloped land is negative, while the relation between GDP and high-quality land is positive. Only the relationship of GDP with RIBs built on undeveloped land was insignificant, at $p \leq 0.05$. We can interpret this as follows: if GDP grows in a region, RBs consume relatively less undeveloped land in that region (explaining 74% of the variability—4b). Conversely, if GDP grows in a region, both RBs and RIBs consume relatively more high-quality land (explaining 45% and 49%, respectively, of the variability—4e and 4f). We cannot explain with significance the relation between GDP growth and RIBs growth on undeveloped land ($p = 0.06$) (Figure 4c).

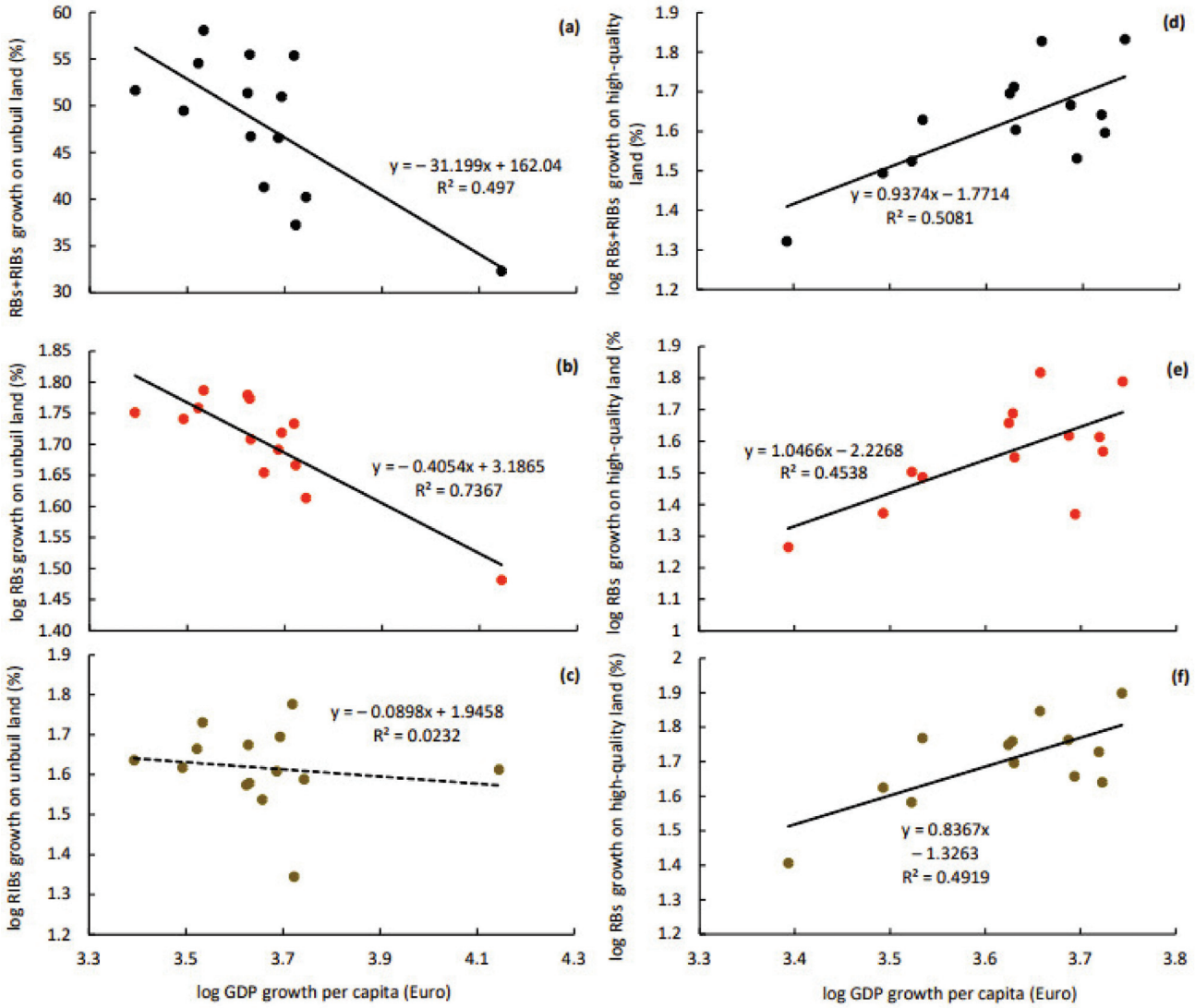


Figure 4. Plots of linear regression analyses showing the relationship between GDP per capita and building growth on undeveloped land (**a**–**c**) and high-quality land (**d**–**f**). The dashed line in the trend line represents a statistically insignificant (on $p \leq 0.05$) result (**c**).

4. Discussion

4.1. The Monitoring of Building Growth on Undeveloped Land

The presented method of processing data on building growth (Chapter 2.2) can be used as an alternative method for the same data derived from remote sensing monitoring [5,13,24–26]. Remote sensing is a widely used method; however, it does not detect small-scale development [27], including the precise resolution of buildings' uses [23]. Nevertheless, most of the current development on undeveloped land in the EU is small-scale, scattered development [26,28], and growth on undeveloped land most frequently comes in the forms of residential and commercial development [1]. The method is undoubtedly limited to countries with a database of existing or newly built buildings. However, most if not all developed countries own such data. The method of defining buildings constructed on undeveloped and built-up land (Chapter 2.3) presented here can thus be applied in all developed countries, if not globally. We compare the ratio of the growth on undeveloped land to the whole, not the amount of growth on undeveloped land. The ratio comparison might support a policy target reflecting the compact city policy.

4.2. Trends in Land Consumption

According to the EU database [5], the Czech Republic is among the average countries in the EU in terms of land consumption. Just as in many EU countries [5], about half of the development here occurred on undeveloped land between 2006 and 2016. As such, the Czech Republic and many other EU countries [11,29] are not on their way to reaching the 'no land take' EU target. There is undoubtedly a need to target the planning tools to protect undeveloped land more efficiently. Based on our results, the policy protecting undeveloped land could primarily target residential development. In the long term, there has been a noticeable decrease in agricultural land in the Czech Republic [24,30], as in other post-socialistic EU countries [15,25], caused by building growth and afforestation (ibid). Our results further indicated a decline in high-quality agricultural land from 2006 to 2016; high-quality land is also much more limited than undeveloped land in the Czech Republic. Therefore, we suggest that the policy protection of high-quality land should be better emphasised. The policy should focus on both types of development. On the one hand, RIBs consume a relatively higher share of high-quality land, but those higher values might be caused by the scale of development, due to the need for large tracts of mostly flat land, which often tend to be high-quality agricultural land. On the other hand, RBs should not be omitted because of a lower share, as this type of development is less sensitive to terrain configuration and location. The policy should be highly regionally differentiated.

Our study did not confirm the relationship between population growth and growth on undeveloped or high-quality land. Although population change does not cause the buildings' growth, RB growth in regions with population decline is not in any case an efficient use of land. We did confirm a paradoxical EU trend that the buildings' growth occurs despite population decline [15,31]. This trend was especially noticeable in post-socialistic countries [32] with a concentration of high-density housing estates in urban peripheries [14]. People's desire for individual housing was the initial impetus for housing expansion beyond the city boundary after the fall of the communist regime. Such a trend continues especially in post-industrial regions (primarily the Moravia-Silesia region) with an exceptionally high concentration of working-class housing estates. People are either moving to individual housing in the city outskirts, while the population in the core city (Ostrava) declines [31], or leaving the whole region towards working opportunities in economically wealthier regions [33]. The same trends were observed in the adjacent Silesia region in Poland [32], eastern Germany [34], and Hungary [35].

Nevertheless, we identified a slight correlation between population growth and RIBs growth on undeveloped land. A possible explanation is that an influx of new inhabitants increases congestion in built-up areas, pushing "unattractive" commercial buildings out of the urban boundaries. Such an explanation is in contradiction with the bid rent theory [36], which says that inhabitants are pushed out by industry. Nevertheless, this theory is based on the American experience in the 1960s. Another explanation might be that the slight correlation is caused by the exceptionality of the Prague region. At the beginning of 2000, commercial centres were built beyond the administrative borders of Prague because EU subsidies for these centres could not be obtained for Prague itself due to its high GDP per capita; therefore, the slightly poorer Central Bohemian Region surrounding Prague obtained the subsidies [18]. Consideration must be given as to whether Prague should be regarded together with the Central Bohemia region for similar cases. European Integrated Territorial Investments might be the tool to overpass the issue.

There was a contradictory effect of GDP growth on the buildings' growth on high-quality land and on undeveloped land. The difference in the results supports the approach of considering growth on undeveloped land and on high-quality land separately at the EU level [37], and, consequently, on national and regional levels. The RIBs growth on undeveloped land does not reflect the level of GDP in the region. This is probably caused by the fact that profit-generating companies are not always based in the same region as the one where they engage in business, i.e., where they build RIBs. RIBs are more often built on high-quality land than RBs, growing more on high-quality land in prosperous

regions. The reasons may lie in a combination of operational and historical reasons. The majority of RIBs (77%—codes 1 and 12) are buildings requiring truck traffic for service. As such, they are concentrated along highways and important transport intersections [38] (primarily undeveloped land), especially near large cities [18]. Such locations probably have high-quality land because prosperous regions with large cities can often be traced back to successful medieval settlement structures with a strong dependence on high-quality agricultural land (the path-dependence theory [39]).

With increasing GDP, RBs grow relatively more on high-quality land, and, at the same time, they grow relatively less on undeveloped land. As high-quality land is situated both on undeveloped land and within built-up areas, we can interpret it as the built-up areas in wealthy regions tend towards greater compactness. This is particularly valid for metropolitan regions (such as with Brno, but not with the structurally affected Ostrava). Such a trend probably reflects a change in the living preferences of people who moved to wealthier regions for work. Low-density suburban housing with greater demands on daily commuting do not meet their needs [40]. Economic reasons can also affect densification trends; land prices are under higher pressure in wealthier regions with population growth. Planning tools could take advantage and become stricter in limiting growth on undeveloped land. Economic reasons probably become more significant during economic crises, such as after 2008. In fact, suburbanisation during the economic crisis in the Czech Republic decreased [18]. Instead of building houses on undeveloped land, the houses in some post-socialistic countries began to be placed in the gaps within the suburban developments of big cities, thus densifying the existing housing estates [41]. The phenomena can be called "inner" suburbanisation [41] (not to be confused with negative trend suburbanisation "within city limits" [42]). We also identified densification trends in the Czech Republic (approximately 53% $\pm$ 7% of RBs occurred on built-up land), and these trends increase in wealthier regions.

In general, the densification trends are in line with the EU policy of sustainable development [8]. However, a negative side effect is a loss of urban greenery with all its positive effects, including broader environmental [43] and social effects, such as recreation and urban agriculture possibilities for inhabitants [28]. Densification should instead take place at the expense of brownfield sites (previously used sites, usually with a lower soil quality) present in every region (a database of brownfields in the Czech Republic can be found at czechinvest.org). The policy must, therefore, primarily support poorer regions with undeveloped land protection. Soil cleaning and brownfield regeneration for RBs should be emphasised within the built-up areas of wealthier regions.

4.3. Study Limitations and Further Research

This study finds associations between the variables, not the mechanism behind them. We present several possible explanations of the results, which should be tested in future research. In particular, the negative relation between per capita GDP growth and the share of new residential development on undeveloped land should be explored in more detail. Another issue is the mechanisms behind the consumption of high-quality agricultural land in regions with higher and lower GDP growths. More in-depth research should focus on variables such as the character of recent built-up land (e.g., the density and densification potential) and planning-related variables (e.g., developable land and its characteristics). These variables might differentiate between economic and planning factors in the explanation of the relations described.

The Czech Republic is a case study, and the results will probably not be universally valid. Nevertheless, we assume the results will be valid for all post-communist countries, as the growth tendencies are similar in this region [14,15].

5. Conclusions

This study presents a complex and detailed alternative methodology for monitoring land consumption in the EU with the aim of establishing effective planning tools. This study

verified population growth and GDP as two highly potential causes of RB and RIB growth on undeveloped and high-quality land. However, GDP was shown to be highly statistically significant, increasing building on undeveloped land and decreasing building on high-quality land with its growth. Based on the results, we recommend that land preservation policies be differentiated according to the NUTS3 units to propose a spatially oriented policy that reflects regional differences. The regions with lower GDPs should obtain more support to protect undeveloped land against residential development. The protection of high-quality land should be emphasised by supporting residential and commercial development on brownfield sites in regions with higher GDPs. Last but not least, this study presents the amount and distribution of RBs and RIBs across the regions (NUTS3) of the Czech Republic between 2006 and 2016, thus contributing to the worldwide debate on land preservation for future generations.

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Spatial Pattern of the Determinants for the Private Housing Rental Prices in Highly Dense Populated Chinese Cities—Case of Chongqing

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Abstract: The private housing rental market has rapidly developed and demonstrated its outstanding contribution to improving affordability for the floating population in China. However, the forming pattern of private housing rental prices (PHRP) remains poorly understood in China's highly dense populated cities. This study aims to comprehensively investigate the determinants of PHRP and depict their spatial pattern, considering the diverse functions of different areas within the city. A theoretical framework of the factors that influence PHRP has been developed based on an extensive literate study. Taking Chongqing city as a case, a Multiscale Geographically Weighted Regression (MGWR) analysis based on data from Lianjia.com and 58.com was conducted to investigate the spatial pattern of those influencing factors. The PHRP in Chongqing were mainly shaped by the factors of traffic condition and the neighborhood environment. The main findings highlighted that the influence of traffic condition on rental prices is more dominating in the industrial and financial zones, and the neighborhood factors represent spatial heterogeneity in the educational and commercial zones. This study provides a comprehensive examination of the spatial pattern of PHRP's determinants in highly dense populated Chinese cities, extending the understanding of factors influencing housing rental prices. Practically, it provides scientific and reliable recommendations for the local governments and housing agencies in developing housing properties that consider the needs of the floating population. Moreover, tenants in highly dense populated cities benefit from suggestions about looking for proper accommodation with high value and accessibility in different functional zones of the city.

Keywords: private housing rental prices (PHRP); highly dense populated city; Multiscale Geographically Weighted Regression (MGWR); spatial heterogeneity

1. Introduction

In recent decades, China's housing market has experienced a meteoric rise. Today, the real estate industry has become one of the most critical driving forces of economic development in the Chinese context. In 2021, China's real estate development investment has achieved 14,762 billion CNY, presenting a 4.4% yearly growth [1]. In traditional Chinese culture, owning a housing property is a critical life goal, which is deeply rooted in the heart of most Chinese people. With the anticipation of rising house prices, plenty of investors and speculators have been seeking opportunism and growing housing demand. High-level housing privatization and overheated market investment have raised the price-income ratio far beyond six, forming an unhealthy market with "real estate bubbles" according to international standards [2]. That is to say, high housing prices have not only contributed to the urban property but also led to a severe public problem: there exist plenty of urban residents who cannot afford private housing property [3].

To address the issue, the government at all administrative levels has taken the responsibility for building the largest housing security system in the world and providing a large amount of public rental housing with limited rental prices, thereby resolving the living problem for citizens, especially the low-income groups [4]. More than 80 million sets of

public rental housing have been built up to 2021, meeting the rigid housing demand for more than 200 million. Nevertheless, due to China's unique "hukou" system, registering citizens' residencies in different cities is difficult. In this situation, numerous well-educated, undocumented white-collar workers with decent jobs in high-tech industries and central business districts, referred to as the "floating population", are being excluded from the local housing security system in most Chinese cities [5,6]. Since many of them cannot afford private housing property, seeking residence in the private rental housing market has become their primary option.

The rental price is the indicator of the private housing rental market regarding the aspects of health, affordability, and development trends. The forming mechanism of PHRP reflects the property's value and tenants' preference, which has drawn much attention from researchers [7]. Particularly, in highly dense populated Chinese cities, the influencing factors of PHRP are much more complicated due to the dramatically growing scale of the floating population. However, the PHRP and spatial pattern of their determinants remain poorly understood for these crowded cities. As such, the hidden rules of how the PHRP is being measured remain unclear, leading to irrational choices in looking for temporary accommodation, especially for newcomers in the metropolis [8]. Moreover, private housing agencies in high-dense cities find it particularly difficult to formulate and adjust the PHRP across regions within the mega-cities, while the spatial characteristic of the PHRP and determinants are not well captured by the supply sides [9].

Chongqing, located in southwest China, is a typical high-density city that has long served as a pilot city for rental housing in China. It has the largest urban area (1496.72 km^2) and the fifth-largest urban population (11.86 million at the end of 2018) of any Chinese city [10]. As a new first-tier Chinese city, Chongqing has the largest net population inflow in China [11]. As a result, there is a substantial rigid demand for private rental housing. However, what is the status quo of the PHRP and its determinants remain unclear in Chongqing. Chongqing is a polycentric city, with each district displaying its particular urban attributes. In this sense, revealing the determining mechanism of the PHRP would further depict the urban space and development characteristics in population-dense mega-cities, thus contributing to better develop urban strategies for promoting urban attraction and competitiveness.

Taking Chongqing as the case city, this paper aims to explore the spatial pattern of the PHRP and its determinants in high-density population Chinese cities. The study is dedicated to achieving two sub-objectives: (1) to probe the influential factors of the PHRP and (2) to investigate the spatial heterogeneity of the determinants of PHRP in different urban districts. Accordingly, this paper is structured as follows. Section 2 presents a comprehensive in-depth literature review. The methodology conducted in this research is illustrated in detail in Section 3. Section 4 presents the empirical results, which is followed by Section 5, the discussion part and practical implication. Finally, the critical information is summarized in Section 6, as well as the limitations and prospects.

2. Literature Review

2.1. Private Housing Rental Market in China

Due to the fast-paced urbanization and exorbitant housing prices in China, the housing rental market has become increasingly important for meeting people's living demands, particularly in metropolises with large "floating populations". To meet such demand, many resources have been invested by the Chinese government in establishing the system and providing the supply of public rental housing [12]. However, the above efforts have not yielded the desired results. It is argued that public rental housing is a failure in China since the projects discriminated against the "floating population" and generated conflicts of interest between central and local governments [13]. Furthermore, due to the low profitability and deplorable rental condition, Chinese public rental housing is unappealing to private investors. Aside from financial barriers, the main issues with public rental housing are household registration and social security payments. To be eligible for public

rental housing, tenants must have a residence registration ("hukou") in the city and a certain number of years of social security contributions [13].

The barriers associated with Chinese public rental housing have increased the significance of private housing rental projects [13]. Although public rental housing has greatly benefited the citizens by providing lower rents than private rental housing, the current Chinese public rental housing system only considers the registered low-income public groups while ignoring the needs of the middle-income population and nonlocal citizens due to limited land and financial resources [14,15]. For the time being, these people cannot afford private housing property, and they are unable to participate in the city's public rental housing system due to insufficient social security contributions and "hukou". These significant impediments have contributed to the rising demand for private rental housing in Chinese cities.

Currently, research on the private housing rental market in China is primarily focused on informal markets, such as the renting basement living and urban villages [16–18]. The rise in demand for basement living in Beijing was mainly due to the unaffordability of private housing property and the inconvenient location of most public rental housing [17]. The low cost of renting in urban villages attracts many low-income residents [18]. Aside from the low PHRP, the restrictions of "hukou" also contribute to the aforementioned informal market. In general, current research mainly focused on the informal market and only considered low-income tenants, while the private housing rental market as a whole also includes many middle-income tenants whose preferences have not drawn enough attention.

2.2. Factors That Influence the PHRP

The affordability of middle-income tenants to the private housing rental market largely depends on the PHRP, which is affected by macro-level and micro-level impact factors. Population [19], household [20], urban economic development [20], and the livability of a community [21] are all impacting elements at the macro-level. However, there is also a lag impact of the macro-level influencing factors. Such impact cannot be exerted directly on PHRP in the short term. Under this context, the micro-level influential factors play a more significant role [22].

Three widely accepted theories—the Hedonic Price Theory; Bid Rent Theory and Henry George Theorem—are used to explain PHRP at the micro-level. (1) Hedonic Price Theory, which was extensively employed in the study of housing prices and PHRP, identified the inherent characteristics of housing [23,24]. The Hedonic Price Theory proposed that a commodity was made up of several attributes. In terms of residential buildings, the characteristics were the architectural structure, including area, floor, orientation, etc. The commodity's price was the comprehensive reflection and expression of all these characteristics. A commodity's prices will fluctuate in line with any changes to its properties. (2) The Bid Rent Theory served as the fundamental framework for analyzing location selection and its evolutionary logic [25]. The highest rent is that which a land user—resident or business—is willing to pay to compete for a plot of urban land (a specific location). A tenant could choose to pay a higher rent amount to be near limited educational and medical resources [26]. (3) The Henry George Theorem was one of the major theoretical explanations for disparities between neighborhoods. The term "neighborhood" was a spatial concept that referred to the spatial scope of the adjacent land. Schools, hospitals as well as parks were classified as quasi-public goods by Henry George Theorem, and because such goods form a local spatial pattern under the aggregation of cities, they were also known as local public goods. Residential land costs were relatively high in the area of strong public goods agglomeration.

Grounded on the aforementioned theories, this study concludes three categories of micro-level influential factors on PHRP, including architecture structure, traffic condition, and neighborhood environment. (1) Architectural structure refers to the inherent attribution of the residential building. Specifically, the attribute includes the floor area of the residential

unit [22], the number of bedrooms [27], the orientation of the living room or master bedroom [28], the floor level [29], and the parking space [30]. Together, these aspects jointly influence the prices of private rental housing to a certain extent. In Chinese culture, the south orientation of the living room or master bedroom is much more attractive to the tenants [28], because a south-orientated room can receive more sunlight throughout the day [31]. (2) Traffic condition refers to the transportation convenience and accessibility of the site. The traffic condition is one of the dominant determinants when selecting whether to buy or rent housing. The PHRP is significantly influenced by the distance between the residential building and the nearest public transportation hub [19]. Especially in high-density cities, living close to a metro station and bus stop are of great priority for working citizens since it helps to considerably cut down on their commuting time [5,32]. (3) The accessibility of the closest services and amenities, such as school, restaurant, and hospital, is defined as the neighborhood environment. The connection between the local environment and PHRP has been the subject of numerous research projects. Residents preferred living in a place that is close to primary and middle schools, universities [33], restaurants [34], shopping centers [35], parks [36], hospitals [37], banks [38] and CBDs [39]. Following a review of the literature on micro-level PHRP, a theoretical framework with three categories and 14 factors was constructed, as shown in Table 1.

Table 1. Factors that influence rental housing prices.

Category	Factors	Definition	References
Architectural structure	Area	The construction floor area of the residential unit	[22]
	Bedroom	Number of bedrooms in a residential unit	[27]
	Orientation	The orientation of the living room or master bedroom	[28]
	Floor Level	The level of the floor	[29]
	Parking	Whether the place has parking spots or not	[30]
Traffic condition	Subway	Distance to the nearest metro station	[5]
	Bus	Distance to the nearest bus stop	[32]
Neighborhood environment	School	Distance to the nearest school	[33]
	Hospital	Distance to the nearest hospital	[37]
	Bank	Distance to the nearest bank	[38]
	Restaurant	Distance to the nearest restaurant	[34]
	Shopping center	Distance to the nearest shopping center	[35]
	Park	Distance to the nearest park	[36]
	CBD	Distance to the nearest central business district	[39]

2.3. Methods for Investigating the Determinants of the Rental Housing Prices

Many academics have dedicated themselves to conducting in-depth research on how PHRP is formed by the influencing factors. There are mainly four methods: (1) Hedonic Price Method (HPM); (2) Geographical Weighted Regression (GWR); (3) Semiparametric Geographical Weighted Regression (SGWR); and (4) Multiscale Geographically Weighted Regression (MGWR). The advantages and disadvantages of these methods are summarized in Table 2.

Table 2. Methods for identifying factors that influence private housing rental prices.

Method	Advantage	Disadvantage
HPM	Calculate a large number of data to obtain an intuitive economic sense	Ignore the spatial heterogeneity
GWR	Deal with spatial heterogeneity	Cannot solve the scale difference of spatial heterogeneity
SGWR	Solve the scale difference of spatial heterogeneity	Cannot distinguish which variables are local and global
MGWR	Subdivision of global and local variables	Not revealed yet

The method of HPM is most frequently applied in studying housing prices and PHRP, depicting the functional relationship between various attributes and PHRP [24]. However, HPM does not provide insight into spatial heterogeneity, and the result can only reflect the status quo of the entire region [40]. It is argued that the result of HPM may lead to an unstable result because it cannot solve spatial heterogeneity to some extent [41,42]. Given the importance of spatial heterogeneity in residential buildings, GWR is used to probe the influential factors of PHRP [43]. GWR considered the spatial non-stationarity between variables, which improved the resolution of heterogeneity issues. However, GWR does not consider the scale difference of spatial heterogeneity [44]. To some extent, SGWR can solve the global and local scale problems, but it has an accuracy problem because the scale cannot be further classified. To deal with the above disadvantages, Fotheringham et al. (2017) developed the MGWR method, which remedies the limitations of SGWR [45,46]. The residential unit can be viewed as a special commodity with spatial heterogeneity at various scales. Based on the above, the MGWR model is the most accurate method for PHRP studies by providing the analysis of spatial patterns considering the regional difference.

3. Methodology

A methodology with four steps was designed in this study to identify the determinants of PHRP and their attributes on the aspect of spatial heterogeneity. Figure 1 depicts an overview of the entire methodology design. Firstly, a comprehensive literature review was used to develop a theoretical framework of influential factors based on three theories (Hedonic Price Theory, Bid Rent Theory, and Henry George Theorem). The second step was to collect data on PHRP and the influential factors, crawling from "Lianjia" and "58.com" using Python 3.8.0. The raw data were then processed in the third step through data cleaning (linear regression), data selection (stratified sampling), and data transfer (API conversion). In the last step, MGWR analysis was performed to identify the determinants of PHRP and their spatial heterogeneity.

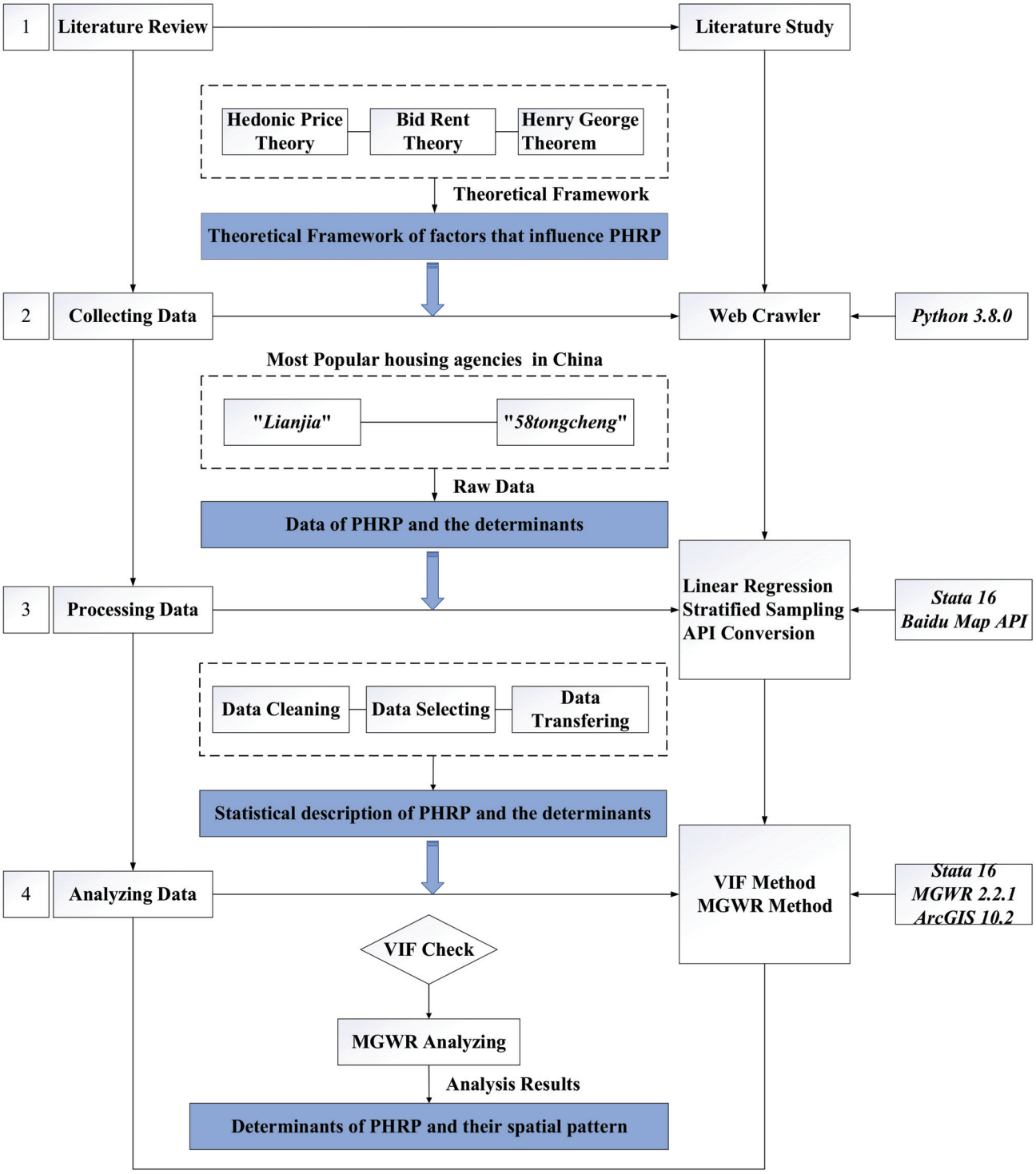

Figure 1. Methodology design.

3.1. Study Area

Being well-known as a high-density mountain city in China, Chongqing has a unique natural topography. The complex terrain variety and limited construction land formed a high-density mountain city landscape [47]. As the industrial and economic center of southwest cities in China, Chongqing has made remarkable achievements in the private housing rental market. The number of rental housing units has reached 73,000 by 2021, accounting for 23% of the total number of housing in the whole city [1]. Along with rapid urbanization, a prominent population agglomeration effect has been revealed. Prosperous urbanization

has created increasing employment opportunities and attracted a new population. The number of floating inhabitants in central urban districts reached 10.3 million in 2020, which makes it one of the largest floating population gatherings in Chinese cities [11]. College students and migrant workers are the main floating population, and they are the target groups of private housing rental tenants.

In this study, eight central urban districts in Chongqing were selected as the study area for data collecting, considering the density of tenants and the data availability [1]. Figure 2 illustrates the location of the study area from three perspectives: the location of Chongqing; the location of the central urban districts in Chongqing, and the location of the four functional zones in central urban districts. As shown in Figure 2, the Jiangbei district is a commercial zone, with an average daily flow of 400,000 people in the Guanyinqiao. The Shapingba district is naturally the educational zone, which is the concentration of many schools and educational institutions. The Yuzhong district is a financial zone, with finance as its first pillar industry. The Yubei district is a typical industrial zone, with secondary industries such as automobile manufacturing and electronic equipment manufacturing flourishing.

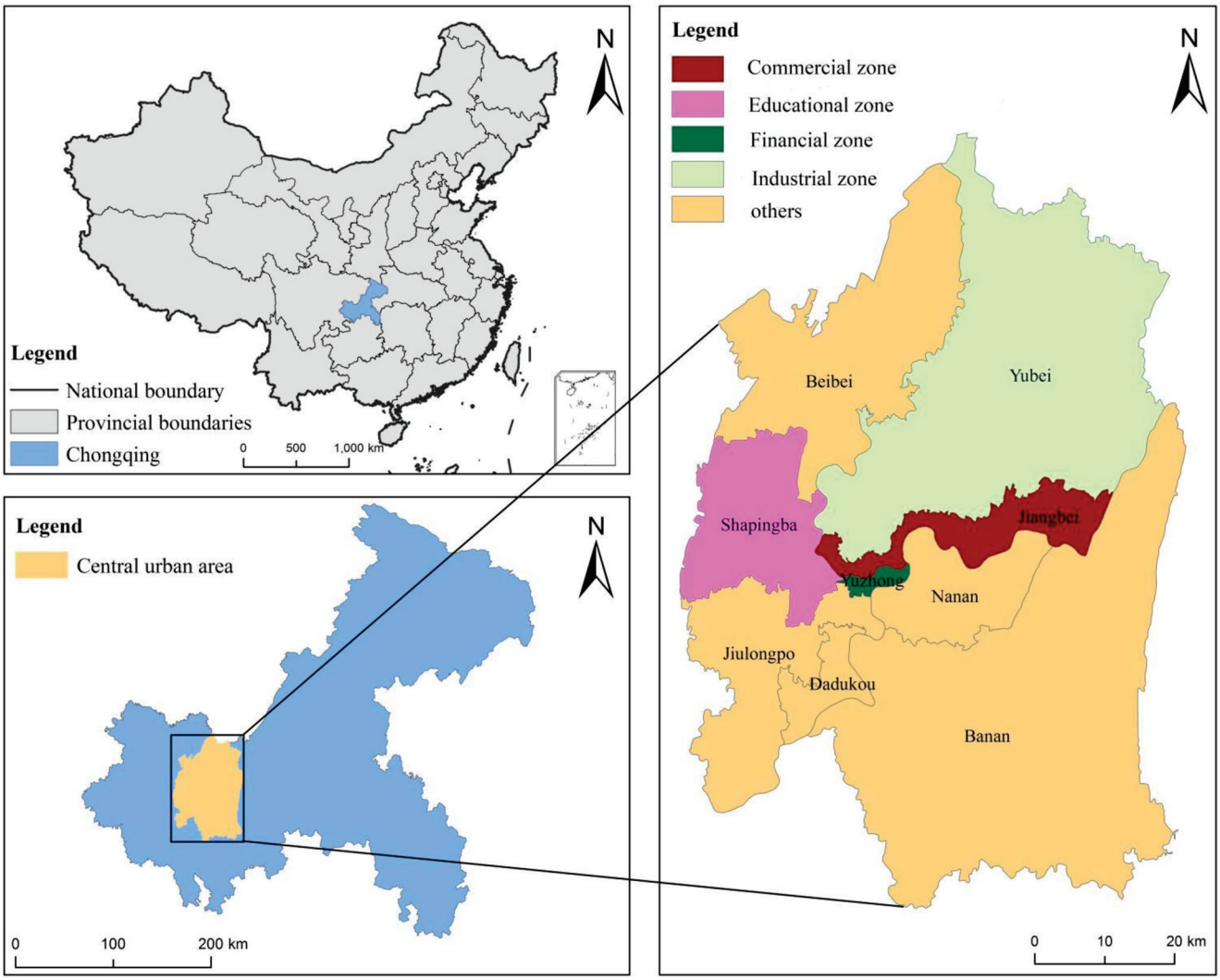

Figure 2. The map of the study area and four urban functional zones in Chongqing.

3.2. The MGWR Model of PHRP

MGWR defines bandwidths of different factors differently, which can reflect variations in the action scales of different variables [45]. Assume that there were n housings, for these housings $i \in \{1, 2, \ldots, n\}$ at location (u_i, v_i). The linear regression model was described by Equation (1):

$$y_i = \sum_{j=0}^{m} \beta_{bwj}(u_i, v_i)x_{ij} + \varepsilon_i \quad (1)$$

where $j \in \{1, 2, \ldots, n\}$ represented the factors that influenced PHRP; x_{ij} was the *jth* influencing factor of the housing I, bwj in β_{bwj} represented the bandwidth used for calibration of the *jth* conditional relationship, $\beta_{bwj}(u_i, v_i)$ was the *jth* factor that influenced PHRP coefficient, ε_i was the error term, and y_i was PHRP.

To calibrate the MGWR model, a back-fitting algorithm was used. The MGWR model can express as generalized additive models (GAMs). According to the logic of GAMs, $\beta_{bwj}x_i$ in MGWR can be represented as the *jth* additive term f_j. The GAMs model was given by Equation (2):

$$y = \sum_{j=0}^{m} f_j + \varepsilon \quad (2)$$

All the additive term f_j should be initialized, and an initial set of estimates y was obtained; subsequently, residuals were calculated. These residuals plus f_0 then regressed on x_0, and an optimal bandwidth bw_0 was obtained. f_0 was updated using a set of estimates of the relationship between y and x_0. The process moved on using the updated f_0 plus f_1 and regressed on x_1 to obtain bw_1. The method was continuous until the last x_m was estimated. The interactions continued until the convergence was reached. The proportional change in the residual sum of squares (RSS) is deemed as a termination criterion. The classical residual sum of squares (RSS) variation ratio was used as the convergence criterion, which was described by Equation (3):

$$SOC_{RSS} = \frac{|RSS_{new} - RSS_{old}|}{RSS_{new}} \quad (3)$$

where SOC_{RSS} represented the proportional change in the residual sum of squares (RSS), RSS_{new} was the residual sum of squares in the present step, and RSS_{old} was the residual sum of squares in the previous step.

3.3. Data Collecting and Processing

Python 3.8.0 was adopted to crawl the data of the factors that influence the PHRP in Chongqing in January 2021. Data from eight central urban districts of Chongqing were collected from two popular rental platforms—Lianjia.com and 58.com [1] (accessed on 15 January 2021). A total of 36,520 raw data from 1935 communities was obtained. Table 3 displays the information (category, unit, and type) of the crawled data for 15 factors that influence PHRP. Continuous variables were valued by their real value; dummy variables were categorized as qualified according to the literature and reality. There are three dummy variables including "Orientation", "Floor level" and "Parking". Specifically, the factor "Orientation" was numbered as "1" (facing south) and "0" (other orientations); Codes "0, 1, 2, 3" were used for qualifying the "Floor level" from low, multi, and middle to high level. The factor of "Parking" was valued as "1" (with parking space) and "0" (without parking space).

Table 3. The information on the factors that influence private housing rental prices.

Category	Variables	Units	Variable Types
Dependent variable	Rent	yuan/month·m^2	C
Architectural structure	Area	m^2	C
	Bedroom	/	C
	Orientation	/	D
	Floor Level	/	D
	Parking	/	D
Traffic condition	Subway	Km	C
	Bus	Km	C
Neighborhood environment	School	Km	C
	Hospital	Km	C
	Bank	Km	C
	Restaurant	Km	C
	Shopping Center	Km	C
	Park	Km	C
	CBD	Km	C

Note: "C" is regarded as continuous variables and "D" is regarded as dummy variables.

The raw data were then processed through three steps: data cleaning, selecting, and transferring. First, a general linear regression was performed to eliminate the outliners by using Stata 16 software. As a result, 29,025 samples were retained as cleaned data. Second, the method of stratified sampling was adopted to further select samples, through which samples from 1935 private housing rental communities were finally prepared. Third, the Baidu Map Application Programming Interface (API) was used for transferring the geocodes (from the open data of Baidu) of the stratified sampling communities to the information on their latitudes and longitudes.

The reliability of the processed data was tested before the operation of MGWR analysis. Table 4 shows the average PHRP of the eight intra-urban districts in Chongqing from 15–45 yuan/month·m^2. The range of the data included consists of the results published by China Real Estate Information (CREI)—China's leading real estate professional database, which contains the PHRP in the majority of cities, indicating the sufficient representativeness of the sample data to the actual situation [1].

Table 4. Statistics of private housing rental prices in eight central districts of Chongqing.

Districts	Available Communities	Minimum Rent (Yuan/m^2/Month)	Maximum Rent (Yuan/m^2/Month)	Average Rent (Yuan/m^2/Month)
Yuzhong	237	21.26	55	29.32
Jiangbei	364	20.93	44.62	27.97
Yubei	228	18.64	40.95	26.82
Nanan	205	16.67	37.57	24.74
Shapingba	198	17.36	31.86	23.13
Jiulongpo	240	18.18	28.57	22.82
Dadukou	211	17.54	24.73	22.20
Banan	252	15.91	22.05	17.43
Total	1935	15.91	44.62	24.30

3.4. Statistical Description

(1) Characteristics of the PHRP in Chongqing

Generally, the average monthly PHRP was relatively equal among the eight central urban districts of Chongqing, but the highest and lowest PHRP in each district differed significantly (Table 4). The average monthly unit private housing rental price was 24.30 CNY/month·m^2 in Chongqing's eight central urban districts. Among them, the

maximum value of the average monthly rent was 44.62 CNY/month·m^2, and the minimum value was 15.91 CNY/month·m^2.

Geographically speaking, PHRP in eight central urban districts of Chongqing decreased from north to south. Private housing with monthly unit PHRP higher than average rent in Chongqing is concentrated in Yuzhong, Yubei, Jiangbei, and Nanan, all of which are in northern Chongqing. This phenomenon appears consistent with the regional development of Chongqing since the high-tech industries, job opportunities, and production services are primarily concentrated in the north of Chongqing. In this sense, it is not surprising that PHRP in the Shapingba, Jiulongpo, Dadukou, and Banan districts in the south of Chongqing are lower than the average PHRP.

(2) Statistical description of the factors that influence the PHRP of Chongqing

Table 5 displays the attributes of the influential factors for PHRP in Chongqing based on the crawled raw data. In terms of architectural structure, the construction floor area of the residential unit ranges from 16 to 158 m^2, while the provided floor area is primarily concentrated between 52 and 160 m^2. The number of bedrooms ranges from one to five; among them, private rental housing with two to three bedrooms accounts for 72% of the total, while rental housings with five bedrooms are rare. The orientation of the living room and master bedroom facing south is nearly identical to that of the non-south. The floor level ranges from low, multi, and middle to high level and assigns values 1 to 4. The maximum distance of traffic conditions and neighborhood environment from the rental housing is 3.7 km, which may reflect tenants' maximum acceptance of the radius of access to these resources.

Table 5. Descriptive statistics of the factors.

	Variable	Mean	Min.	Max.
Architectural Structure	Bedroom	2.30	1	5
	Area	81.582	52	160
	Orientation	0.484	0	1
	Floor Level	2.115	1	4
	Parking	0.749	0	1
Traffic Condition	Subway	2.657	0.100	3.683
	Bus	1.167	0.300	2.572
Neighborhood Environment	School	2.462	0.110	3.330
	Hospital	2.592	0.700	3.732
	Bank	1.694	0.800	2.504
	Restaurant	2.957	0.100	3.172
	Shopping center	1.591	0.300	2.381
	Park	2.369	0.800	3.688
	CBD	1.592	0.300	2.362

4. Results of the MGWR Analysis

4.1. An MGWR Model for Analyzing the Determinants of PHRP in Chongqing

A multicollinearity test for the identified factors was conducted before establishing the MGWR model. Only the factors with non-multicollinearity (VIF < 10) were retained as the input variables for MGWR analysis [48]. The hypothesis of multicollinearity is not rejected for only two factors (Park and CBD), as their variance inflation factors (VIF) exceed the critical value of 10.

Engaging 12 non-collinear factors, the MGWR model first identified the influential factors of PHRP through regression analysis. Table 6 summarized the regression analysis results, revealing that eight factors—Area, Parking, Bus, Subway, School, Hospital, Restaurant, and Shopping—were identified as influential factors that significantly stimulus PHRP in Chongqing, while Bedroom, Orientation, Floor level, and Bank were identified as the non-influential factors. The criteria in MWGR for identifying the significant variables is

that all the p values of the independent variable meet the benchmark ($p < 0.05$). In this study, eight of the twelve factors indicate 100% of $p < 0.05$. There were 1936 p values for each factor.

Table 6. The regression analysis results of the MGWR analysis.

Category	Variable	Significant $p < 0.05$ (%)	Non-Significant $p > 0.05$ (%)
Architectural structure	Bedroom		15.71
	Floor Area	100.00	
	Direction		8.62
	Floor		12.49
	Parking	100.00	
Traffic condition	Bus	100.00	
	Subway	100.00	
Neighborhood environment	School	100.00	
	Hospital	100.00	
	Bank		19.30
	Restaurant	100.00	
	Shopping	100.00	

The MGWR model investigated in depth how these eight influential factors determine the PHRP. Table 7 depicts the coefficient description of the MGWR model, indicating the determinants effects of the influential factors on two aspects: direction and degree. The plus–minus sign of the Mean indicates whether the influential factors have a positive or negative impact on PHRP. Among the eight influential factors, only *Area* had a positive effect on PHRP. The net value of the Mean represents the influential degree of the factor on PHRP. The distance to the subway imposed the strongest impact on PHRP, increasing them by 0.074 yuan/m^2 per kilometer closer. Next to it, the distance to the nearest bus stop and school has the same effect on PHRP, rising by 0.037 yuan/m^2 when the distance is shortened by 1 km. Notably, a mean value of 0.009 indicated the weakest influential effect of the *area* on PHRP in Chongqing.

Table 7. The coefficient description of the MGWR model.

Category	Influential Factors	Mean	STD	Min.	Med.	Max.
Architectural structure	Area	0.009 *	0.271	0.002	0.009	0.017
	Parking	−0.017 *	0.053	−0.024	−0.018	−0.008
Traffic condition	Bus	−0.037 *	0.002	−0.074	−0.037	−0.017
	Subway	−0.074 *	0.002	−0.108	−0.074	−0.059
Neighborhood environment	School	−0.037 *	0.012	−0.061	−0.038	−0.048
	Hospital	−0.034	0.062	−0.038	−0.032	−0.010
	Restaurant	−0.028 *	0.086	−0.039	−0.028	−0.015
	Shopping	−0.052 *	0.000	−0.053	−0.052	−0.052

Note: "*" indicates an effect of the influential factor on private housing rental prices.

4.2. Analyzing the Spatial Heterogeneity of the Influential Factors of the PHRP

The spatial heterogeneity effects of the influential factors were further investigated using the MGWR analysis to analyze better and compare the spatial pattern of the influential factors. The spatial inhomogeneity and complexity of variables are referred to as spatial heterogeneity. Local and global influential factors are used to identify whether there is spatial heterogeneity in these factors. The calibration of local and global factors provides an optimized bandwidth that describes the spatial scale over which the processes being modeled vary [45]. The percentage of the bandwidth was applied as a rule in this study to categorize the influential factors into global and local groups for the spatial heterogeneity analysis. When the percentage of the bandwidth of the influential factors is less than 20%,

that indicates the factors as local influential factors. As shown in Table 8, five factors—Parking, Bus, Subway, School, and Shopping—were classified as the local influential factors considering their sample size at the level of less than 20% of the total.

Table 8. Optimal bandwidth for each influencing factor obtained from MGWR.

Category	Influential Factors	MGWR Bandwidth	Bandwidth as a Percentage of the Total Sample Size
Architectural structure	Area	1927	99.6%
	Parking	168	8.7% *
Traffic condition	Bus	265	13.7% *
	Subway	253	13.1% *
Neighborhood environment	School	185	9.6% *
	Hospital	1572	81.2%
	Restaurant	1798	92.9%
	Shopping	365	18.9% *

Note: "*" indicates the local influential factors of private housing rental prices.

Figure 3 illustrates the spatial heterogeneity of five local influential factors according to the spatial distribution of the coefficients: Parking, Bus, Subway, School, and Shopping. As shown in Figure 3b,c, the distribution of traffic condition (Bus and Subway) was highly uneven. Subway had the greatest influence on PHRP in the Yubei district (industrial zone), which was followed by the Yuzhong district (financial zone). The School coefficient had been found more important to tenants living in the Shapingba district, where educational resources were abundant.

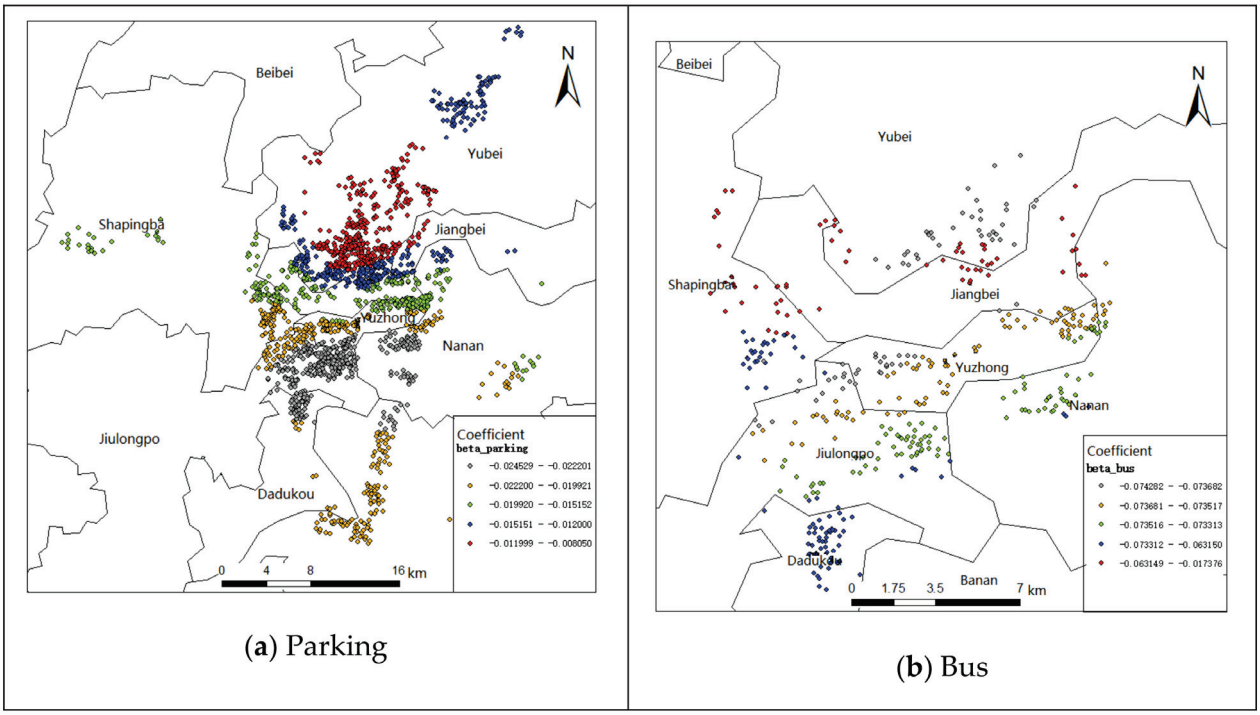

Figure 3. *Cont.*

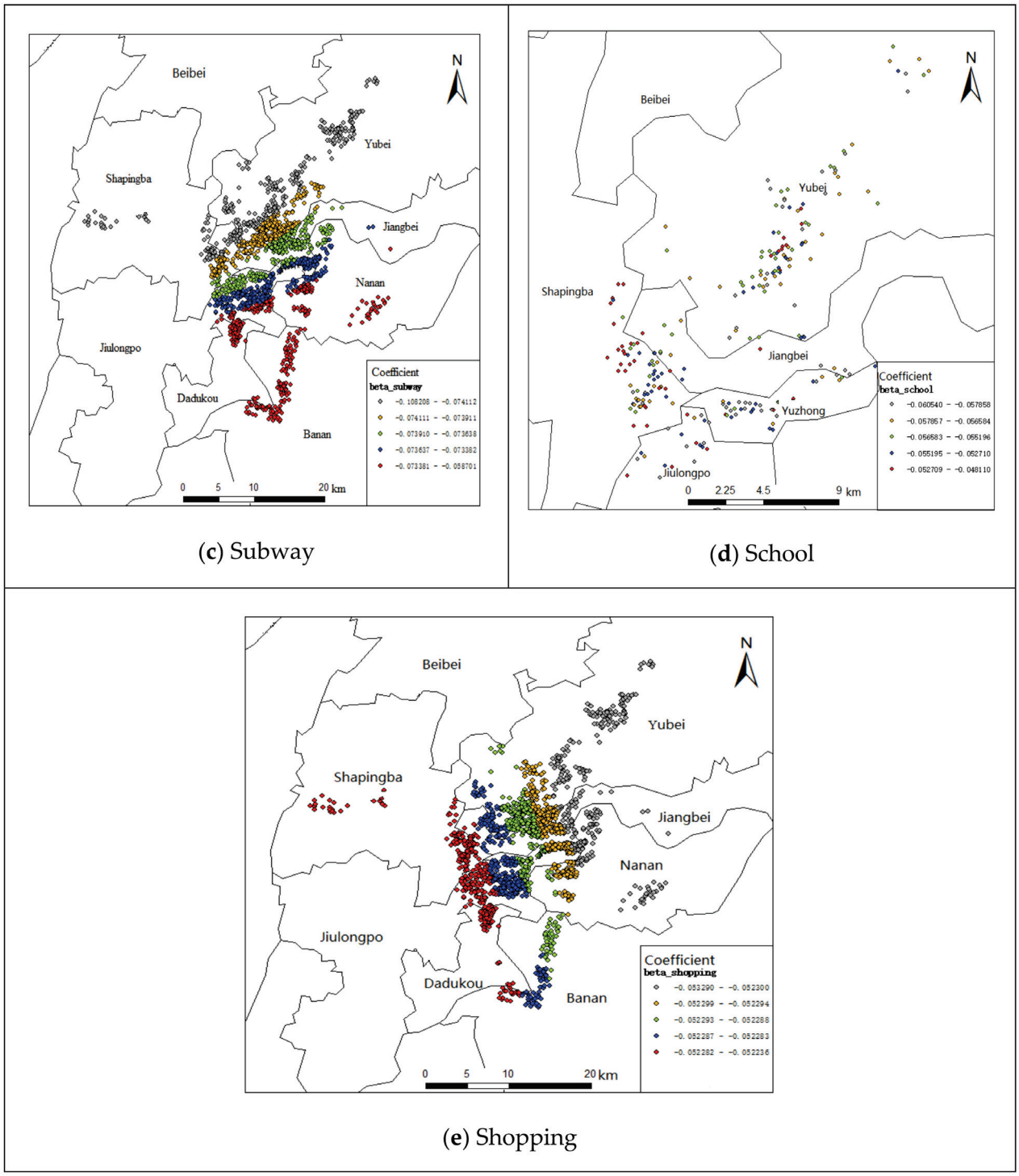

Figure 3. Spatial distribution of the local influential factors for the private housing rental prices in eight central urban districts of Chongqing.

Three globally influential factors are also represented in Figure 4. As shown in Figure 4a–c, the Area, Hospital, and Restaurant coefficients represent spatial homogeneity. The three influential factors have the same degree of impact on PHRP in the eight central urban districts of Chongqing, indicating no spatial heterogeneity.

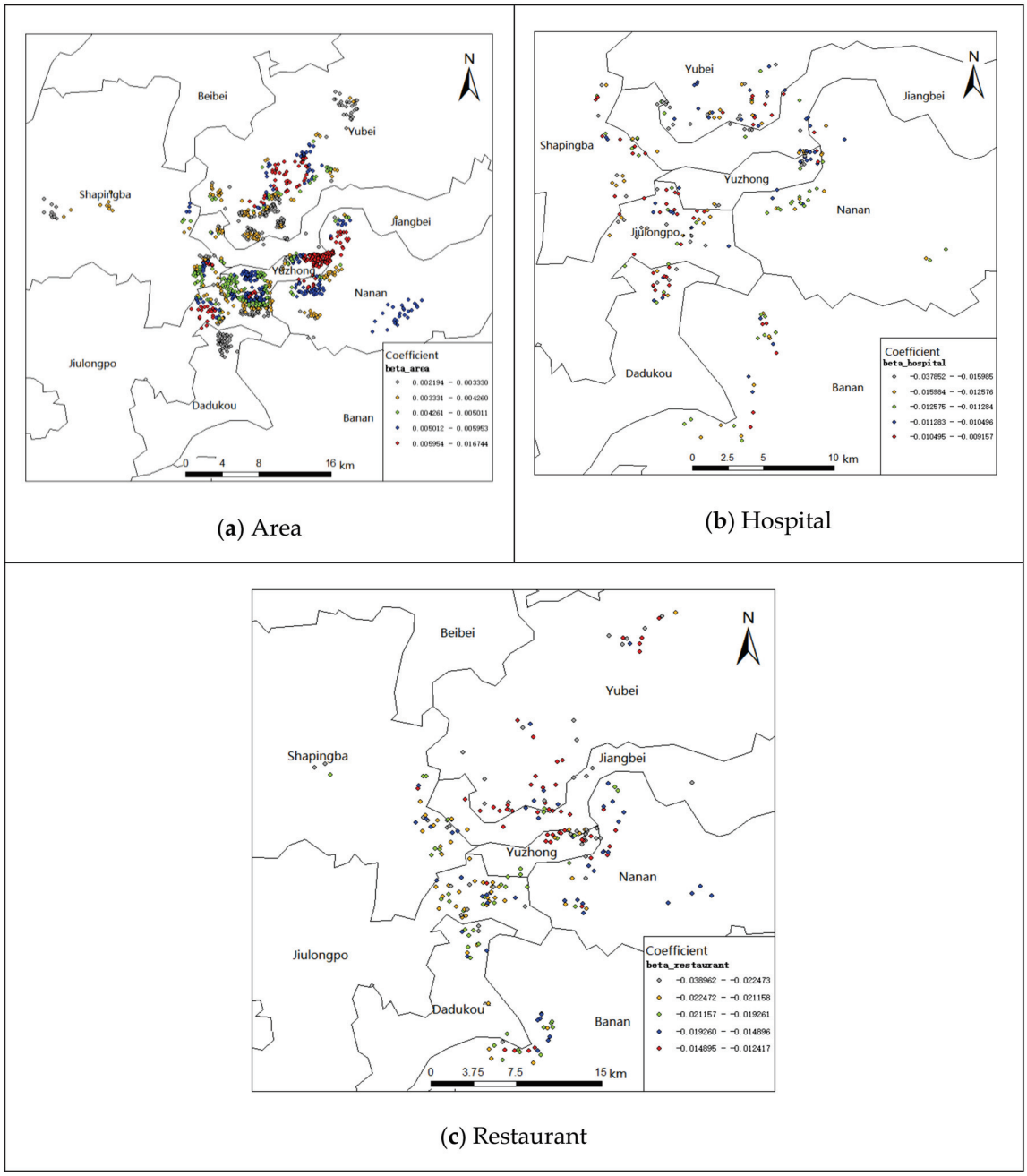

Figure 4. Spatial distribution of the global influential factors for the private housing rental prices in eight central urban districts of Chongqing.

4.3. Robustness Test

To ensure the accuracy and reliability of the MGWR analysis results, another analysis for the determinants of PHRP was performed by the GWR model as a robustness test. A comparison of the results of GWR and MGWR was conducted. First, the OLS analysis is performed to filter variables for further analysis. The results showed that the VIF values of the 12/14 factors were less than 10, indicating that these 12 variables had no multicollinearities. Then, the GWR analysis was followed for the 12 factors. Table 9 describes the significance of eight variables in influencing the PHRP, which is completely consistent with the results of MGWR (Table 6 in the paper). Third, the GWR analysis also showed the coefficients of each variable to the PHRP (see Table 10). In comparing with the results of MGWR, the influence of these critical factors on the PHRP was in the same direction in the GWR analysis (Mean value), although the absolute values of the

coefficients were a bit different. In general, the comparison of the results by GWR and MGWR confirmed the accuracy of identifying the critical determinants and their impacts on PHRP.

Table 9. The regression analysis results of the GWR.

Category	Variable	Significant $p < 0.05$ (%)	Non-Significant $p < 0.05$ (%)
Architectural structure	Bedroom		88.40
	Area	100.00	
	Direction		94.3
	Floor Level		91.6
	Parking	100.00	
Traffic condition	Bus	100.00	
	Subway	100.00	
Neighborhood environment	School	100.00	
	Hospital	100.00	
	Bank		99.9
	Restaurant	100.00	
	Shopping	100.00	

Table 10. The coefficient description of the GWR model.

Category	Influential Factors	Mean	STD	Min.	Med.	Max.
Architectural structure	Area	0.004	0.142	0.002	0.004	0.006
	Parking	−0.016	0.081	−0.032	−0.019	−0.016
Traffic condition	Bus	−0.040	0.064	−0.056	−0.041	−0.038
	Subway	−0.088	0.073	−0.125	−0.085	−0.079
Neighborhood environment	School	−0.043	0.065	−0.058	−0.046	−0.031
	Hospital	−0.037	0.072	−0.061	−0.039	−0.026
	Restaurant	−0.020	0.065	−0.037	−0.020	−0.019
	Shopping	−0.079	0.033	−0.146	−0.078	−0.067

As for the accuracy of the models themselves, the model indexes are given in Table 11. The R2 of MGWR is 0.708 higher than that of GWR, reflecting the higher goodness of fit for MGWR. Additionally, the MGWR model describes the fact of data better than the GWR model with smaller values on the Akaike information criterion (AICc), the number of effective parameters (ENP_j), and residual sum of squares (SSE)., indicating the superiority of MGWR.

Table 11. Comparison of the model indexes of MGWR model and GWR.

Model Index	MGWR	GWR
R^2	0.708	0.635
AICc	4838.829	5128.535
ENP_j	179.785	213.375
SSE	1145.749	1581.171

Given the robustness test above, the results of MGWR analysis are considered as of high validity in this paper.

5. Interpretation and Discussion

5.1. The Determinants of PHRP in Chongqing

Generally, the PHRP is determined by *architectural structure*, *traffic condition*, and neighborhood *environment*. In Chongqing, the PHRP revealed a strong sensitivity to the

Traffic Condition factors in terms of distance to the subway and bus station, while Shopping and Hospital—indicators of the *Neighborhood Environment*—also imposed a significant impact on PHRP.

(1) Transportation facilities add significant value to private housing properties in densely populated cities. This study indicated the strong influence of the distance to the subway and bus stations on PHRP, supporting a common argument that transportation facilities add value to the housing properties in the case of a high-density city. Given the fact that Chongqing is a city with high-pressure traffic, citizens prefer to take public transportation rather than drive. Public transportation's superiority in the aspects of time and cost saving makes the distance to the subway and bus station the most potent determinant in driving the rising of PHRP.

(2) The convenient neighborhood environment increases the PHRP in supplying scarce social resources. The proximity to the shopping center raises the PHRP of private housing in Chongqing, which is a finding that consists of previous research [33,34,37]. The fundamental reason for this is that the comprehensive function of the shopping center conveniences the life of the residents around by meeting their basic daily needs and enriching leisure time. People prefer to live in places where they can meet basic daily needs, and areas near shopping centers are ideal for meeting daily demands, so tenants prefer to pay higher rent. Currently, most shopping centers in Chongqing encompass the services of shopping, catering, and amusement, attracting a large group of young and dynamic citizens. In that sense, young tenants prefer to live near a shopping center, making a shopping center one of their top priorities when looking for temporary accommodation. Similarly, it is reasonable that a living community near a hospital benefits from medical services, contributing to the higher PHRP. Usually, those who rent near the hospital are patients and their accompanying family members, so living near the hospital can satisfy tenants' demand for medical resources.

Moreover, it is worth noticing that some commonly recognized *architectural* factors in the existing literature did not have a significant impact on PHRP in Chongqing. Floor level and housing orientation, two significant elements of *Architectural Structure*, had almost no absolute effect on PHRP.

There is no obvious relationship between the floor level and PHRP in Chongqing. A common misconception about PHRP is that rent climbs with the height of the floor level [22], which, however, is not applicable in Chongqing. The reason behind this unusual occurrence is that the discrepancy in elevation in Chongqing offsets the benefits of living on higher floors with better privacy, which is a common preference of tenants in plain cities [29].

The orientation of the residential building had almost no effect on its PHRP in the mountainous city, even though the orientation of buildings had historically played a significant role in Chinese traditional culture. Traditionally, the south-facing nature of the master room is the most respected direction by Chinese people not only because of the longest daylight hours and good ventilation but also because of its good morale in traditional Chinese culture geomancy—Fengshui [38]. However, tenants' preference for south-facing housing was not obvious in Chongqing due to the objective limitation of geography. On the design aspect, the south orientation is not easy to be always ensured when the architectural design needs to be settled while coordinating with the complex mountainous geographic features of Chongqing. On the occupant aspect, the north-facing and south-facing housing developments in plain Chinese cities enjoy the coolest indoor temperature in summer due to favorable natural wind ventilation and the best natural lighting in winter. This practical advantage of the south orientation, however, cannot be achieved due to the blockage of the mountainous terrain in Chongqing. As previously stated, the PHRP of Chongqing reflect an insensitivity to the housing orientation, which contrasts with the situation in most plain Chinese cities.

5.2. Spatial Pattern of the PHRP's Determinants in Chongqing

A distinct spatial pattern of the determinants of PHRP has been revealed from MGWR analysis results, echoing the polycentric geographic feature of Chongqing city. Strong spatial heterogeneity effects were observed regarding the influential factors of Traffic, Neighborhood, and Architectural, whereas other influential factors of Neighborhood and Architectural indicated spatial homogeneity in forming PHRP (as shown in Table 12).

Table 12. Spatial heterogeneity of the influential factors in different functional zones.

Category	Influential Factors	Educational Zone	Industrial Zone	Commercial Zone	Financial Zone
Traffic condition	Subway		***		***
	Bus		***		***
Neighborhood environment	School	***			
	Shopping			***	
Architectural structure	Parking		***		***

Note: "***" indicates a strong spatial heterogeneity effect of the influential factor.

(1) Variability of influential factors in different functional zones of Chongqing

1) Spatial heterogeneity of the Traffic condition factors

In depicting the rental prices of Chongqing's private housing, Subway and Bus revealed strong spatial heterogeneity, playing more dominant roles in both the industrial zone (Yubei district) and financial zone (Yuzhong district) than in the other districts. In other words, Subway and Bus affect PHRP more significantly in the industrial zone and financial zone in contrast with other zones, which is consistent with the existing academic viewpoint [49]. Naturally, the industrial and financial zones aggregate a large number of migrant people who are well-educated with decent white-collar jobs. These newcomers generally choose to rent housing in the district where they work; even if the rental location is far from their workplace, they alternatively choose a location closer to public transportation for ease of commuting.

2) Spatial heterogeneity of the Neighborhood environment factors

The critical neighborhood environment factors (school and shopping) exhibit significant spatial heterogeneity in affecting the PHRP of Chongqing. This finding is consistent with the viewpoint of Henry George Theorem, which contends that quasi-public resources bring benefits to the residents and raise the local housing prices.

Distance to school showed a significant influence on PHRP in the educational zone of Chongqing. In China, it is a common phenomenon that zones with excellent educational resources attract families with children who rent close to schools, resulting in the exorbitant prices of housing around. In particular, the vast demands for school district housings lead to higher PHRP in the educational zone.

The Shopping of the Neighborhood environment reveals significant spatial heterogeneity in a commercial zone that is consistent with a previous study [38]. Compared with the other districts in Chongqing, the better shopping options and the more entertainment activities in the commercial zone (Jiangbei district) attract the new generations who prefer fun. In other words, living closer to the commercial zone is more attractive to the younger generation of tenants, driving the rents higher than in other districts.

3) Spatial heterogeneity of the Architectural Structure factors

Parking is an architectural structure that represents greater spatial heterogeneity in the industrial zone (Yubei district) and financial zone (Yuzhong district) of Chongqing, which is consistent with the previous study [30]. For most young white-collar workers in the industrial zone and financial zone, owning a private car has become a common occurrence. Considering the parking problem, most car owners prefer to live in a community with a parking space.

(2) Spatial homogeneity of influential factors in different functional zones of Chongqing

The Hospital and Restaurant factors of a Neighborhood environment exhibit non-spatial heterogeneity in this study. The hospital distributes its influence on PHRP evenly across eight districts of Chongqing, which appears to violate the law of the Henry George Theorem. This unusual phenomenon makes sense when viewed through the lens of traditional Chinese culture. Most Chinese are reluctant to live near hospitals; in terms of Chinese geomancy, Fengshui, the hospital symbolizes unhealthy whether for the young or the elderly. The Restaurant factor does not show spatial heterogeneity in affecting PHRP. Restaurant is not a scarce resource in the same way that educational resources are, and the commercial value of the housing near Restaurants is not high [34,37]. Similarly, the prevalence of Restaurants' distribution in Chongqing results in non-spatial heterogeneity in their impact on surrounding rent.

Architectural structures represent spatial homogeneity in Chongqing. Regardless of the location, it is a general truth that PHRP increases as the area expands. When all the other factors influencing PHRP remain unchanged, PHRP will be determined by the floor area of housing [38].

5.3. Practical Implications

(1) The local government of Chongqing should address the most concerned needs of the floating population by providing better public services in transportation and health care. First, it is suggested that the local government improves traffic accessibility by scientifically improving the coverage of the subway and bus lines. This study emphasized tenants' top priorities for proximity to subway and bus stations, reflecting the vital demand for public transportation in high-density cities. The "15-min walk of life circle" should be formed by scientifically planning public transportation facilities stations in close collaboration with the urban planning and transportation departments. Second, we recommend that the local government make greater efforts to provide sufficient medical services, according to the discovery of spatial homogeneity of hospitals across all districts/zones of the city. It reflects how medical services are commonly needed by all citizens, regardless of where they live or whether they are permanent or temporary residents. The vital impact of the availability of medical services on PHRP necessitates an equitable governmental planning strategy for distributing medical resources to ensure the city's housing rental market develops in a balanced manner.

(2) The housing rental agencies are suggested to obtain the housing by fully considering the diverse preferences of the tenants from different function zones. The majority of housing rental agencies in China are private companies that have their strategies to develop or collect housing from the market. They, however, do not regard the function of the zone as the most critical consideration for strategy making. In other words, spatial heterogeneity is not well understood and exploited to maximize their profits. This study recommends those housing rental agencies collect more rental properties near the schools in the educational zone and obtain more rental housing close to shopping centers in the commercial zone. This strategy will benefit both the housing rental agencies and the tenants by improving the investment value and meeting specific accommodating demands, respectively.

(3) Tenants in Chongqing, especially newcomers, are suggested to pay more attention to the transportation and service facilities nearby rather than the floor level and orientation of the rooms. This seemingly perverse suggestion is derived from the discovery that south

orientation and higher floor level do not bring the expected benefits of more sunlight and better privacy due to its unique terrain and climate. In comparison to the tenants' top demands on the architectural attributes in plain city, it is more important for people in mountain cities to pay higher rents to obtain better access to transportation and public service.

6. Conclusions

The private housing rental market has been developing quickly and has demonstrated its outstanding contribution, coping with the public housing, in improving affordability for residents in China. Affordable private rental housing has alleviated housing issues for some newcomers in the metropolis. This phenomenon has attracted increasing attention in the housing rental field [22]. However, few kinds of research comprehensively revealed the forming rules of the PHRP and the spatial pattern of PHRP determinants. Moreover, due to the previous lack of open data sources, an in-depth study on such issues is very insufficient. The purpose of this study is to provide comprehensive research on PHRP and the spatial pattern of its determinant factors based on real-time big data in a typical high-density mountainous Chinese city.

Python 3.8.0 was adopted to crawl the data of the factors that influence PHRP in Chongqing in January 2021. The data from eight central urban districts of Chongqing were gathered from two most popular rental platforms—Lianjia.com and 58.com. An MGWR model was used for analyzing the determinants of PHRP and the influential factors' spatial heterogeneity. The private housing rental market is shaped by architectural structure, traffic conditions, and neighborhood environment. Three significant forming rules of PHRP were revealed: (1) The closer distance to the bus and metro station positively raises the PHRP, verifying the argument that transportation facilities add great value to housing in densely populated cities. (2) The convenient neighborhood environment increases PHRP in supplying scarce social resources, as evidenced by the factors of school and shopping center. (3) The architectural structure, such as floor level and orientation, does not show obvious influential effects in high-density mountain cities as it does in plain cities.

Based on this, the MGWR analysis further investigated how the influence of the determinants on PHRP is differentiated across functional zones. Being identified as the local factors, the distance to schools and shopping centers presented a significant influence on the PHRP in the educational and commercial zone. The Subway and Bus factors affect traffic conditions and also showed strong spatial heterogeneity, playing a more dominating role in the industrial and financial zones. The hospitals and restaurants of the neighborhood environment were clustered into a global factors group, indicating non-spatial heterogeneity in influencing PHRP. Accordingly, practical recommendations are provided for local governments, rental agencies, and tenants to meet market demands.

Methodologically, a deepening research process provides valuable and reliable findings based on a solid theoretical framework, detailed data from extensive samples, and an MGWR analysis revealing the spatial variance. Compared with existing literature, this study investigates the determinants of PHRP by fully considering the heterogeneity across regions within a city. This study demonstrates its authenticity by engaging real-time big data, which eliminates the limitation of many previous studies with small samples and surveyed data.

Theoretically, this study contributes to uncovering the spatial pattern of the determinants of PHRP in high-density population cities. In addition, a combined application of the theories, Hedonic Price Theory, Bid Rent Theory, and Henry George Theory, extends the pool for identifying the influencing factor of the PHRP. Practically, this study inspires both the supply and demand sides. For the supply side, it helps the housing rental agencies obtain insight into the primary preferences of tenants, and it assists them in developing housing properties by fully considering the spatial characteristics of PHRP's determinants. The local government is suggested to increase the coverage of subway and bus lines in its municipal plans. For the demand side, the floating population is reminded to pay

more attention to transportation and service facilities rather than the floor level and the orientation when renting in highly dense populated mountainous cities. A comprehensive examination of the determinants and their spatial patterns in the study not only bridges the literature weakness of how PHRP is formed in high-dense populated cities but also inspires future housing price studies in the emerging metropolis.

This paper does, however, have limitations. First, due to the short period of the data, the time factor (low and high seasons) may have a certain degree of impact on PHRP. Data with a long-time span are unavailable due to the rapid update of data on Lianjia.com (accessed on 15 January 2021) and 58.com (accessed on 15 January 2021). Attempts could be made in the future to analyze the influential factors of rent using data with a long-time horizon. Second, macro-level influences that were not considered in this study may have an impact on rent. This study focuses on the impact of micro-level data on rent while ignoring the macro-level impact on rent. Future research can look at the factors that influence rent at both macro- and micro-levels.

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Notes

[1] Available online: https://cq.lianjia.com/zufang/rs/; http://cq.58.com/chuzu/ (accessed on 1 October 2022).

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Effect of Housing Support Programs on Residential Satisfaction and the Housing Cost Burden: Analysis of the Effect of Housing Support Programs in Korea Based on Household Attributes

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Abstract: Korea is implementing housing support programs such as public rental housing and housing allowances to improve the housing welfare of low-income households. In this study, we empirically analyzed the effects of the public rental housing program and the housing allowance program on residential satisfaction and the housing cost burden of policy beneficiaries. In accordance with household attributes, we analyzed how the status of using these programs affected each group's residential satisfaction and housing cost burden. We used the data from the 2020 Korea Housing Survey conducted by the Ministry of Land, Infrastructure and Transport. We examined the housing support programs' effects on each of the following household groups: all households, one-person households, households of newlywed couples, young adult households, and households of the elderly. The status of residing in public rental housing positively affected the residential satisfaction among all households, one-person households, and households of the elderly. It reduced the housing cost burden for all household types. The status of receiving the housing allowance negatively affected the residential satisfaction for all households and increased the housing cost burden for young adult households. We present policy implications for future housing support programs based on the findings.

Keywords: housing support programs; residential satisfaction; housing cost burden; public rental housing program; housing allowance program

1. Introduction

Housing in locations with social and topographical advantages and favorable living environments generally has a high cost burden. In Korea, the pricing gap between housing with a favorable environment and that with an unfavorable environment is increasing, and the housing cost burden of households with a favorable housing environment is also increasing [1]. Those who cannot carry the cost burden are more likely to choose a housing area with a relatively poor housing environment, and this results in a low level of residential satisfaction. The issue of housing instability, manifested in residential dissatisfaction and a housing cost burden, significantly affects family finances as well as quality of life. Further, it negatively affects the community and the country. In particular, the housing problem can pose a serious financial hardship for low-income families, driving disadvantaged and vulnerable housing groups into a poor housing environment [2,3].

Policymakers strive to resolve the problem of housing instability by implementing various housing welfare policies. To ensure housing stability for low-income households, policy support is indispensable, and the government expects these policies to improve the housing environment and reduce the housing cost burden. Most countries have adequate housing standards for their citizens and implement various housing welfare policies to ensure a minimum level of housing [4]. In Korea, the government is implementing housing

support programs with the ultimate goal of housing stability for disadvantaged groups such as low-income families.

The common types of housing support programs include public rental housing programs, housing allowance programs, and housing loans for purchase or rental. Public rental housing is a common measure of the housing support program from the supplier's perspective, whereas housing allowances and housing loans for rental are typical measures from the user's perspective [5,6]. The public rental housing supply places a significant financial burden on the government, and the supply method is rigid. Due to these limitations, a consumer-subsidized housing support program has increasingly been implemented in recent years [7]. In particular, the housing allowance program is a representative example of the relatively new demand-side housing support program, which was implemented in 2015. Owing to the limitations in obtaining data that can be used to evaluate the policy's effect, sufficient research findings on the policy's effectiveness do not exist. In addition, the findings from previous studies are somewhat contradictory. Therefore, an empirical study on the policy effectiveness of housing support programs can be seen as timely.

In this study, we aimed to analyze empirically the effects of housing support programs in Korea on residential satisfaction and the housing cost burden. In particular, we examined the effects of two representative housing support programs—the public rental housing program and the housing allowance program—on residential satisfaction and the housing cost burden. To this end, we posed the following research questions: first, how does the status of residing in public rental housing and that of receiving a housing allowance affect residential satisfaction and the housing cost burden? Second, how does the effect of housing support programs on residential satisfaction and the housing cost burden differ based on household attributes?

Our paper is organized as follows: in Section 2, we have reviewed the current status of public rental housing and housing support programs in Korea, as well as previous studies on residential satisfaction and the burden of housing costs. Section 3 details the variables for empirical analysis we selected using data from the 2020 Housing Survey conducted by the Ministry of Land, Infrastructure, and Transport and provides explanations for the variables. Section 4 describes the multiple regression analysis and sequential logistic regression analysis we conducted to analyze how the housing support program affected residential satisfaction and the housing cost burden and how these effects change according to household characteristics. In Section 5, we have attempted to present policy implications for housing support programs based on the analysis results.

2. Literature Review

2.1. Representative Housing Support Programs: Public Rental Housing Program and Housing Allowance Program

To uphold human dignity and worth, a certain housing condition must be ensured, and a housing policy for low-income families, in particular, is important to guarantee the right to housing [4,8,9]. A housing support program aims to resolve the housing instability issue among low-income families and improve housing welfare [10,11]. As a housing support program for low-income households, the Korean government is operating housing support programs such as public rental housing, housing allowance programs, and housing loans for purchase or rental [12]. Policies related to housing support programs are categorized into supply-side and demand-side policies [13]. Public rental housing is a representative supply-side policy measure; housing support programs mainly comprise constructions of supply-side public rental housing [5,14]. Public rental housing is low-price rental housing that the government or public organizations provide to ensure a stable housing supply for low-income households. Different government administrations have called public rental housing by different names throughout the years, and since the supply of permanent rental housing began in 1989, various public rental housing has been supplied in earnest since 2008 [15]. In the early phase, the goal was to stabilize the housing price, but opinions on whether the intended effect was achieved are divided [16]. Eligible beneficiaries of the

public rental housing include household members with no housing, those with an average monthly income below 150% of the standard median income, those with total assets in the third income quintile, and those with average net assets below KRW 288 million (as of 2020). To provide low-income families with the opportunity to move into public rental housing, 60% of the housing supply is first offered to low-income families as follows: young adults, newlywed couples, and the elderly, accounting for 11%, 7%, and 10%, respectively.

However, it was pointed out that the quantitative-oriented supply-side policy did not take into account the quality of housing [17,18] and faced physical limitations, such as the lack of housing sites for supply. Owing to the limitations of implementing only the supply-side housing policy, the existing supply-side programs have been switched to a consumer-subsidized policy [4]. The housing allowance program is a representative demand-side housing support program, and the subject and scope of support are expanding. The housing allowance program is a system that subsidizes housing expenses for low-income families to stabilize their residence. The previous housing benefit was included in the integrated benefit, which was enforced in 2000 according to the National Basic Livelihood Security Act. The integrated benefit was provided to only those who were selected as recipients of the basic livelihood allowance, and these recipients were guaranteed to receive daily living subsidies, housing, medical care, and other subsidies. This clear-cut measure that supported all or none was limited in that the possibility that some disadvantaged groups would continue to live in poverty remained. In 2015, the integrated benefit system was changed to a customized support system, allowing even the non-recipients of basic livelihood security to receive the necessary support. Along with this reorganization, the supervising ministry was also changed from the Ministry of Health and Welfare to the Ministry of Land, Infrastructure and Transport. Renting families now receive the monthly rent subsidy, and homeowners receive a subsidy for home repair and maintenance of their housing facility. Ever since the payment system of the housing allowance program was reformed, the government has continued to increase the eligibility criteria and strived to provide a practical payment amount according to the level of the housing cost burden. Currently, households eligible for the housing allowance program include those with a recognized income below 46% of the standard median income. The government also pays differential amounts based on the recognized income, the number of household members, housing type, and housing cost burden. The amount of subsidy also differs based on the area of residence. To take one-person households as an example, the government pays KRW 327,000 in Seoul, KRW 253,000 in Gyeonggi and Incheon, and KRW 201,000 in other special case cities excluding six metropolitan cities, Sejong, and the Seoul metropolitan area (a metropolitan area comprising Seoul, Incheon, and Gyeonggi-do, located in northwest Korea. It is the residential, commercial, industrial, and cultural center of Korea). Additionally, housing benefit recipients can receive duplicate benefits from both housing benefits and the public rental housing system if their eligibility to move into public rental housing is recognized.

2.2. Various Factors Affecting Residential Satisfaction and Housing Cost Burden

Residential satisfaction is the difference between occupants' actual and expected residential attributes [19]. It depicts how satisfied a resident is with the current residence and housing environment, and this serves as an important reference for establishing a housing policy [20]. Residential satisfaction has been defined by focusing on various environmental factors along with the evaluation of housing needs' satisfaction. Residential satisfaction is an individual's subjective judgment that comprehensively considers the direct and indirect influencing factors of residential life, including the overall satisfaction with a house's physical facility elements and the surrounding environment [21,22].

Residential satisfaction is known to be affected by household attributes (such as age, gender, and income), housing attributes (such as housing type and occupancy type), and neighborhood attributes (such as accessibility to facilities and green space, public order, and neighbor attributes) [23–27]. Residential satisfaction is closely related to personal

variables, and factors such as income, age, gender, social status, family composition, and age are known to influence it [28]. Residential satisfaction is also known to influence the status of ownership, type of housing, and degree of social participation, as well as the surrounding environment; that is, the characteristics of the neighborhood environment near the residence [29,30]. For example, elderly households often have difficulty accessing community facilities that are important for daily life, which can affect physical and social health and welfare, which negatively affects residential satisfaction [31].

The housing cost burden refers to all expenses incurred continuously while living in a house; that is, the housing-related expenses for each household [32]. In Korea, the housing cost burden continues to grow due to the high housing and rent prices [33]. The housing cost burden is known to be affected by various factors such as household attributes and housing attributes. Among household attributes, sociodemographic factors (such as occupation and education level of the household head) and family factors (such as income and number of household members) affect the housing cost burden [34–36].

As for households' characteristics, sociodemographic factors, such as the household owner's occupation and educational background, and household factors, such as income and the number of household members, are known to influence the housing cost burden [34–36]. Along with educational background, the household owner's job is also known to influence the housing cost burden, and the low-income class is known to have a relatively high housing cost burden [33,37]. Further, the actual housing cost of a household varies depending on the household's residential characteristics and socioeconomic characteristics [35,38]. As for residential attributes, housing type, residential area, and residence period are known to influence the housing expense burden [32,39,40]. The degree of housing cost burden has been confirmed to vary depending on the type of house, region, and duration of residence, and the housing cost burden is significantly influenced in the case of monthly rental households [41]. In addition, a study on neighborhood attributes was conducted by expanding the range of factors affecting the housing cost burden, and accessibility to facilities such as public transportation was found to affect the housing cost burden [40].

2.3. The Effect of the Housing Support Programs on Residential Satisfaction and Housing Cost Burden

In urban space, the socially vulnerable or low-income class continuously experience instability in the residential environment [42]. The public sector needs to come up with various support measures to improve housing instability for these vulnerable groups. The policy goal of a housing support program is housing stability. Planners use housing support programs to help low-income households escape poverty and live in a better neighborhood [43]. Many countries have housing support programs, such as supplying affordable housing or providing vouchers, and these policies are showing some expected effects [44–46]. As a way of measuring whether the housing support program is achieving the policy purpose, we examined residential satisfaction and the housing cost burden. By so doing, we could verify the degree of improvement in housing instability.

Housing policy is one of the factors that influence residential satisfaction. Different types of housing policies have been found to exert their effects on residential satisfaction [47]. In particular, many researchers have studied how public rental housing, which is a representative supply-oriented housing support program, affects Korean people's residential satisfaction. They revealed that different types of public rental housing had different effects on residential satisfaction [25,48]. However, few studies have focused on how a demand-side housing support program affects residential satisfaction. Some studies have reported that the residential satisfaction of households receiving the housing allowance is lower than that of households residing in public rental housing. Contrarily, other studies have argued that the demand-side housing support program improved residential satisfaction to some extent [14,49].

Housing policy is one of the factors that influence the housing cost burden. Public rental housing, which is a representative supply-side policy, is generally known to reduce

tenants' housing cost burden [32,50]. In addition, due to the difference in the housing supply method for each housing type, the housing cost burden differs among various public rental housing types such as permanent rental housing and multi-household housing, purchased or rental housing [51]. Concerning the effect of the demand-side policy on housing cost burden, study results are conflicting. Some studies have reported that the customized housing allowance program revised in 2015 reduced renting households' housing cost burden. Other studies have reported that the households receiving the housing allowance had an increased housing cost burden compared to households residing in public rental housing or non-beneficiary households with a similar income level [7,37]. In addition, another finding suggested that the demand-side housing support program did not relieve the housing cost burden [49]. Aside from these, some scholars have also suggested that the housing allowance program as a driving force to improve housing standards was limited despite its contribution to reducing the rent and housing cost burden. As such, studies on the effect of the housing support program on the housing cost burden do not provide consistent findings [52].

2.4. Limitations of Prior Studies

As discussed above, many studies have focused on the effectiveness of the supply-side policy in Korea. However, few studies have analyzed the effectiveness of housing support programs that implemented the demand-side policy in the context of diversified housing support programs. In particular, few studies have empirically investigated the direct effects of housing support programs on residential satisfaction and the housing cost burden. Therefore, this study aimed to analyze the effectiveness of housing support programs and provide policy implications for efficient housing support programs in the future.

Prior studies on the effectiveness of housing support programs have mainly analyzed supply-side policies. In particular, most studies have empirically examined residential satisfaction and housing cost burden for public rental housing residents [48,51]. Studies on demand-side housing policies are relatively rare. Although studies on the effect of housing vouchers have been conducted in other countries [53,54], few Korean researchers have investigated the demand-side housing policy in Korea. Before the housing allowance program was revised, some researchers studied the residential satisfaction of households receiving the housing allowance and the effect of housing loans for *jeonsei* or purchase. Nonetheless, they failed to provide a thorough analysis due to a lack of available data about the new housing allowance program, which was implemented for only a short period [14,49,55]. Therefore, to derive more meaningful research results, we used the data from the 2020 Korea Housing Survey for analysis and data accrued up to five years since the implementation of the new housing allowance program.

Next, we divided the vulnerable housing groups based on household attributes and analyzed the effectiveness of the housing support programs. According to the Korean government's 2017 housing welfare roadmap, customized housing support plans for each stage of life and income level would be provided based on household composition (young adults, newlywed couples, the elderly, and low-income families) to implement the policy effectively. Further, more than 30% of one-person households were found to have an excessive housing cost burden, and this number has been rapidly increasing in recent years. This demonstrates the need for a housing policy that reflects the attributes of one-person households [56] as well. In this study, we analyzed the effect of the housing support programs based on household attributes by comprehensively considering the changes in the policy direction of the housing support programs.

3. Method

3.1. Data and Conceptual Framework

The study area was the entire country of Korea (see Figure 1). In this study, we used data from the 2020 Korea Housing Survey conducted by the Ministry of Land, Infrastructure and Transport. The total number of households and household heads in Korea at the time

of the survey made up the total survey population. The survey investigated overall matters of residential life, such as household characteristics, residential environment, and residential movement of the Korean people, to provide information necessary for policy establishment related to residential welfare improvement. The main items included housing characteristics, housing cost burden, residential satisfaction, and the status of home ownership of the current residential house. The structured survey was carried out from July to December 2020 throughout the country, via face-to-face interviews by trained interviewers. Rental households were extracted from the data of households in the Korea Housing Survey sample, and households that did not respond to the questionnaire related to public rental housing and housing benefits were excluded. Then, 2950 households were considered for the final analysis after removing outliers and missing values.

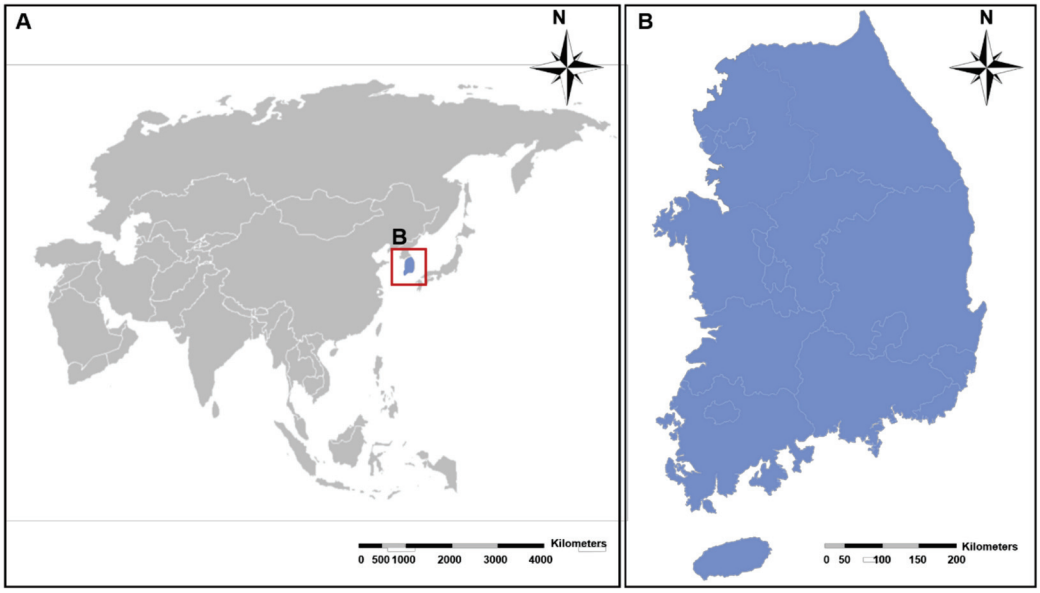

Figure 1. Study area: geographical location of (**A**) the continent of Asia, (**B**) the Republic of Korea.

For the classification of households, the criteria defined in Korea's housing policy were considered. One-person households are defined as households comprising one member regardless of the household owner's age. Newlyweds are defined as couples within seven years of the marriage registration period. In the case of young households, youth is defined as those under 39 years of age. In this study, young households are defined as households with a household owner under 39 years of age. Further, those 65 years of age or older comprise the elderly, and elderly households are households whose owners are 65 years of age or older. The final sample included 1504 surveys from one-person households, 189 surveys from newlywed couple households, 473 surveys from households of young adults, and 1089 surveys from households of the elderly.

We aimed to verify the effect of housing support programs on residential satisfaction and the housing cost burden. To this end, we conducted two analyses. In one, we considered "residential satisfaction" as the dependent variable and utilized multiple regression; in the other, we considered "housing cost burden" as the dependent variable and utilized ordinal logistic regression. The dependent variable of the housing satisfaction model was a continuous variable, and the dependent variable of the housing cost burden model was measured on a Likert scale. Therefore, we used multiple regression and ordered logistic regression analysis in consideration of the characteristics of the dependent variable. Figure 2 demonstrates the conceptual framework of this study.

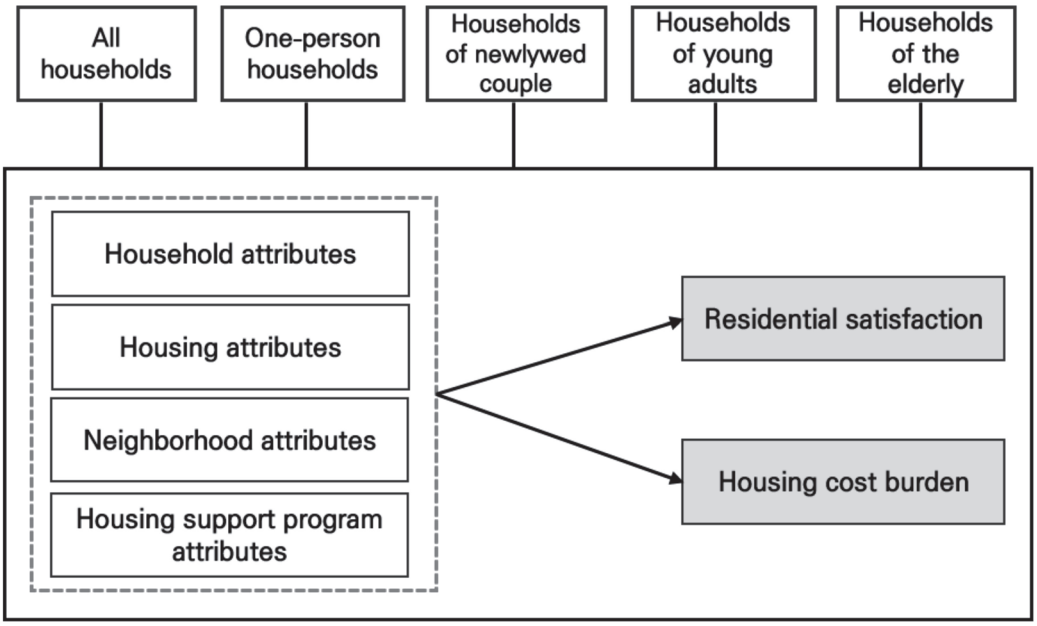

Figure 2. Conceptual framework.

3.2. Variables and Measurements

Table 1 presents the description of the dependent and independent variables. The dependent variables of this study are residential satisfaction and housing cost burden. The level of residential satisfaction is the average of the scores on the items related to "General satisfaction with housing condition" and "General satisfaction with neighborhood environment"; we measured these scores on a 4-point Likert scale. We used the level of housing cost burden as a variable after measuring it on a 4-point Likert scale in response to the degree of housing cost burden at the current residence. We implemented three methods to assess housing cost burden: ratio measurement method, residual income valuation method, and a behavioral (subjective) method [57]. The ratio measurement method, which is typically indicated as the rent-to-income ratio (RIR), calculates cash flow using rent as a measure. This method is limited in that it is difficult to accurately calculate the housing cost burden in the form of stock such as monthly rent [32,58]. The residual income valuation is a method of determining the affordability of housing by comparing the income after housing payment with the non-housing expenditure of the household. This method is also limited in that it is difficult to reflect the discrepancy in non-housing expenditures by region. In other words, this method is good for studying small areas [59]. This study aimed to analyze empirically whether the reduction of housing cost burden through the housing support program affects policy beneficiaries' subjective experience. In this regard, it must be mentioned that rental households in Korea pay housing costs not only in the form of cash but also often in the form of *jeonsei* and deposits. This means that the housing cost burden measurement method using RIR cannot reflect Korean rental households' actual housing cost burden [58]. Therefore, we considered a subjective judgment method as an appropriate method for measuring the housing cost burden. Further, we considered residents' subjective judgment regarding the current level of housing cost burden as a variable.

Table 1. Variable measurement.

Variable		Measurement	
Independent variable	Dependent variable	Residential satisfaction	Average value of overall satisfaction with housing condition and neighborhood environment measured on a 4-point Likert scale.
		Housing cost burden	The degree to which the resident subjectively feels the housing cost burden of the current residential house: (1 = none, 2 = not much, 3 = some, 4 = very much).
	Household attributes	Gender of household head	Male = 1, female = 0.
		Age of household head	Age of household head (years of age).
		Occupation of household head	Office job = 1, service/sales = 2, technical job = 3, other =4, unemployed = 5.
		Education level of household head	High school or below = 1, college = 2, graduate school or higher = 3.
		Low-income family	Household income below 50% of the median income = 1, other = 0.
		Number of household members	Number of household members living together (# number).
	Housing attributes	Seoul metropolitan area	Residence in Seoul metropolitan area = 1, other areas = 0.
		Occupancy period	Period of occupying the current housing (years).
		Housing type	Types of current residence: private housing = 1, apartment = 2, townhouse/multi-family housing = 3, studio = 4, other = 5.
		Monthly rental house	The occupancy type of the current housing: monthly rental house = 1, other = 0.
	Neighborhood attributes	Accessibility to other facilities	The average score of questions related to satisfaction regarding the accessibility to four types of facilities (commercial facilities, medical facilities, cultural facilities, and public institutions) measured on a 4-point Likert scale.
		Accessibility to parks and green	Satisfaction with the accessibility to city parks and green space (4-point Likert scale).
		Accessibility to public transportation	Satisfaction with the accessibility to public transportation (4-point Likert scale).
		Public order	Satisfaction with the level of public order and crime prevention (4-point Likert scale).
		Relationship with neighbors	Satisfaction with the relationship with neighbors (4-point Likert scale).

Table 1. *Cont.*

Variable		Measurement
Housing support program attributes	Public rental housing	User status of public rental housing: currently using = 1, currently not using = 0.
	Housing allowance program	User status of rental assistance as a housing allowance program: currently using = 1, currently not using = 0.

Based on the review of previous studies, we selected the following as independent variables: household attributes, housing attributes, neighborhood environment attributes, and housing support programs' attributes. As variables of household attributes, we selected the following: gender, age, occupation, and education level of the household head, as well as low-income class status and the number of household members. Not all beneficiaries of the housing support program are low-income families because the selection criteria are different for each type of housing support program. Conversely, not all low-income people are automatically beneficiaries of the housing support program, so we considered low-income people as control variables for the residential satisfaction and housing cost burden model. We classified low-income households as households with a median income of 50% or less of the median income according to the criteria for median income by the number of household members. This standard is used for selecting the recipients of various welfare projects, including Korea's basic living security system. In the survey, we directly asked participants about their monthly income, but we divided the income variable, which is a continuous variable, into categories and used them to determine the difference in the effectiveness of housing support programs for low-income and non-low-income households. As variables of housing attributes, we selected the following: residence in the Seoul Metropolitan Area, occupancy period, housing type, and occupancy type. We classified housing types into private housing, apartments, townhouse/multi-family housing, studio, and others, and all these housing types could be paid for via monthly rent or considered ownership housing. As variables of neighborhood attributes, we selected the following: accessibility to facilities, parks and green space accessibility, public transportation accessibility, public order, and relationships with neighbors. As variables of housing support programs, we selected the status of residing in public rental housing and the status of receiving rental assistance such as a housing allowance. Public rental housing and the housing allowance can be considered typical examples of a supply-side housing policy and a demand-side housing policy, respectively. We selected them as variables because they are the most significant as supply-side and demand-side housing policies, respectively, thereby making it easy to obtain significant results through analysis.

4. Results

4.1. Descriptive Statistics

Table 2 presents the descriptive statistics of variables used in the analysis. As for the whole sample, the mean of each dependent variable—residential satisfaction and housing cost burden—was 2.917 (sd = 0.46) and 2.923 (sd = 0.51), respectively. When we examined the dependent variables based on household attributes, the one-person household group had the lowest level of residential satisfaction and the highest housing cost burden among all household types. The newlywed couple household group had the highest level of residential satisfaction, and the young adult household group had the lowest level of housing cost burden. Of all the data used for the analysis, the descriptive statistics of the whole sample are as follows. Low-income families accounted for 50%, and the average number of household members was 1.8 (sd = 1.13). Households residing in the Seoul metropolitan area accounted for 39.7%, and the average occupancy period was

6.1 years (sd = 6.04). In terms of housing type, apartments had the highest percentage at 48.41%. Further, 87.2% of all households paid monthly rent. In terms of satisfaction with the neighborhood, the mean for each variable was as follows: 2.847 (sd = 0.54) for accessibility to other facilities, 2.951 (sd = 0.71) for accessibility to parks and green space, 3.033 (sd = 0.63) for public transportation accessibility, 3.016 (sd = 0.55) for public order, and 2.988 (sd = 0.51) for the relationship with neighbors.

Table 2. Descriptive statistics.

			All Households	One-Person Households	Household of Newlywed Couples	Households of Young Adults	Households of the Elderly
			Mean/Frequency (S.D./%)	Mean/Frequency (S.D./%)	Mean/Frequency (S.D./%)	Mean/Frequency (S.D./%)	Mean/Frequency (S.D./%)
Dependent variable	residential satisfaction		2.917 (0.46)	2.900 (0.51)	2.979 (0.53)	2.970 (0.55)	2.912 (0.48)
	Housing cost burden		2.923 (0.51)	2.921 (0.83)	2.884 (0.77)	2.827 (0.79)	2.901 (0.82)
Household attributes	Gender of household head		0.621 (0.49)	0.503 (0.50)	0.989 (0.10)	0.721 (0.45)	0.512 (0.50)
	Age of household head		57.583 (16.16)	61.500 (16.59)	36.386 (5.22)	32.677 (4.61)	74.502 (6.96)
	Occupation of household head	Office job	395 (13.39)	132 (8.78)	100 (52.91)	219 (46.30)	3 (0.28)
		Service/sales	441 (14.95)	60 (10.64)	38 (20.11)	111 (23.47)	31 (2.85)
		Technical job	284 (9.63)	86 (5.72)	34 (17.99)	59 (12.47)	31 (2.85)
		Other	280 (9.49)	110 (7.31)	10 (5.29)	17 (3.59)	109 (10.01)
		Unemployed	1550 (52.54)	1016 (67.55)	7 (3.70)	67 (14.16)	915 (84.02)
	Education level of household head	High school	2247 (76.17)	1267 (84.24)	45 (23.81)	158 (33.40)	1057 (97.06)
		College	663 (22.47)	226 (15.03)	134 (70.90)	302 (63.85)	28 (2.57)
		Graduate school	40 (1.36)	11 (0.73)	10 (5.29)	13 (2.75)	4 (0.37)
	Low-income families		0.500 (0.500)	0.632 (0.482)	0.05 (0.214)	0.146 (0.353)	0.796 (0.403)
	Number of household members		1.885 (1.13)	1.000 (0.00)	2.815 (0.78)	2.053 (1.14)	1.418 (0.71)
Housing attributes	Seoul metropolitan areas		0.397 (0.49)	0.408 (0.49)	0.540 (0.50)	0.488 (0.50)	0.379 (0.49)
	Occupancy period		6.129 (6.04)	6.217 (6.32)	2.656 (1.53)	2.579 (1.72)	8.364 (7.41)
	Housing type	Private housing	969 (32.85)	588 (39.10)	28 (14.81)	138 (29.18)	380 (34.89)
		Apartment	1428 (48.41)	570 (37.90)	123 (65.08)	203 (42.92)	560 (51.42)
		Townhouse/ multi-family housing	314 (10.64)	132 (8.78)	33 (17.46)	64 (13.53)	86 (7.90)
		Studio	83 (2.81)	68 (4.52)	5 (2.65)	50 (10.57)	6 (0.55)
		Other	156 (5.29)	146 (9.71)	-	18 (3.81)	57 (5.23)
	Monthly rental house		0.872 (0.33)	0.936 (0.24)	0.497 (0.50)	0.672 (0.47)	0.961 (0.19)
Neighborhood attributes	Accessibility to other facilities		2.847 (0.54)	2.817 (0.55)	2.968 (0.55)	2.953 (0.55)	2.779 (0.54)
	Accessibility to parks/green space		2.951 (0.71)	2.882 (0.72)	3.016 (0.60)	2.915 (0.70)	2.958 (0.71)
	Accessibility to public transportation		3.033 (0.63)	3.048 (0.63)	3.026 (0.65)	3.076 (0.66)	3.026 (0.62)
	Public order		3.016 (0.55)	2.981 (0.55)	3.090 (0.54)	3.044 (0.58)	3.018 (0.54)
	Relationship with neighbors		2.988 (0.51)	2.951 (0.52)	3.000 (0.48)	2.956 (0.51)	3.028 (0.49)
Housing support program attributes	Public rental housing		0.428 (0.49)	0.408 (0.49)	0.265 (0.44)	0.207 (0.41)	0.562 (0.50)
	Housing allowance program		0.487 (0.50)	0.612 (0.49)	0.048 (0.21)	0.121 (0.33)	0.750 (0.43)
	N		2950	1504	189	473	1089

Households residing in public rental housing accounted for 42.8%, and households receiving a housing allowance accounted for 48.7%. The households of the elderly (56.2%) had the highest rate of occupancy in public rental housing, whereas young adult households had the lowest rate of occupancy in public rental housing (20.7%). Further, the households of the elderly (75%) had the highest rate of receiving a housing allowance,

whereas the newlywed couple household group had the lowest rate of receiving a housing allowance (4.8%).

4.2. Factors Influencing Residential Satisfaction

Table 3 presents the regression analysis results regarding residential satisfaction. The findings for the whole sample were as follows. Among household attributes, gender, occupation, education level, and the number of household members significantly affected residential satisfaction. In terms of gender, households with a male household head had a higher level of residential satisfaction. In terms of occupation, households whose heads had office jobs had a higher level of residential satisfaction than those whose heads had technical jobs. In terms of the household head's education level, the level of residential satisfaction was lower among households whose heads had college degrees than those whose heads had high school degrees. Further, the number of household members negatively affected residential satisfaction. Of all housing attributes, occupancy period and housing type significantly affected residential satisfaction. In particular, occupancy period negatively affected residential satisfaction. Among the variables of housing types, households residing in apartments, townhouse/multi-family housing, or studio had a higher level of residential satisfaction than those residing in private housing. Among neighborhood attributes, accessibility to other facilities, accessibility to parks and greens, public transportation accessibility, public order, and the relationship with neighbors all had a significant positive effect on residential satisfaction. Of all the housing support program attributes, the variables of public rental housing and the housing allowance program showed statistically significant effects. In particular, households residing in public rental housing had a higher level of residential satisfaction than those residing in other types of housing. Households receiving a housing allowance had lower residential satisfaction than those not receiving a housing allowance.

Table 3. Results of residential satisfaction model.

			Whole Sample	One-Person Households	Households of Newlywed Couples	Households of Young Adults	Households of the Elderly
			Coef. (S.E.)	**Coef. (S.E.)**	**Coef. (S.E.)**	**Coef. (S.E.)**	**Coef. (S.E.)**
Constant			0.847 * (0.06)	0.739 *** (0.10)	0.735 * (0.41)	0.765 *** (0.17)	1.122 *** (0.25)
Household attributes	Gender of household head		0.621 (0.49)	0.503 (0.50)	0.989 (0.10)	0.721 (0.45)	0.512 (0.50)
	Age of household head		0.007 ** (0.01)	0.000 (0.02)	0.165 (0.27)	−0.026 (0.04)	0.025 (0.02)
	Occupation of household head (ref. office)	Service/sales	−0.028 (0.03)	0.023 (0.05)	−0.040 (0.08)	0.023 (0.04)	−0.254 (0.21)
		Technical job	−0.076 ** (0.03)	−0.016 **(0.05)	−0.072 (0.09)	−0.107 ** (0.05)	−0.346 * (0.21)
		Other	−0.055 (0.03)	−0.076(0.05)	0.102 (0.15)	−0.022 (0.09)	−0.295 (0.20)
		Unemployed	−0.027 (0.03)	0.000 (0.05)	−0.341 (0.21)	−0.029 (0.06)	−0.274 (0.20)
	Education level of household head (ref. high school)	College	−0.034 * (0.02)	0.033 (0.03)	−0.083 (0.08)	−0.067 (0.04)	−0.068 (0.07)
		Graduate school	−0.072 (0.06)	−0.028 (0.11)	−0.141 (0.15)	−0.064 (0.10)	0.034 (0.17)
	Low-income families		−0.003 (0.02)	−0.005 (0.03)	0.085 (0.21)	−0.055 (0.06)	0.037 (0.03)
	Number of household members		−0.018 *** (0.01)	-	−0.025 (0.04)	−0.045 *** (0.02)	−0.005 (0.02)

Table 3. *Cont.*

			Whole Sample	One-Person Households	Households of Newlywed Couples	Households of Young Adults	Households of the Elderly
			Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)
Housing attributes	Seoul metropolitan areas		−0.006 (0.01)	−0.015 (0.02)	−0.009 (0.06)	−0.077 ** (0.03)	0.031 (0.02)
	Occupancy period		−0.004 *** (0.00)	−0.003 ** (0.00)	0.009 (0.02)	−0.001 (0.01)	−0.004 ** (0.00)
	Housing type (ref. private housing)	Apartment	0.069 *** (0.02)	0.062 ** (0.03)	−0.036 (0.09)	−0.003 (0.04)	0.132 *** (0.03)
		Townhouse/ multi-family housing	83 (2.81)	68 (4.52)	5 (2.65)	50 (10.57)	6 (0.55)
		Studio	0.125 *** (0.04)	0.086 * (0.05)	0.088 (0.20)	0.117 ** (0.06)	0.093 (0.14)
		Other	−0.142 ***(0.03)	−0.136 *** (0.03)	-	−0.028 (0.08)	−0.227 *** (0.05)
	Monthly rental house		0.021 (0.02)	0.023 (0.04)	−0.014 (0.07)	−0.020 (0.04)	0.019 (0.05)
Neighborhood attributes	Accessibility to other facilities		0.213 *** (0.01)	0.229 *** (0.02)	0.188 ** (0.07)	0.257 *** (0.04)	0.176 *** (0.02)
	Accessibility to parks/greens		0.072 *** (0.01)	0.080 *** (0.01)	0.173 *** (0.05)	0.107 *** (0.03)	0.072 *** (0.02)
	Accessibility to public transportation		0.038 *** (0.01)	0.045 *** (0.02)	0.008 (0.06)	0.004 (0.03)	0.078 *** (0.02)
	Public order		0.223 *** (0.01)	0.239 *** (0.02)	0.258 *** (0.06)	0.233 *** (0.03)	0.180 *** (0.02)
	Relationship with neighbors		0.184 *** (0.01)	0.164 *** (0.02)	0.173 ** (0.07)	0.202 *** (0.04)	0.167 *** (0.02)
Housing support Program attributes	Public rental housing		0.092 *** (0.02)	0.110 *** (0.03)	0.056 (0.08)	0.057 (0.05)	0.061 * (0.03)
	Housing allowance program		−0.034 * (0.02)	−0.028 (0.03)	−0.031 (0.18)	0.030 (0.07)	−0.032 (0.03)
	N		2950	1504	189	473	1089
	F		106.85 ***	61.09 ***	6.58 ***	25.71 ***	36.35 ***
	Log likelihood		−966.762	−503.004	−59.894	−118.274	−330.372
	R^2		0.467	0.487	0.478	0.579	0.451
	Adjust R^2		0.463	0.479	0.406	0.557	0.438

In the one-person household group, households with one member are the subject of analysis, so the variable 'number of members' is excluded from the analysis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The findings for the one-person household group were as follows. Among household attributes, the age and occupation of the household head significantly influenced residential satisfaction. In particular, the older the household head, the lower the residential satisfaction. In terms of occupation, those with office jobs had higher residential satisfaction than those with technical jobs. Among housing attributes, occupancy period and housing type significantly affected residential satisfaction. In particular, the occupancy period negatively affected residential satisfaction. Among the variables of housing types, households residing in an apartment or studio had a higher level of residential satisfaction than those residing in private housing. Among neighborhood attributes, accessibility to other facilities, accessibility to parks and greens, public transportation accessibility, public order, and the relationship with neighbors had significant positive effects on residential satisfaction. Among the variables of housing support programs, only public rental housing had a significant effect; and households residing in public rental housing had a higher level of residential satisfaction than those not residing in public rental housing.

The findings for the newlywed couple household group were as follows. None of the household and housing attributes significantly affected residential satisfaction. Among neighborhood attributes, accessibility to other facilities, accessibility to parks and greens, public order, and the relationship with neighbors positively affected residential satisfaction. None of the housing support program variables significantly affected residential satisfaction.

The findings for the young adult household group were as follows. Among household attributes, the occupation of the household head and the number of household members significantly affected residential satisfaction. Households whose household heads had office jobs had a higher level of residential satisfaction than those whose household heads had technical jobs. Further, the number of household members negatively affected residential satisfaction. Among housing attributes, housing type and residence in the Seoul metropolitan area significantly affected residential satisfaction. In particular, households residing in the Seoul metropolitan area had a lower level of residential satisfaction than those residing in other areas. As for young adult households, the percentage of employment of the household head was higher than that of other household groups. This can be seen as the representation of the reality that households living in the Seoul metropolitan area due to work cannot afford high housing costs in areas with favorable housing conditions. Among the variables of housing types, households residing in townhouse/multi-family housing or studio had a higher level of residential satisfaction than those residing in private housing. Among neighborhood attributes, accessibility to other facilities, accessibility to parks/greens, public order, and the relationship with neighbors positively affected residential satisfaction. Finally, the user status of public rental housing and the housing allowance program did not have a significant effect on residential satisfaction.

The findings for the households of the elderly were as follows. Among household attributes, the occupation of the household head was the only variable that significantly affected residential satisfaction. In particular, households whose household heads had office jobs had a higher level of residential satisfaction than those whose household heads had technical jobs. Of all housing attributes, occupancy period and housing type significantly affected residential satisfaction. Occupancy period negatively affected residential satisfaction. Among the variables of housing types, households residing in an apartment had a higher level of residential satisfaction than those residing in private housing. Among neighborhood attributes, accessibility to other facilities, accessibility to parks and greens, public transportation accessibility, public order, and the relationship with neighbors positively affected residential satisfaction. Among the attributes of housing support programs, households residing in public rental housing had a higher level of residential satisfaction than those who did not reside in public rental housing.

Our findings regarding the variables that significantly affected residential satisfaction, such as household, housing, and housing environment attributes, are consistent with previous findings [27,47]. Among housing characteristics, the period of residence negatively affected residential satisfaction in all households, one-person households, and elderly households. This may have led to a decrease in residential satisfaction as residence period increased. Most housing environment variables affected residential satisfaction irrespective of household attributes.

The user status of public rental housing positively affected residential satisfaction among all households, one-person households, and households of the elderly. This means that public rental housing increased residential satisfaction among households that did not have their own home.

In contrast, public rental housing did not have a significant effect on residential satisfaction among the newlywed couple and young adult household groups. This may be due to the low user status of these two household groups. The housing allowance program had a significant positive effect on the residential satisfaction of only the whole sample group. Its effect on other household groups was negative. This may be because of their area of residence. Most households benefiting from the housing allowance program resided in areas with a poor housing environment and were from low-income families.

4.3. Factors Influencing Housing Cost Burden

Table 4 presents the results of the logical regression analysis related to the housing cost burden. The pseudo R2 value of the housing cost burden model was relatively lower than the R2 value of the housing satisfaction model, but in general, the pseudo R2 value tends to be significantly lower than R2 in OLS [60]. In addition, this analysis aimed to find out how the independent variable affects the housing cost burden, and it was judged that the low pseudo R2 value was not a big problem. The findings for whole sample were as follows. Among household attributes, the occupation and education level of the household head, as well as the number of household members significantly affected the housing cost burden. The housing cost burden was greater for households whose heads had office jobs than those whose heads had technical jobs. The housing cost burden was also greater for households whose heads had other jobs or no jobs at all than those whose heads had office jobs. The number of household members positively affected the housing cost burden. Among housing attributes, residence in Seoul metropolitan areas, occupancy period, housing type, and monthly rent significantly affected the housing cost burden. Households residing in the Seoul metropolitan area were more likely to have a greater housing cost burden than those residing in other areas. The occupancy period negatively affected the housing cost burden. Among the variables of housing types, households residing in an apartment were more likely to have a greater housing cost burden than those residing in private housing. Among the variables of occupancy types, households paying monthly rent were more likely to have a greater housing cost burden than those not paying monthly rent. Among neighborhood attributes, the relationship with neighbors negatively affected the housing cost burden. Among the housing support program variables, households residing in public rental housing were more likely to have a low housing cost burden than households not residing in public rental housing.

Table 4. Results of housing cost burden model.

			Whole Sample	One-Person Households	Households of Newlywed Couples	Households of Young Adults	Households of the Elderly
			Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)
Household attributes	Gender of household head		0.911 (0.073)	0.957 (0.103)	0.000 (0.000)	0.715 (0.165)	0.780 * (0.100)
	Age of household head		1.002 (0.003)	1.002 (0.004)	1.021 (0.033)	1.020 (0.024)	0.997 (0.009)
	Occupation of household head (ref. office)	Service/sales	1.166 (0.173)	1.248 (0.314)	0.830 (0.360)	1.080 (0.272)	0.679 (0.715)
		Technical job	0.720 * (0.121)	0.559 * (0.166)	0.505 (0.240)	0.709 (0.218)	0.345 (0.368)
		Other	1.716 *** (0.315)	1.779 * (0.536)	1.939 (1.691)	1.378 (0.734)	1.250 (1.279)
		Unemployed	1.528 ** (0.262)	1.685 * (0.480)	1.059 (1.187)	1.390 (0.538)	1.101 (1.118)
	Education level of household head (ref. high school)	College	0.765 ** (0.088)	0.790 (0.147)	0.688 (0.329)	1.219 (0.302)	0.731 (0.270)
		Graduate school	0.724 (0.238)	0.843 (0.538)	0.392 (0.336)	0.384 (0.236)	0.421 (0.451)
	Low-income families		1.024 (0.114)	0.991 (0.164)	0.460 (0.549)	0.530 * (0.201)	0.837 (0.149)
	Number of household members		1.182 *** (0.043)	-	1.887***(0.409)	1.276**(0.127)	1.258**(0.115)

Table 4. *Cont.*

			Whole Sample	One-Person Households	Households of Newlywed Couples	Households of Young Adults	Households of the Elderly
			Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)
Housing attributes	Seoul metropolitan areas		1.226 *** (0.095)	1.177 (0.126)	2.255 ** (0.817)	2.486 *** (0.511)	1.363 ** (0.172)
	Occupancy period		0.987 ** (0.006)	0.993 (0.008)	0.844 (0.094)	0.934 (0.052)	0.997 (0.008)
	Housing type(ref. private housing)	Apartment	1.604 *** (0.169)	1.818 *** (0.292)	1.968 (1.017)	1.693 ** (0.442)	1.608 ** (0.314)
		Townhouse/multi-family housing	0.946 (0.125)	1.289 (0.247)	0.794 (0.470)	0.844 (0.259)	0.981 (0.236)
		Studio	0.860 (0.205)	0.953 (0.256)	0.119 * (0.151)	0.527 * (0.186)	2.423 (2.229)
		Other	1.301 (0.227)	1.408 * (0.265)	-	0.889 (0.478)	1.259 (0.358)
	Occupancy type		2.209 *** (0.265)	2.135 *** (0.449)	3.628 *** (1.513)	2.031 *** (0.459)	4.932 *** (1.478)
Neighborhood attributes	Accessibility to other facilities		0.972 (0.079)	0.973 (0.108)	0.690 (0.285)	0.655 * (0.151)	0.946 (0.120)
	Accessibility to parks/greens		0.946 (0.054)	0.972 (0.076)	1.309 (0.372)	0.902 (0.139)	0.910 (0.084)
	Accessibility to public transportation		1.095 (0.072)	1.026 (0.095)	1.794 * (0.561)	1.334 * (0.232)	0.993 (0.106)
	Public order		0.926 (0.071)	0.981 (0.104)	0.786 (0.281)	1.061 (0.215)	0.932 (0.119)
	Relationship with neighbors		0.701 *** (0.056)	0.656 *** (0.071)	0.426 ** (0.169)	0.572 ** (0.125)	0.713 ** (0.099)
Housing support Program attributes	Public rental housing		0.239 *** (0.025)	0.212 *** (0.034)	0.132 *** (0.062)	0.249 *** (0.070)	0.210 *** (0.040)
	Housing allowance program		0.970 (0.102)	1.011 (0.152)	1.304 (1.264)	3.556 *** (1.459)	0.869 (0.134)
	/Cut1		−3.596 (0.379)	−3.604 (0.548)	−21.231 (1137.494)	−3.537 (1.064)	−4.029 (1.345)
	/Cut2		−1.502 (0.370)	−1.619 (0.538)	−18.544 (1137.494)	−1.435 (1.049)	−1.928 (1.339)
	/Cut3		0.929 (0.370)	0.665 (0.538)	−15.604 (1137.494)	1.210 (1.050)	0.450 (1.338)
	N		2950	1504	189	473	1089
	F		367.70 ***	203.83 ***	67.48 ***	82.35 ***	177.78 ***
	Log likelihood		−3240.008	−1694.800	−181.317	−509.344	−1203.468
	Pseudo R^2		0.130	0.140	0.335	0.177	0.166

In the one-person household group, households with one member are the subject of analysis, so the variable 'number of members' is excluded from the analysis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The findings for one-person households were as follows. Among household attributes, only the occupation of the household head significantly affected the housing cost burden. Households whose heads had office jobs had a greater housing cost burden than those whose heads had technical jobs. Further, household heads with other jobs or no jobs were more likely to have a greater housing cost burden than household heads with office jobs. Among housing attributes, housing type and monthly rent significantly increased the housing cost burden. Those who resided in an apartment were more likely to have a greater housing cost burden than those who resided in private housing. Households paying monthly rent were more likely to have a greater housing cost burden than other households. Among neighborhood attributes, the relationship with neighbors negatively affected the housing cost burden. Among the housing support program variables, households residing

in public rental housing were more likely to have a low housing cost burden than those residing in public rental housing.

The findings for the newlywed couple household group were as follows. Among household attributes, the number of household members positively affected the housing cost burden. Among housing attributes, housing type and monthly rent significantly affected the housing cost burden. Among the variables of housing types, households that resided in an apartment had a greater housing cost burden than those that resided in private housing. Households that paid monthly rent had a greater housing cost burden than those that did not pay monthly rent. Among neighborhood attributes, public transportation accessibility and the relationship with neighbors significantly affected the housing cost burden. The higher the satisfaction with public transportation accessibility, the higher the housing cost burden, which is generally considered to be the result of higher housing costs located in places with good public transportation accessibility. The relationship with neighbors negatively affected the housing cost burden. Among housing support program attributes, households residing in public rental housing were more likely to have a low housing cost burden compared to those not residing in public rental housing.

Next, the findings on young adult households were as follows. Among household attributes, the number of household members positively affected the housing cost burden. Among housing attributes, residence in the Seoul metropolitan area, housing type, and monthly rent significantly affected the housing cost burden. Households residing in the Seoul metropolitan area were more likely to have a greater housing cost burden than those residing in other areas. Among the variables of housing types, households residing in an apartment were more likely to have a greater housing cost burden than those residing in private housing. Further, households residing in private housing had a greater housing cost burden than those residing in studios. Households paying monthly rent were more likely to have a greater housing cost burden than those not paying a monthly rent. Among neighborhood attributes, accessibility to other facilities and public transportation accessibility, and the relationship with neighbors significantly affected the housing cost burden. Accessibility to facilities and relationship with neighbors negatively affected the housing cost burden, whereas public transportation accessibility positively affected the housing cost burden. Among housing support program attributes, both public rental housing and the housing allowance program, which were dummy variables, significantly affected the housing cost burden. Households residing in public rental housing were more likely to have a low housing cost burden than those not residing in public rental housing. Households using a housing allowance program were more likely to have a high housing cost burden than those not using a housing allowance program.

The findings for the households of the elderly were as follows. Among household attributes, the gender of the household head and the number of household members significantly affected the housing cost burden. In particular, households with a female household head were more likely to have a high housing cost burden than those with a male household head. The number of household members positively affected the housing cost burden. Among housing attributes, residence in the Seoul metropolitan area, housing type, and monthly rent significantly affected the housing cost burden. In particular, households residing in the Seoul metropolitan area were more likely to have a high housing cost burden than those living in other areas. Among the variables of housing types, households residing in an apartment were more likely to have a high housing cost burden than those residing in private housing. Households paying monthly rent were more likely to have a high housing cost burden than those not paying monthly rent. Among neighborhood attributes, the relationship with neighbors negatively affected the housing cost burden. Among the housing support program attributes, households residing in public rental housing were more likely to have a low housing cost burden than those not residing in public rental housing.

To sum up, the analysis of housing cost burden in all household groups showed that households paying monthly rent had a greater housing cost burden than those not

paying a monthly rent. In all household groups, except for one-person households, those who resided in the Seoul metropolitan area had a greater housing cost burden than those who did not. This finding is in line with that of previous research that households paying monthly rent and households residing in the Seoul metropolitan area have a greater housing cost burden than other households [7,32,61]. Further, public rental housing decreased the housing cost burden for all household groups. This indicates that public rental housing has a lower housing cost burden than other types of rental housing [62]. Among young adult households, households that received a housing allowance had a greater housing cost burden than those that did not receive it. Finally, the benefit amount of housing assistance is insufficient to reduce the housing cost burden for households eligible for the housing allowance program.

5. Discussion

Housing support programs are public policies to ensure minimum housing rights, and research has been steadily conducted on how various housing support programs affect housing stability. This study confirmed the effect on housing satisfaction and the housing cost burden to evaluate the effect of the housing support program in Korea. As widely known from previous studies, it was confirmed that the supply-oriented policy had a positive effect on housing satisfaction and reduction of the housing cost burden. However, the demand-oriented policy was not found to have a significant effect on housing satisfaction and reduction of the housing cost burden, as known from previous studies.

Based on our findings, we provide the following policy suggestions for the housing support programs. First, to maximize the effectiveness of the policy when screening eligible beneficiaries of the public rental housing program and the housing allowance program, the ratio must be considered based on household attributes. As for the public rental housing policy, it had a positive effect on reducing the housing cost burden. However, it is not fiscally or physically feasible to keep increasing the supply of public rental housing. When an integrated public rental housing policy is established in the future, the policy's effectiveness must be maximized by properly allocating the preferential supply ratio according to household attributes. As for the housing allowance program, support must be increased for those households that urgently need housing cost assistance. Among the households residing in rental housing, one-person households and elderly households had a higher monthly rent as well as a greater cost burden than other household groups. Therefore, the government must increase support for those households that urgently need housing assistance to increase the effectiveness of the housing allowance program.

Second, to increase the effectiveness of the housing allowance program, the current eligibility criteria and payment must be reviewed. According to a study conducted in an early stage when the housing allowance program was revised and implemented, backup measures for the program operation were needed because the housing assistance program did not have a significant effect [14,55]. Since the program's revision in 2015 to ensure that it is tailored to beneficiaries' needs, the Korean government has worked towards increasing the eligibility of the housing allowance program and offered practical housing assistance based on the level of housing cost burden. Continuing to make such improvements will help increase the program's effectiveness. Further, considering that the renting households in the Seoul metropolitan area carry a relatively high housing cost burden, a comprehensive and differential housing support program must be implemented by considering the area of residence and the actual rent.

Our study is significant in that we conducted an empirical analysis by utilizing data from a certain period after the housing support programs were revised and implemented. However, it is limited in that we could not include various housing support programs in the analysis. In addition, in the case of Korea, there was a limit to the analysis because housing policies such as housing allowance were implemented relatively recently. Therefore, a follow-up study must analyze the effect of not only the public rental housing and housing allowance program but also other housing support programs to demonstrate a general effect

of the housing support programs. Moreover, if follow-up studies perform longitudinal analysis using time series data, they will be able to provide more diverse policy suggestions and implications than those provided in this study.

6. Conclusions

The housing problem is a major concern and significantly affects people's lives. Those who cannot afford high housing costs are more likely to be driven out into a poor housing environment, and this negatively impacts housing as well as other areas of their life [3,63]. To solve the housing problem of low-income households, the Korean government has been implementing welfare policies and supporting vulnerable groups by introducing various housing support programs. In recent years, there has been a movement to promote the demand-oriented housing support program due to the limitations of the supply-oriented housing support program. However, few studies have covered this topic. Therefore, this empirical study investigated the effects of the public rental housing program and the housing allowance program on residential satisfaction and the housing cost burden.

The findings revealed that the housing support programs had differential effects on residential satisfaction and housing cost burden based on household attributes. As for public rental housing, the program generally had a positive effect on residential satisfaction. This finding is in line with a previous finding that the supply-oriented housing support program increases residential satisfaction [48,49]. However, the user status of the housing allowance program negatively affected residential satisfaction.

Further, the public rental housing program had a positive effect on reducing the housing cost burden among the whole sample and all household groups. This can be seen as reflecting the reality that tenants ineligible for public rental housing programs are bearing a relatively higher housing cost burden for *jeonsei* or monthly rent than households using the public rental housing. Further, the housing allowance program significantly affected young adult households. Households receiving the housing allowance had a greater housing cost burden than those not receiving the allowance. This means that the amount of housing assistance does not lower the housing cost burden among low-income families to a significant extent. However, these results need not be regarded as a failure of the housing allowance program, but as a basis for revising parts of the program, such as the current eligibility criteria and payment.

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Analyzing Spatial Location Preference of Urban Activities with Mode-Dependent Accessibility Using Integrated Land Use–Transport Models

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Abstract: Accessibility is the ease of reaching opportunities (goods, services, activities, and destinations). Accessibility of desirable locations such as households and commercial locations, is typically scaffolded by land use patterns and transportation infrastructure. It can reflect people's travel convenience, cities' viability, sustainability, and mitigate the negative effects on the environment and public safety. Consequently, it is recognized as a fundamental principle in urban sustainable development policies worldwide. In the literature, most of the studies have used a static or partially dynamic approach with a single mode such as a car or public transportation by using conventional models. These "static" models assume that household locations are static and that transportation supply and opportunities for social practice activities are fixed in time and space, which can lead to biased or even misleading assumptions in accessibility models. Therefore, the aim of this study is to evaluate the impact of dynamic spatial accessibility through Mode-Dependent Accessibility (MDA) on the location choice behaviors of urban activities such as households and commercialin the City of Wuhan, China. This study employed the Mode-Dependent Travel Demand Model (M-TDM) to measure the impact of short-term MDA on household and commercial activities for the years 2012 and 2015. Additionally, an integrated spatial economic (ISE) model such as PECAS (Production, Exchange, Consumption, Allocation, System) in order to investigate location preferences of urban activities over space and time. Regarding household and commercial location choice, the ISE modeling results revealed that households and commercial activities are sensitive to MDA, especially using transit. The ISE method predicted that the R^2 for household and commercial location choice models was 0.84 to 0.90 for transit-based accessibility, whereas the R^2 for logsum-based static models was 0.48 to 0.72. In addition, their findings suggest that highly accessible locations that are well served by auto are more appealing for household and commercial activities. The findings of this study will help urban planners, transportation planners, and policymakers take into account the dynamic nature of short-term MDA when zoning and allocating urban activities and public amenities, instead of using static accessibility.

Keywords: accessibility; urban planning; integrated land use—transportation models; multimodal spatial accessibility; PECAS model; Wuhan

1. Introduction

According to the United Nations Sustainable Development Goals (SDGs) 2030 agenda, cities, and human settlements should be inclusive, safe, sustainable, and resilient. Sustainable mobility is included in goal 11.2 of the United Nations SDGs. This goal states that all

citizens should have access to clean and safe transportation systems that are inexpensive, accessible, and sustainable, and that road safety should be improved by expanding public transportation and paying special attention to the needs of those in vulnerable situations, such as women, children, and the elderly [1]. Accessibility provides a central framework for the integration of transportation and land use planning, which is universally recognized to be vital for sustainable development and transit network planning [2]. Accessibility is the most important notion that has been proposed to define the relationship between land use and transportation. Improved accessibility can make a significant contribution to the quality of life [3]. Accessibility is the primary objective of transportation policy. It relates to the capability for interaction and exchange with services and facilities [4]. Transportation geography studies have been interested in it for a long time since it is a major subject of public transportation. In the literature, accessibility is typically defined as the ease of travelers to reach any activity location utilizing a specific transportation system [5]. Accessibility of desirable locations (such as households and commercial locations) is typically scaffolded by land use patterns and transportation infrastructure. It can reflect people's travel convenience cities' viability, and sustainability, and it can mitigate the negative effects on the environment and public safety. Consequently, it is a core principle in urban sustainable development policies worldwide [6]. Good accessibility enables people to participate more effectively in a number of activities such as going to school, work, hospital, shopping, and social interaction. Contrarily, poor accessibility offered by cities is the most significant hurdle to improved living standards and sustainable growth [6].

In the literature, spatial accessibility has received considerable attention, but the majority of previous studies have focused on jobs [7], food (restaurants, grocery) [8,9], and healthcare services (hospitals, emergency services) [8,10]. However, multimodal spatial accessibility improves the precision and predictability of measurements, capturing the dynamics of the real world. It was proposed to use multimodal transportation to overcome the constraint of conventional spatial accessibility metrics, which assumed only a single mode of mobility (i.e., automobile) and alternative forms of mobility (e.g., public transportation, bicycles, and walking) may be necessary for individuals with low socioeconomic status, as they may not have access to private vehicles [11]. Moreover, public transit accounts for a substantial proportion of travelers, particularly in large cities and among the elderly [12]. Mao and Nekorchuk [11] conducted the first study to evaluate multimodal accessibility in Florida using the two-step floating catchment area (2SFCA) method. They revealed that the single-mode technique tends to overestimate accessibility in urban areas with heterogeneous transportation modes while underestimating accessibility in rural areas with homogeneous transportation modes. These erroneous estimations arise from the assumption of a homogeneous mode, resulting in the identification of a larger underserved population. By taking into consideration multiple modes of transportation within populations, the multi-mode method yielded a more accurate estimate and hence provides better direction for policymakers to create cost-effective mitigation strategies. Several empirical findings, such as significant interregional and intermodal accessibility inequalities, have emerged from multimodal spatial accessibility research [13]. Most previous research employed a constant or static travel time, such as the average or peak hour travel time, to quantify accessibility, assuming that the travel time is fixed [14]. However, commuting occurs frequently during off-peak hours, as flexible work hours have become normal days. Constant travel time metrics may overestimate accessibility, undermining the credibility of accessibility studies. This overestimation may lead commuters to underestimate their travel time; consequently, they may not reach their destinations on time [15]. Accessibility of activity locations (households, commercial, and firms) and advances in the formulation and estimation of econometric models have led to tremendous development in urban planning/modeling in recent years [16]. However, the literature demonstrates that these techniques have largely ignored taking into account subtle details of accessibility, such as those relating to a specific time of day or mode [17,18].

Due to rapid motorization, urbanization, and population growth, cities in developing nations face severe challenges such as traffic congestion, traffic accidents, increasing demand for land, environmental pollution, and the impact on the existing demand and supply for the transportation system, which ultimately impacts public health, city sustainability, and the country's economy [19–21]. Most developed countries, such as the United States and countries in Europe, have implemented integrated land use—transport models for sustainable urban planning [22,23]. However, such models have not been implemented in most developing countries. To combat these issues, a few cities in the China mainland have begun to construct urban models that can integrate economic, land use, transportation, and environmental protection strategies during the planning process. Such models are utilized to examine the relationship between transport demand and changes in economic growth, spatial distribution/location choices of socio-economic activities, and resulting land use patterns, and to forecast their future evolution. Accessibility, which is seen as the crucial link between the transportation system and the land use system, is the fundamental analysis tool within such models and explains how the two interact across time and space. There are few studies that only examine MDA for auto and metro or bus by utilizing traditional models such as 2SFCA and gravity models [8,11,13]. Traditional accessibility parameters do not adequately account for the short- and long-term needs of urban activities. Accessibility is a dynamic attribute of locations that fluctuates by mode as a result of changes to the transport network and varying activity distribution patterns [15]. In principle, most economic activities are dependent on an acceptable level of accessibility in order to survive and develop, so a range of accessibility measures need to be considered rather than static accessibility. Therefore, it is crucial to create a solution that might provide a more effective planning tool for a thorough understanding of the urban system.

The objectives of this study are two-fold: first, to evaluate the impact of short-term spatial accessibility through Mode-Dependent Accessibility (MDA) on location choice behaviors of urban activities such as households and commercial locations in the City of Wuhan, China. This study proposed a hypothesis that the location preference of urban activities have a strong relationship with "dynamic" MDA measures, rather than traditional "static" accessibility value (e.g., those logsums calculated using the averaged or congested travel time and combining all available modes). Accessibility to population/employment distributed in the city varies depending on the type of activities that predominate, which can be analyzed from the population's digital footprint at each point in the city. Therefore, it should be reasonable to assume that such a dynamic nature of MDA may have a significantly greater influence than the traditional, static accessibility term (e.g., those using free-flow travel time) on the location choices of urban activities. This study uses dynamic short-term accessibility by considering the working hours of the day. This study uses auto (private cars and taxis) and public transit (metro, and bus) for measuring MDA. To comprehensively capture accessibility and location choice behaviors of urban activities, this study analyzes explicitly the effects of the metro and bus, as well as their combined effects. Second, this study employs the Mode-Dependent Travel Demand Model (M-TDM) to measure the impact of short-term MDA on household and commercial activities for the years 2012 and 2015. Additionally, an integrated spatial economic (ISE) model/integrated land use transport model such as PECAS (Production, Exchange, Consumption, Allocation, System) in order to investigate location preferences of urban activities over space and time. The PECAS approach imitates the spatial economic systems under consideration and has been improved with several distinct features such as an improved representation of socioeconomic systems through a social accounting matrix and microsimulation-based space development. It is built on the theories and experiences of its pioneers MEPLAN and TRANUS. PECAS model is a scientifically sound ISE model which has widely been used for forecasting and policy-making at urban and regional levels. The advantages of such short-term MDA could offer more significant results than conventional static accessibility on the location choices of urban activities. This study will assist stakeholders and policy-

makers in better understanding to develop effective policies and therefore enhance their urban planning exercises.

This study attempts to examine the impact of MDA on spatial economic activities by answering the following major questions:

(i) Which MDA measures are most valuable when choosing the home location of household activities?
(ii) Which MDA measures are most valuable when choosing the location by other socio-economic activities, such as commercial?
(iii) Are long-term location decisions of individuals or firms correlated with short-term "dynamic" accessibility factors such as those related to mode?
(iv) Does the accessibility to various activities (e.g., school, work, and shopping) by different modes influence the short-term or long-term location decisions of households or firms?

The rest of the paper is sequenced as follows: Section 2 presents an overview of the recent literature regarding accessibility measures and modeling approaches. Section 3 provides the study area and study data including transportation network data and land use data. Section 4 elucidates the methods including the multimodal travel demand model and multimodal integrated spatial economic models. Section 5 explains the study results and discussion. Finally, Section 6 delineates the main findings, limitations, and recommendations for future studies.

2. Literature Review

The accessibility concept was firstly introduced by Hansen in 1959 [24], and he stated that accessibility is the potential of opportunities for interaction and an assessment of the spatial distribution of activities around a point, adjusted for the ability and desire of individuals or firms to overcome physical separation. Accessibility can be broadly defined as the ease with which one place of activity can be accessible from another using a particular mode of transportation or any available modes (such as walking, bus, rail, bike, car, etc.) [25]. Accessibility is defined by Ben-Akiva and Lerman [26] as "the benefits offered by a transportation/land-use system." Bhat et al. [27] described accessibility as "the ease with which an individual can pursue an activity of a desired type, at a desired place, using a desired mode, and at a desired time." Accessibility is a primary focus of interdisciplinary research including transportation, health, economics, social sciences, urban studies, and geography [4,28]. The origins of spatial systems can be traced back to Tobler's law of geography, which states that "everything is connected to everything else, but nearby objects are more connected than distant things" [29]. Primarily, distance, speed, and travel time estimations, also known as impedance measurements, are used to determine accessibility in geographical systems [4]. Evaluating accessibility as the total travel time reduced by road users and the number of additional locations reached by various road users within their budgeted travel time is another practice [30]. In transportation planning, the terms accessibility and mobility are usually confused. Accessibility is the ease of reaching opportunities (goods, services, activities, and destinations), as opposed to mobility, which is the ease of moving people and goods. Mobility falls under accessibility. Accessibility reflects both mobility (the ability of individuals to travel) and land use patterns (the location of activities). This approach provides more importance to nonmotorized modes and accessible land use patterns. Multimodal transportation and more compact, mixed-use, walkable communities tend to optimize accessibility, hence reducing the amount of travel required to reach destinations [31].

In Europe and the United States, we have witnessed a revitalization of city centers over the past two decades, despite the increasing accessibility of metropolitan regions [32]. This re-urbanization is perhaps driven primarily by younger generations, the so-called millennials (roughly, those born in the 1980s and 1990s) [33]. Young households prefer to reside in urban areas that are easily accessible and have enough public transportation, as opposed to the sprawling, automobile-dependent suburbs [33,34]. A previous study

on household location preferences in Paris revealed that renters place greater value on a location's accessibility than owners [35]. Another study conducted in Canada indicated that households were more sensitive to accessibility with time [36]. In addition, Inoa et al. [35] identified commuting time as a crucial element in household decision making, which is true in European cities with larger population densities and better access to public transportation than in developing countries. In developing countries with a high rate of unemployment, households are often ready to travel further or even walk the entire distance to work. Zhang et al. [37] examined public transit-based accessibility to healthcare services in Shanghai. They selected census tracts in central Shanghai that are less accessible to health facilities via public transportation. In contrast, the accessibility of peripheral areas is adequate, despite the lack of neighboring healthcare facilities.

According to a recent study, Ahuja and Tiwari [4] stated that the selection of accessibility measures depends on the context of the application. The fundamental strategy for measuring accessibility can be divided into six categories: (i) Infrastructure approach: this focuses on the speed, travel time, length of the road, density of the road network, and overall congestion level in terms of lost vehicle hours are the major measures. (ii) Activity approach: this focuses on catering to accessing activities. The majority of measures consist of land use and location, potential paths, dwelling, working, recreation, shopping, and the number of activities available within a specific range of travel time or distance. (iii) Individual's personal preferences approach: this focuses on an individual's traits, activities, and preferences. Measures range from a person's socioeconomic variables (car ownership, education, age, and gender) to his or her attitudes and views towards use. (iv) Social exclusion and geographic location approach: this considers an area access/geographical location when the aggregation is at the community level. Although the individualistic method may appear disaggregated and unachievable for inclusive planning, it enables us to understand the fundamental components of all accessibility research. (v) Utility-based approach: this is based on the benefits acquired by people when accessing spatially dispersed activities, opportunities, and challenges, taking into account individual characteristics, characteristics of different transport modes, time budgets, speed, spatial-temporal constraints, and daily activity schedules. (vi) Mixed-measures approach: this is used when there are numerous focal points such as travel costs (monetary, time, risk, comfort, and quality attributes), volume (number of individuals, vehicle units, bus stops, etc.), and location (from one place to another or many places to many places).

The measurements of spatial accessibility are derived from the interaction of three input variables: supply (i.e., locations of infrastructure), demand (i.e., locations of expected infrastructure users), and mobility (i.e., travel costs from demand locations to supply locations). Sometimes, other variables, such as distance decay functions and threshold travel time, are introduced into measurements to indicate the population's desire to visit infrastructure [38]. In the literature different approach has been employed for the measurement of spatially accessibility such as the gravity model, Shen's model, and 2SFCA [13]. Firstly, in the gravity model, also known as the cumulative opportunity model, the number of opportunities (i.e., supply facilities) accessible from a given place while taking spatial impedance into account is determined [24]. Secondly, Shen enhanced the precision of geographic accessibility measurement by including a new variable (i.e., demand), whereas the gravity model assumes a homogeneous distribution of individuals [39]. Thirdly, the 2SFCA technique addresses the limitation of Shen's model, in which every supply facility is assumed to serve every demand location in the case of an inappropriate distance decay function. A threshold travel time is incorporated into the model to reflect the desires of the consumer and to identify the areas accessible within the threshold travel time, such as a catchment area [40].

Several Land Use Transportation Interaction (LUTI) models have been developed over the past decades for location preference and interactions of urban activities, including the Lowry model, IMREL, MEPLAN, TRESSIS, METROSIM, MUSSA, URBANSIM, REURBAN, TLUMIP, TRANUS, DELTA, and PECAS [41–51]. These models estimate production and

consumption positions in the metropolitan area using a multi-industry, multi-regional input–output system, with households of various types regarded as labor-producing industries and commodity-consuming industries. PECAS is one of the recently developed integrated land use—transport modeling frameworks. It integrates land use, transportation, the economy, and the environment. The PECAS approach has been implemented in various locations around the world over the last 18 years, including the following: Oregon (statewide), California (statewide), Atlanta, San Diego, Los Angeles, and San Francisco, USA; the City of Edmonton, Province of Alberta, Canada; Caracas, Venezuela; Mumbai, India [52].

In conclusion, each accessibility measure has benefits and drawbacks. Thus, researchers should select the best approach based on their study interests, objectives, and data collection. Most previous research employed a static travel time, such as the peak hour and off-peak hour travel time, to quantify accessibility, assuming that the travel time is fixed and static. These "static" models assume that household locations are static and that transportation supply and opportunities for social practice activities are fixed in time and space, which can lead to biased or even misleading assumptions in accessibility models. Nevertheless, the primary components of accessibility, such as opportunities and social activities, are dynamic and influence the location selection behavior of activities [9]. The majority of previous research evaluated accessibility using a single mode or transit mode with a fixed time, such as peak hours [9,53]. On the other hand, people's preferences vary according to the time of day and transportation modes. When directly comparing accessibility indicators in different geographical regions, the majority of them fail to account for spatial variability. Hence, it is feasible that high accessibility zones, however, lack public transportation services, which earlier methods cannot identify. Therefore, comparing the degree of public transportation services in areas with similar spatial proximity to urban activity is more reasonable. In this context, by including spatial heterogeneity in the evaluation criterion, this study intends to improve spatial accessibility to urban activities. Furthermore, there has been little research on the accessibility of urban activities such as residential, commercial, and industrial locations. Existing models failed to capture fine features of accessibility, particularly their temporal and mode distribution. The current trends in transportation and urban planning are not sustainable, and improvements in transportation and land use systems are required to meet the needs [54]. Thus, the purpose of this study is to contribute to the current literature by investigating the location choice behavior of urban activities with the MDA employing advanced ISE models, i.e., the PECAS model. The advantages of this method are that it captures very fine details of how various urban activities (such as households, businesses, firms, and so on) are located. The PECAS model is a scientifically sound integrated spatial economic model that has been widely utilized for forecasting and policy formulation at the municipal and regional levels [52].

3. Data Collection

3.1. Study Area

This study considers the City of Wuhan as a Case study, as shown in Figure 1. Wuhan is the capital city of Hubei Province, China. The City of Wuhan is located at 29°58′–31°22′ north latitude and 113°41′–115°05′ east longitude. The City of Wuhan has jurisdiction over thirteen districts. The City of Wuhan includes 690 Traffic Analysis Zones (TAZs) and 147 Land Use Zones (LUZs), with a population of 10.1 million permanent residents by 2012, comprising 6.83 million urban population and 3.28 million rural population. The population increased to 10.6 million by 2015, with the urban population increasing to 7.48 million and the rural population decreasing to 3.11 million because of the urbanization process. As of 2020, the population of Wuhan was 12.48 million (http://tjj.wuhan.gov.cn/tjfw/tjnj/ (accessed on 15 January 2021)).

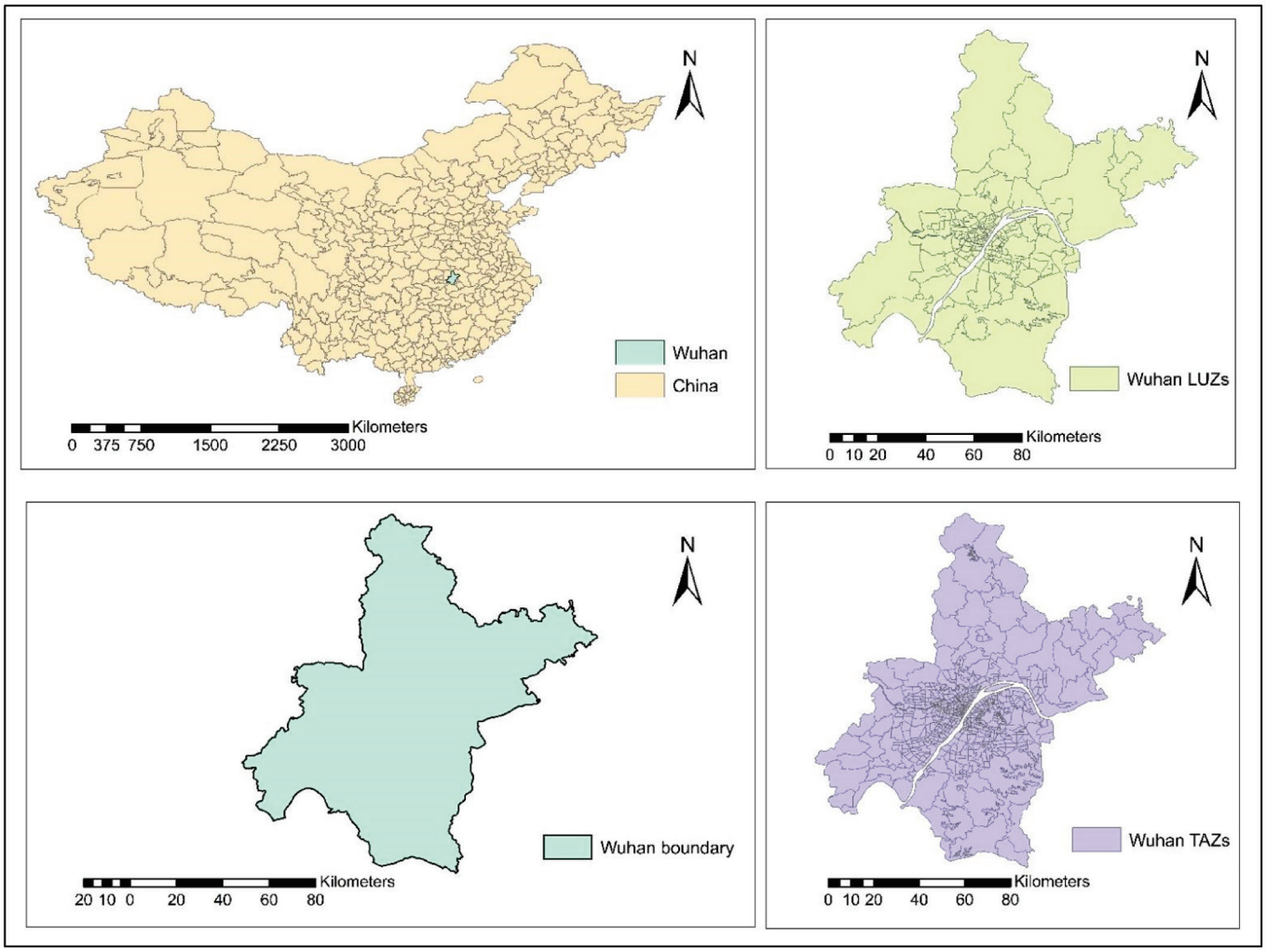

Figure 1. Study area, Wuhan City, China.

3.2. Study Data

Urban and rural households and employment by industry type are major datasets used in the development of the M-TDM and ISE models. The rural and urban households and average household size data were obtained from Wuhan statistical Yearbooks (http://tjj.wuhan.gov.cn/tjfw/tjnj/ (accessed on 10 March 2021)). However, the employment by industry data was obtained from Wuhan Transportation Planning Institute (WHTPI). The household travel survey (HTS) data which is a primary source of information that contains all vital information to understand and quantify travelers' traveling behavior using the actual transport network are obtained from WHTPI (http://www.whtpi.com/Default.html (accessed on 10 March 2021)). This dataset contains, the number of trips by modes, total trip time, trip distance, trip origin and destination, gender, and age of trip makers.

The development of M-TDM for two cross-sectional years, 2012 and 2015, need various levels of networks such as road network and public transit network. The road network contains link type information, link distance, free-flow speed, daily link capacity by link type, and the number of lanes in each road link, as presented in Table 1, and the transit network contains detailed information about transit, as shown in Table 2. A well-connected transit network encourages the commuter to use a transit system that enables easy transfer between different transit modes (such as bus to bus, bus to metro, metro to bus, and metro to metro). An extensive transit network was developed to capture the fine details of the transit system. This includes a complete representation of transit lines and stations, transfer times, transfer links, walking to and from transit stations, different transit fare systems

(static fare system for bus and distance-based fare system for metro), and other relevant information presented in Table 2. Figure 2 depicts the transit network of Wuhan, China, in 2015, including the metro, bus, and their corresponding stations.

Table 1. Road network attributes.

Road Network	Description
Link Type	Freeway, expressway, arterial, collector, and local roads
Distance	Link distance (km)
Road Capacity	Daily capacity of each link
Lanes	Number of lanes in each link
AADTs	Average annual daily traffic counts collected at main road corridors
Screen Lines	Screen line number associated with each AADT (used for model calibration)
Speed	Free flow and Congested speed

Table 2. Transit network attributes.

Name	Bus Name/Metro Name	
Time	Congested time (minutes)	
Distance	Lines distance (km)	
Line ID	Bus and Metro line number	
Fare	Static fare for bus and distance-based for Metro	
Waiting time	Initial waiting time at and transfer waiting time at bus and metro station	
Modes	Metro	Bus
Transfer distance allowed (meters)	550 (Metro to bus, metro to metro)	550 (bus to metro, bus to bus)
Walking distance allowed (meters)	960	650
Average Service Frequency of modes (minutes)	5	6

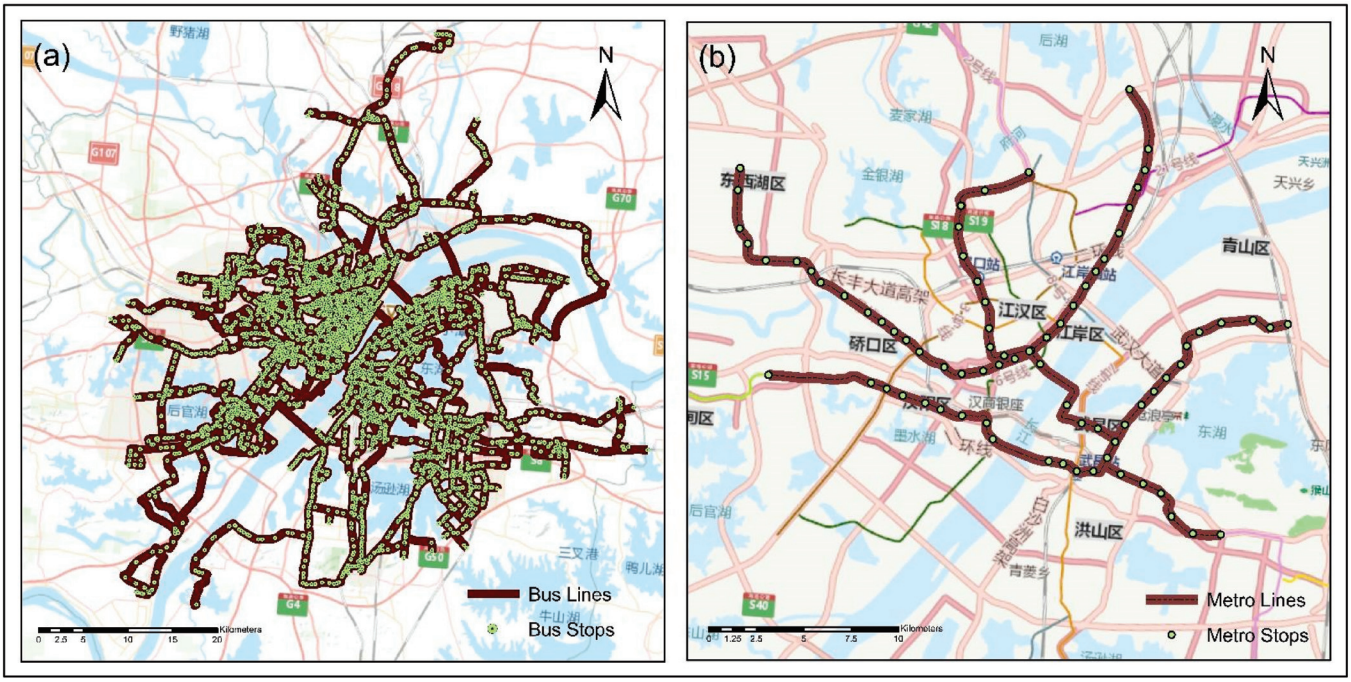

Figure 2. (**a**,**b**) Transit network of Wuhan in the year 2015: (**a**) bus lines and stops; (**b**) metro lines and stops.

Walking and transfer distance thresholds are specified to enable transfer with the specified distance limits. The transfer distance thresholds are used to avoid the generation

of unnecessary non-transit legs during the route enumeration process. Two curves were developed to calculate waiting and transfer times, as shown in Figure 3.

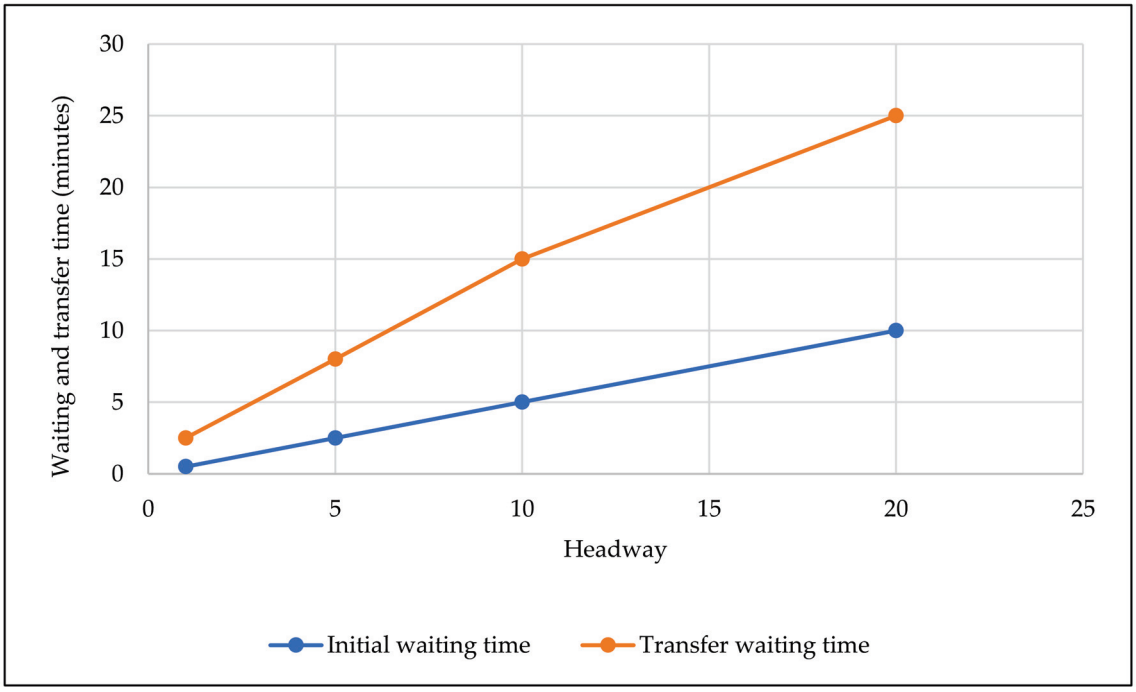

Figure 3. Initial waiting and transfer waiting for curves.

The initial waiting time curves were used to calculate the initial perceived waiting time (minutes) at bus and metro stations. The initial waiting time calculated is half of the headway, as shown in Figure 3. Meanwhile, the transfer waiting time curve is developed to calculate transfer waiting time at bus and metro stations. Usually, the transfer waiting time is perceived differently compared to the initial waiting time as shown in Figure 3. Most of the commuters prefer direct routes which involve no transfer or minimal transfer waiting and walking times. The initial waiting time and transfer waiting time were used during the route evaluation process to find the best path from origin 'i' to destination 'j', with minimal walking, transfer, and travel cost.

Land Use Data

The land use data in Figure 4 shows aggregate spatial input–output data which represents the interaction of activities and commodity flows. These input values represent the amount of economic activity for a particular combination of sectors. The land use data includes various industrial sectors (such as agriculture, industry, and commercial household activities (such as urban and rural), commodity types (including agricultural products, industrial products, commercial products, and transport products), labor types (such as management and technical labor, retail labor and outdoor labor) and space types (such as residential, commercial and industrial). For instance, household activity produced labor and consumed various commodities during this process, and it also consumed residential space during the allocation process, which could be done at either LUZ or TAZ level.

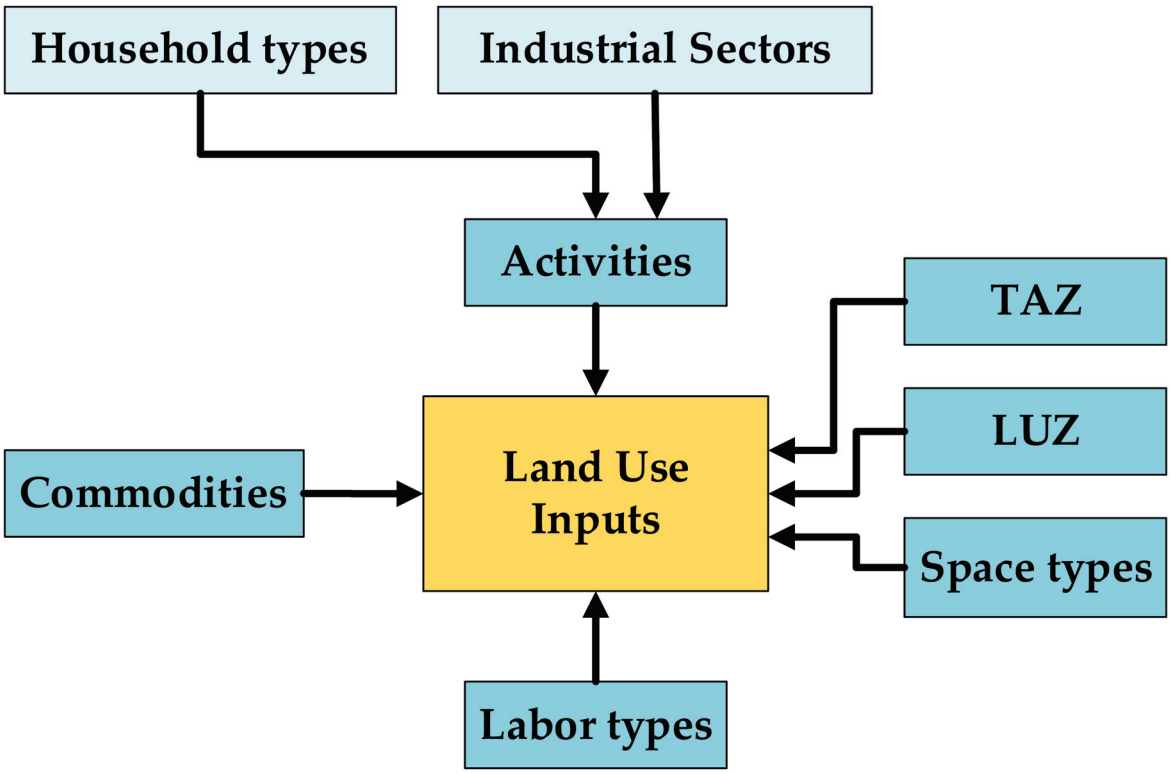

Figure 4. Land use input data types.

4. Method

In this study, a M-TDM was developed at the TAZ level to calculate MDA to various activity locations (such as households and commercial). Additionally, the accessibility measures from a multimodal are input into ISE models such as the PECAS model. The ISE model estimates the locations based on MDA measures inputs, and as a result, it influences the location/allocation of urban activities (such as households, businesses, firms, etc.) over time and space [47]. This study used an advanced transport modeling tool, Cube Voyager version 6.5, and ArcGIS version 10.8 software to develop a multimodal transport system.

4.1. Multimodal Travel Demand Model

The developed M-TDM is used to calculate MDA (such as time, distance, and logsum) to various activities located within the study area. The M-TDM for the years 2012 and 2015 is developed using socioeconomic data (such as population, and employment). Additionally, M-TDM is calibrated and validated for the years 2012 and 2015. The developed M-TDM model for the years 2012 and 2015 was used to calculate MDA for goods, services, labor, and other activities, as shown in Figure 5.

As discussed earlier, a multimodal transport model was developed for the years 2012 and 2015 using the road network, transit routes, LUZs, and TAZs. The M-TDM development starts with the calculation of trip production and attraction rates using population, employment, and household travel survey data. The friction factors (FF), which are input into trip distribution, were calculated using the travel survey data. Furthermore, the FF are smoothed using the gamma distribution approach before being input into the trip distribution model. Trip length frequencies by trip purpose were calibrated and verified against the observed trip lengths obtained from travel survey data. Transport utilities by trip purpose (such as home-based work, home-based other, home-based school, and non-home-based) and by modes (such as metro, bus, taxi, personal car, and bike) were calculated and input into the nested logit model, as shown in Table 3. The value of α varies depending on trip purpose and availability of a personal car. In this study, home-based work and home-based other trips by car are considered. As mentioned in Section 3.2, the

various modes of transportation attribute coefficients such as in-vehicle time, waiting time, walking time, metro and bus fare, transfer time, and cost per km by different trip purpose (HBW, HBO, HBS, and NHB) were obtained from the Wuhan Transportation Planning Institute (WHTPI) (http://www.whtpi.com/Default.html (accessed on 10 March 2021)).

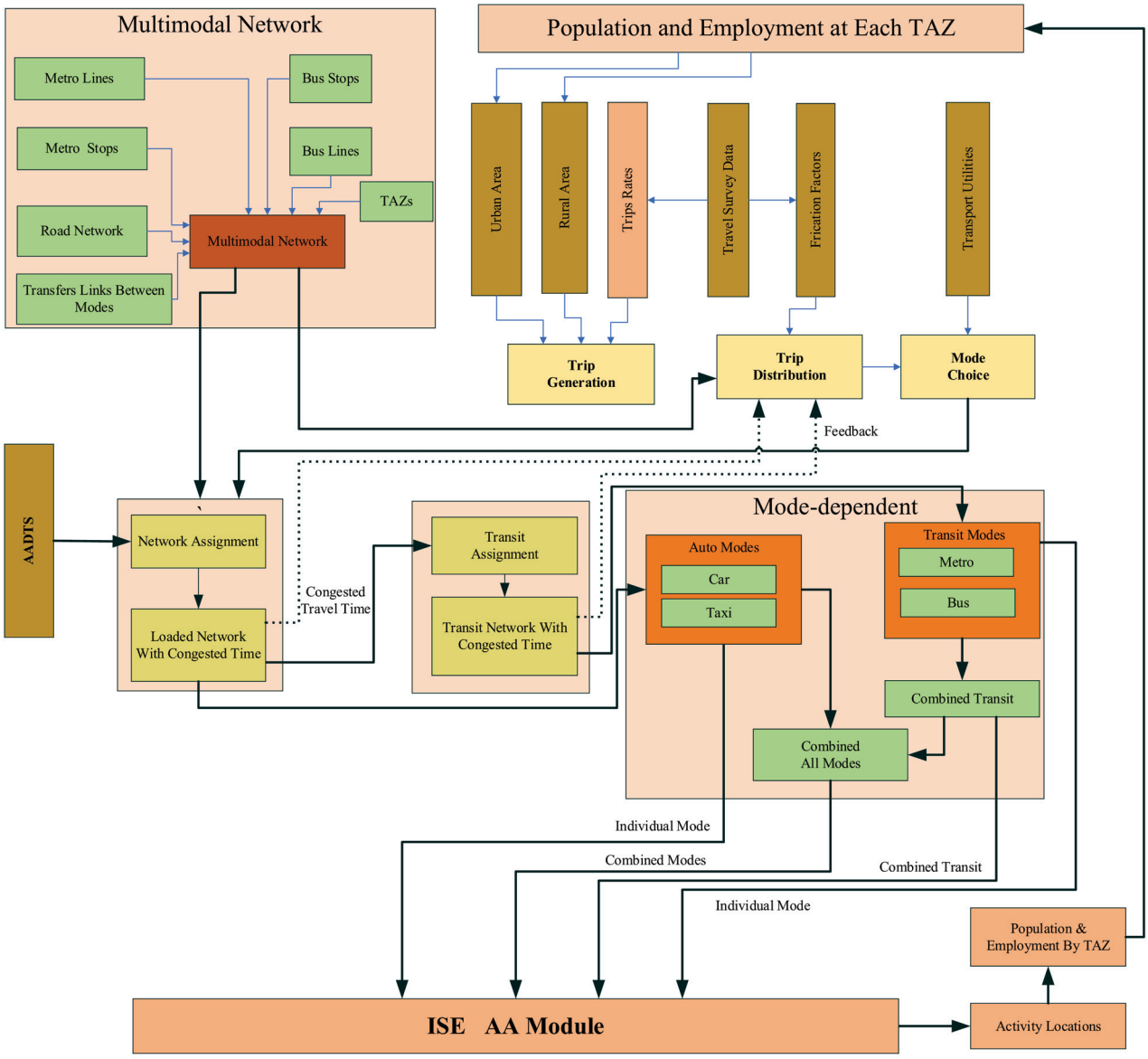

Figure 5. Workflow of mode-dependent transport model.

Equations (1)–(5) determine the individual's preferences for a specific transport mode for specific trip purposes. The structure of the nested logit model is illustrated in Figure 6.

$$U_{Metro} = \alpha1 \times IVT + \alpha2 \times IWT + \alpha3 \times WT + \alpha4 \times MF + \alpha5 \times MMTT + \alpha5 \times MTBT \quad (1)$$

$$U_{Bus} = \alpha1 \times IVT + \alpha2 \times IWT + \alpha3 \times WT + \alpha4 \times BF + \alpha5 \times TT \quad (2)$$

$$U_{Taxi} = \alpha1 \times IVT + \alpha2 \times WT + \alpha3 \times DC \quad (3)$$

$$U_{Car} = \alpha1 \times IVT + \alpha2 \times WT + \alpha3 \times DC \quad (4)$$

$$U_{Bike} = \alpha1 \times IVT + \alpha2 \times WT \quad (5)$$

where the following are defined:

- IVT = in-vehicle time (actual time);
- IWT = initial waiting time at bus and metro station;
- WT = walking time from home to bus and metro station;
- MF = metro fare;
- MMTT = metro-to-metro transfer time;
- MTBT = metro-to-bus transfer time;
- BF = bus fare;
- TT = bus-to-bus and bus-to-metro transfer time;
- WT = waiting time (in case of taxi), access time in case of car and bike;
- DC = cost per km drive.

Table 3. Transport utilities by modes.

	Home-Based Work (HBW) Car Available						**Home-Based Other (HBO) Car Available**					
Modes	α1	α2	α3	α4	α5	α6	α1	α2	α3	α4	α5	α6
Metro	−0.02	−0.04	−0.04	−0.039	−0.1	−0.2	−0.02	−0.04	−0.04	−0.078	−0.1	−0.2
Bus	−0.02	−0.04	−0.04	−0.039	−0.2		−0.02	−0.04	−0.04	−0.078	−0.2	
Taxi	−0.02	−0.04	−0.039				−0.02	−0.04	−0.078			
Car	−0.02	−0.04	−0.039				−0.02	−0.04	−0.078			
Bike	−0.02	−0.04					−0.02	−0.04				
	Home-based school (HBS)						**Non-home-based (NHB)**					
Modes	α1	α2	α3	α4	α5	α6	α1	α2	α3	α4	α5	α6
Metro	−0.02	−0.04	−0.04	−0.305	−0.1	−0.2	−0.02	−0.04	−0.04	−0.114	−0.1	−0.2
Bus	−0.02	−0.04	−0.04	−0.305	−0.2		−0.02	−0.04	−0.04	−0.114	−0.2	
Taxi	−0.02	−0.04	−0.305				−0.02	−0.04	−0.114			
Car	−0.02	−0.04	−0.305				−0.02	−0.04	−0.114			
Bike	−0.02	−0.04					−0.02	−0.04				

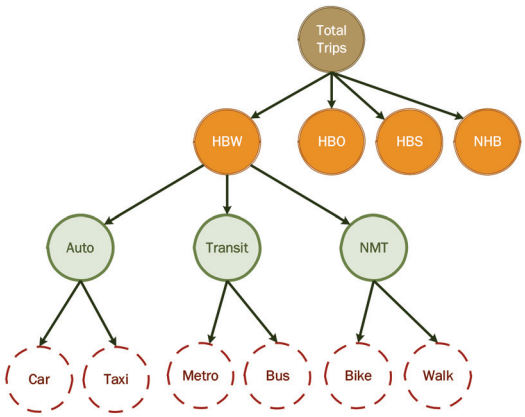

Figure 6. Nested logit model.

The mode choice module uses congested travel time, transport utilities, and scaling parameters (calculated and calibrated against observed mode shares by mode type) to split trips by different modes. Finally, network assignment (user-equilibrium) and transit assigned (multi-routing) is calculated and calibrated against annual average daily traffic (AADTs) counts. The M-TDM calibration was performed at trip generation, distribution, mode choice, and assignment level. After the M-TDM was fully calibrated and converged, the MDA measure was calculated using Equation (6).

$$A_i = \ln \sum_{j=1}^{n} e^{(\phi_T Transport_{UMij}) \times O_J} \quad (6)$$

where the following are defined:

- A_i = Utility-based accessibility measure;
- Transport_{UMij} = Transport utility (disutility) from origin i to destination j using mode M;
- ϕ_T = Transport Coefficients (these represent the sensitivity of commuters to mode and trip type;
- O_J = Opportunities at destination zone j (in the case of households, jobs are considered as the opportunities, while in the case of commercial services, the residential population is considered as the opportunity).

Furthermore, the MDA (congested mode-specific skims), which is input into the ISE model, is used to calculate the locational preferences of urban activities as shown in Figure 5.

4.2. Multimodal Integrated Spatial Economic (ISE) Models

Several ISE models (such as auto-based, metro-based, bus-based, and transit-based) were used in this study. The graphical representation of the ISE model framework is depicted in Figure 7. The major components of the developed ISE models are:

1. Economic and demographic module: This module consists of economic and demographic information about the study area including population and employment.
2. Activity Allocation (AA) module: The AA module of the multimodal ISE model is using nested and additive logit theory, for the location/allocation of urban activities. The AA module of the ISE model is an aggregate representation of urban activities, commodities flow between origin and destination, markets (selling and buying) with aggregate demands and supplies, and exchange prices, which are usually determined at the exchange locations.
3. Space development (SD) module: The SD module of the multimodal ISE represents real-estate developer behavior (developed space based on the market demand). This module is sensitive to market prices and developed space accordingly.
4. Transport module: The transport model was developed to calculate MDA for various activity locations within the study area, for the years 2012 and 2015.

As mentioned earlier SD module uses the price signal (market prices sets during location/allocation of activities) to develop the space. The formulation of the SD module is given in Equation (7).

$$F = max\left[1, \quad F_b + \exp\left(\frac{(P * \beta - P_b)}{P_b}\right)\right] \tag{7}$$

where the following are defined:

- F = Factors applied to the current space;
- β = Scale factors;
- P = Current price;
- P_b = Base price.

The factors represent the growth factors applied to the current floor space, which is further input into the next modeling yea (Year T+1).

The primary function of the M-TDM is to provide access to other people and companies so that they can participate actively in all kinds of spatially and temporally distributed activities (social, economic, etc.) and exchange information, goods, and services in a physical manner [18]. The AA module represents activity locations that occur as a result of the location choice behavior of activities based on the nested and additive logit approaches.

The locations considered for this study were TAZs which were large enough to be distinct markets for the location/allocation of various activities over time and space. The relation between MDA and location choice of activities is well understood using mode-specific ISE models. To evaluate the locational choice behavior of activities using MDA, it is important to understand which mode influences the locational preferences of activities more. The specific modes used in the study considered the auto mode (car and taxi), metro,

bus, and combination of bus and metro (transit) for both production and consumption of urban activities.

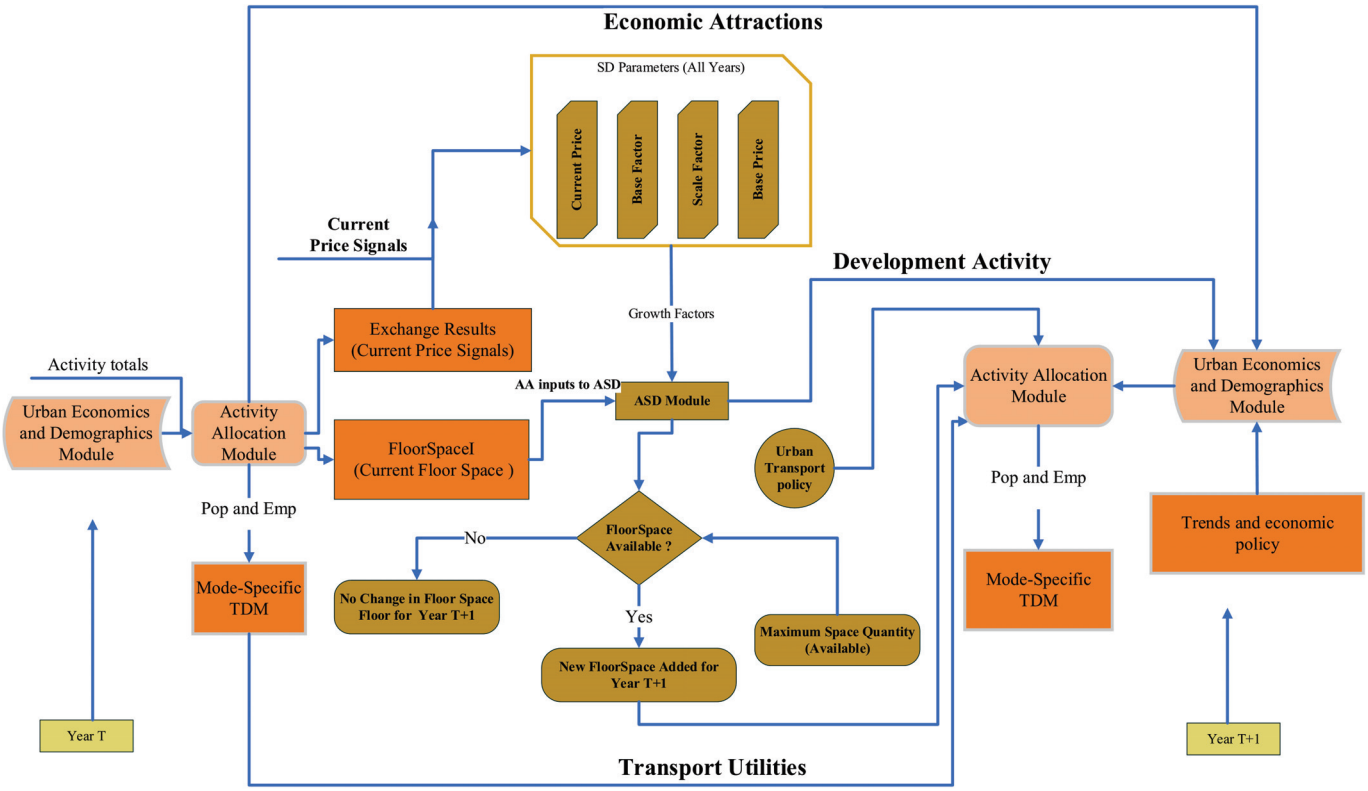

Figure 7. ISE model design diagram.

4.3. Simulating Activity Location Choices with the ISE Model

The random utility maximization approach was adopted to simulate the location decisions of the activities (household and industrial sector). It is assumed that the agents (such as households, businesses, and firms) assign a utility to each zone and choose the one that maximizes it. In the ISE, joint choice utility is calculated using Equation (8).

$$Utility_{d,k} = \frac{1}{\lambda} ln \sum_{z=0}^{n} e^{\lambda(\phi_{T,d} Transport_{z,k,d,M} + \phi_{p,d} Price_{z,d} + \frac{1}{\lambda} lnSize_{z,d})} \quad (8)$$

- D = buying (consuming) or selling (producing) the commodity;
- k = index for zone of production or consumption of the commodity;
- z = index for an exchange zone;
- λ = dispersion parameter for the exchange location choice for the commodity;
- $Size_{z,d}$ = an indicator of the relative amount of the commodity offered in exchange zone z;
- $\phi_{T,d}$ = transport cost coefficient;
- $Transport_{z,k,d,T}$ = transport cost between z and k for d = buying and selling, M = transporting modes;
- $\phi_{p,d}$ = price coefficient (always set to 1 for d = selling and -1 for d = buying because the utility is in monetary units);
- Price z = price of a commodity in z;
- Ln = natural log.

The utility of transporting a unit of each commodity from origin to destination zone was using the transport attributes from M-TDM.

5. Results and Discussion

5.1. Results

The developed multimodal ISE models were used to determine the relationship between MDA and location preferences of urban activities within the study area. In the case of ISE models, the households are producers of labor, and this labor is consumed by industries and firms during the production process. Likewise, firms and industries are the producers of jobs, and these jobs are consumed by households. The location choice behavior of household and industrial sector activities was further classified: (i) locational preferences of household activities; (ii) locational preferences of commercial services (household-obtained services such as retail services).

In general, most economic activities rely on an appropriate level of accessibility to survive and progress; hence, a variety of accessibility approaches must be considered. As previously stated, for the years 2012 and 2015, M-TDM was built, calibrated, and validated before being used to calculate MDA. The MDA measure is used to calculate short-term dynamic accessibility to goods, services, and other activities located in the City of Wuhan using different modes. The MDA considers only main modes of transport (such as auto, bus, and metro) and excludes non-motorized modes such as walking and biking as they do not affect traffic congestion. The flow of commodities from where they are produced to where they are consumed influence the transport system. The location/allocation of these activities changes the attractiveness of the location for households, businesses, and firms. The utilities (Equation (8)) are critical in driving decisions in the ISE system. These utilities influence the location choice behavior of households, businesses, and industries. Because these activities are subject to commodity utilities, changes in the utility function affect consumers and producers of the given commodity for households and other activities.

Goods and services are grouped based on their defined industry. These groups interact with each other over time and space using a transport system. Households are social units that typically provide labor, and consume goods and services. Meanwhile, as illustrated in Figure 8, industries, firms, and businesses produce goods and consume labor during the location/allocation process.

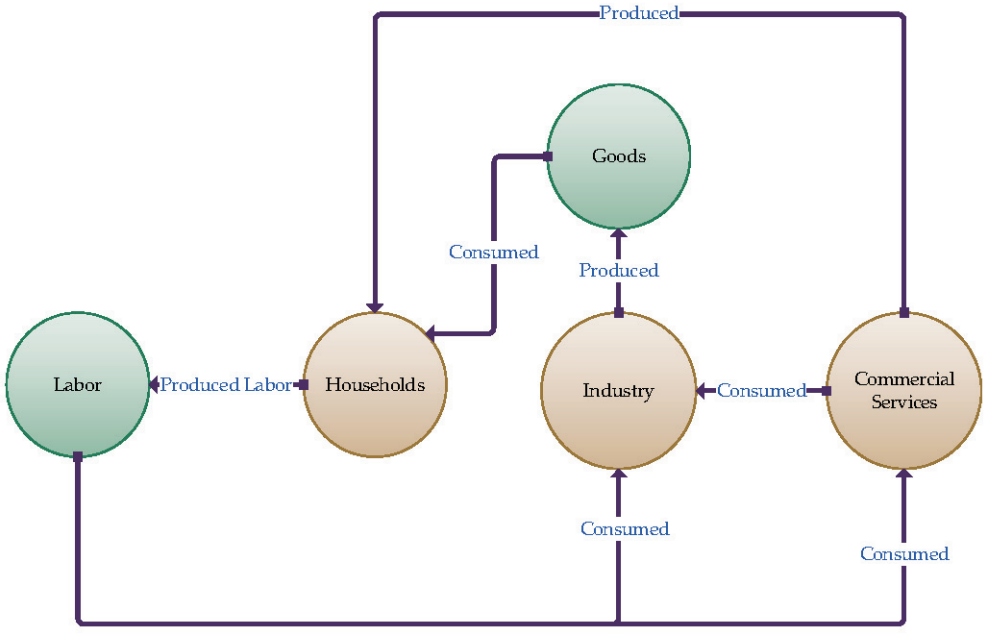

Figure 8. Location choice behavior of urban activities.

Table 4 depicts activities, commodities, and their production and consumption process. The connectivity between TAZs is based on the congested network (time, distance, logsum, etc.) by different modes. The transport utilities which, in transport terms, are referred to

as disutilities are used by the ISE model during the location/allocation process. These disutilities influence the buying and selling of various commodities at each TAZ.

Table 4. Locational preferences of activities parameters.

Activity Type	Commodity	Labor, Services, and Goods Type	Consume By	Transport Modes	Utility (Disutility)
Households	Labor	Management and technical labor Retail service labor Operators labor Other labor	Industry and services	Auto, bus, metro, and combinations	logsum
Commercial services	Services	Commercial services	Households and industry		

The primary hypothesis is that residents prefer a location close to their job place or prefer a place with high accessibility to their primary needs using a specific transport mode. The results revealed that the actual influence of residential location and accessibility to the desired job location depends primarily on the underlying geographical location (spatial) and temporal (transport mode).

Overall, the R^2 for the models show a strong relationship between MDA and residential locations where most of the adjusted R^2 value were found higher than 0.81. Results revealed that there is a significant improvement in the residual square from the year 2012 to 2015, due to the improved level of transit accessibility in the year 2015, as shown in Table 5.

Table 5. Results for the MDA to household activities.

Year		2012	2015
Auto	Residual Squares	23.79	59.16
	R^2	0.71	0.79
	Adjusted R^2	0.63	0.75
Bus	Residual Squares	49.72	102.50
	R^2	0.46	0.64
	Adjusted R^2	0.32	0.62
Metro	Residual Squares	49.98	102.06
	R^2	0.46	0.64
	Adjusted R^2	0.32	0.63
Transit	Residual Squares	21.34	43.77
	R^2	0.77	0.85
	Adjusted R^2	0.70	0.81

Table 6 presents the results for the MDA to commercial activities. Overall, the results showed that there is a strong relationship between MDA and commercial locations. For the years 2012 and 2015, the adjusted R^2 value for transit was 0.81 and 0.89, respectively. Additionally, the results indicated that transit accessibility to commercial locations had a high R^2 value as compared to auto, bus, and metro.

Accessibility indexes (AI) provide a synthetic measurement of the ability to reach a particular type of opportunity from a place of origin using a particular type of mode used to present the MDA levels at each TAZ. For instance, higher values of AI represent high accessibility using specific transport modes. Meanwhile, the household location index (HLI) and commercial location index (CLI) terms are used to represent the ISE model estimated household and commercial locations. For instance, higher values of HLI and CLI represent a high density of household and commercial locations in each TAZ, while low HLI and CLI represent the low density of household and commercial locations in each TAZ.

Table 6. Results for the MDA to commercial activities.

Year		2012	2015
Auto	Residual Squares	493.37	142.87
	R^2	0.72	0.84
	Adjusted R^2	0.69	0.80
Bus	Residual Squares	550.60	137.70
	R^2	0.50	0.53
	Adjusted R^2	0.49	0.49
Metro	Residual Squares	547.63	136.73
	R^2	0.70	0.70
	Adjusted R^2	0.63	0.63
Transit	Residual Squares	35.52	2.52
	R^2	0.81	0.91
	Adjusted R^2	0.81	0.89

5.1.1. Locational Preferences for Household Activities

Labor is produced by households and consumed by businesses, firms, and other industries. The industry sectors including import and export, labor wages, production, and consumption are defined in terms of the (Chinese Renminbi—RMB) and households are defined in terms of household numbers. The commuting costs between origin and destination for commodity flows are calculated during the model run, and wages of labor are adjusted to match the supply and demand in each location for each occupation. The occupation in each industry was used to categorize employment by industry.

Figure 9a,b shows the result of AI to household activities (such as accessibility to work and other activities) for the years 2012 and 2015 using auto (car and taxi) mode. The results revealed that most of the study area was accessible using auto as a commuting mode. Additionally, it was found that the AI, especially in the downtown areas where most households lives and work, were high (AI ranges between 12–16), as shown in Figure 9a,b. However, this result is intuitive that a majority of households living in the downtown area prefer other modes such as metro and bus for their daily commute. In Figure 9a,b, the ranges of AI values indicate the following: low accessibility (0~8.0); low–medium accessibility (8.1~10); medium accessibility (10.1~12); medium–high accessibility (12.1~14); high accessibility (14.1~16).

As indicated earlier, auto as a commuting mode provides accessibility to the entire study area; as a result, it was found that households with private cars prefer locations with high auto accessibility. The household location index (HLI), which is the result of the allocation process (Equation (8)), is adopted to indicate the location choice behavior of urban activities. Figure 9c,d presents the range of HLI as a result of ISE estimations using auto-based accessibility for the years 2012 and 2015. The HLI ISE-estimated value ranges using auto mode are as follows: low level of household locations (0.0~1.0); low–medium level of household locations (1.1~1.5); medium level of households location (1.6~2.0); medium–high level of household locations (2.1~2.5); high level of household location (2.6~4.0).

Figure 10a,b shows accessibility to household activities (such as accessibility to work and other activities) using the metro for the years 2012 and 2015. In 2012, there were only two metro lines; however, in 2015, there were three metro lines with limited stations, which only provided access to a limited area. In Figure 10a,b, the range of AI values represents no accessibility (0.0), low–medium accessibility (0.1~10), medium accessibility (10.1~12), medium–high accessibility (12.1~14), and high accessibility (14.1~16).

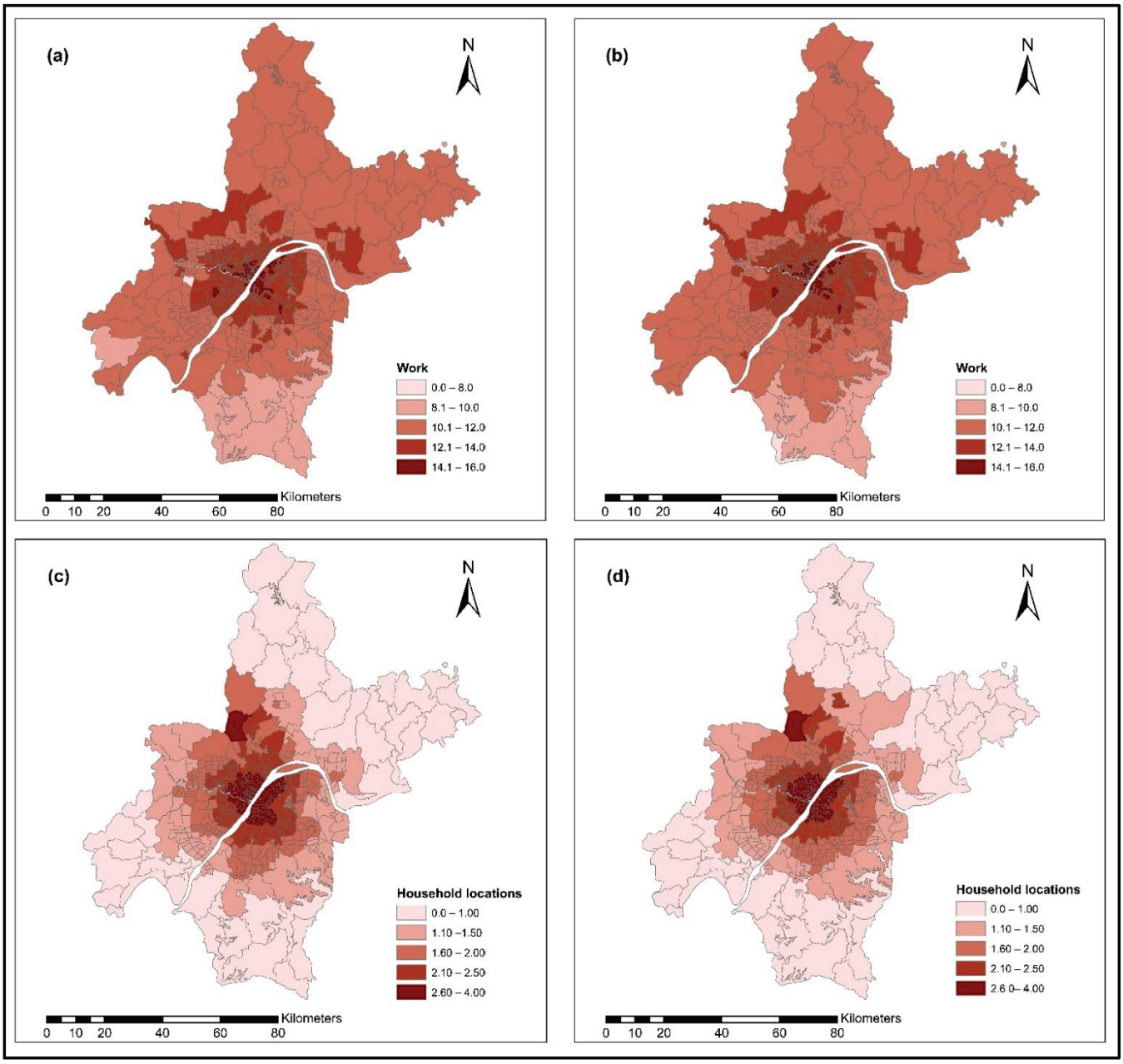

Figure 9. (**a**–**d**) Accessibility to household activities and ISE household locations: (**a**) accessibility using auto for the year 2012; (**b**) accessibility using auto for the year 2015; (**c**) household locations using auto during 2012; (**d**) household locations using auto during 2015.

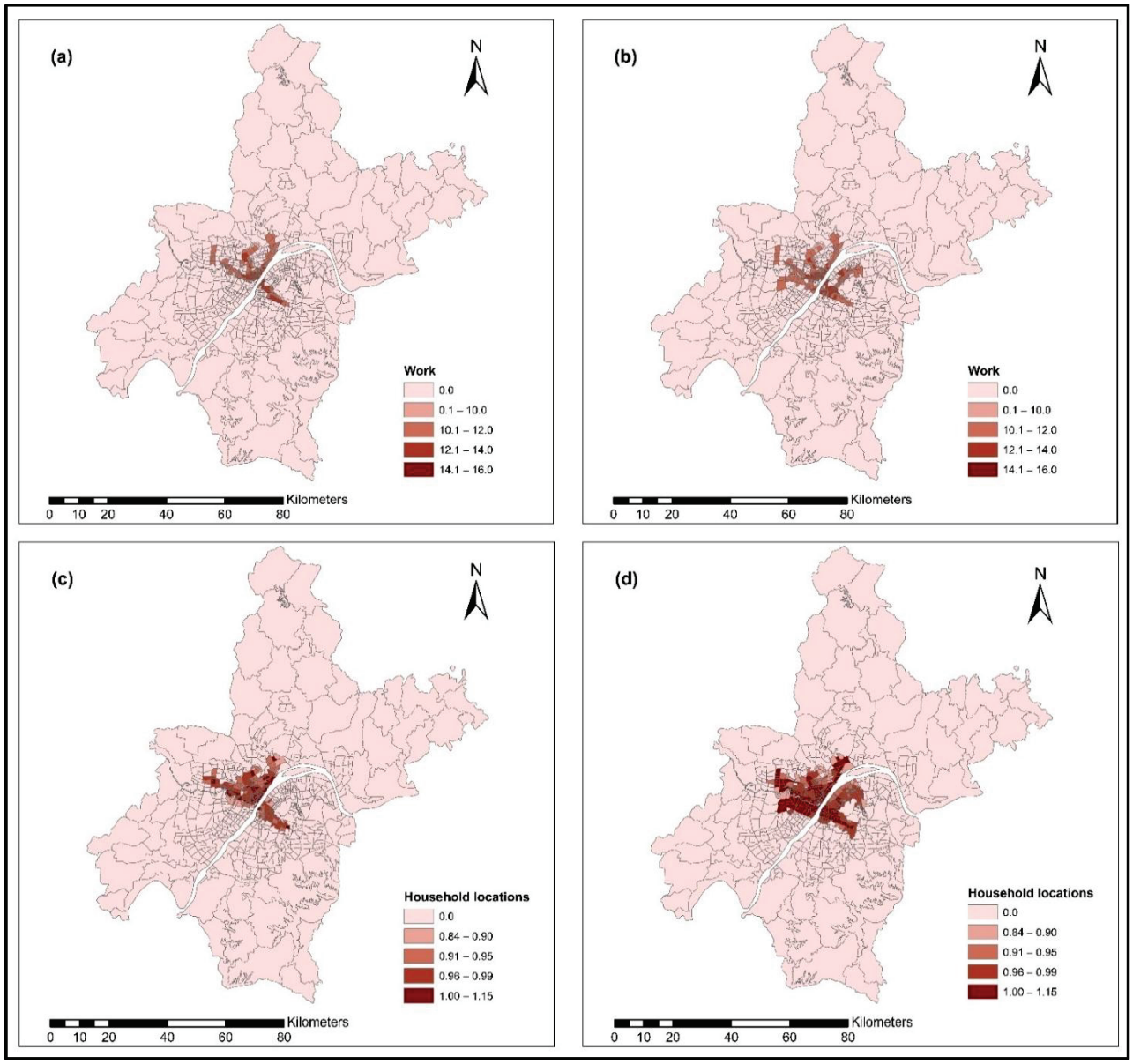

Figure 10. (**a**–**d**) Accessibility to household activities and ISE household locations: (**a**) accessibility using metro for the year 2012; (**b**) accessibility using metro for the year 2015; (**c**) household locations using metro during 2012; (**d**) household locations using metro during 2015.

Figure 10c,d presents the range of HLI as a result of ISE estimations using metro-based accessibility for the years 2012 and 2015. The HLI ISE-estimated value ranges using metro mode are as follows: no household locations (0.0); low–medium level of household locations (0.84~0.90); medium level of households location (0.91~0.95); medium–high level of household locations (0.96~0.99); high level of household location (1.0~1.15).

Compared to the metro, bus services covered most of the downtown area during the years 2012 and 2015. The bus provides accessibility to most of the household activities located in the downtown area and its surrounding areas. Figure 11a,b indicates the accessibility to household activities using bus mode for the years 2012 and 2015. The range of AI values represents the following: no accessibility (0.0); low–medium accessibility (0.1~10); medium accessibility (10.1~12); medium–high accessibility (12.1~14); and high accessibility (14.1~16).

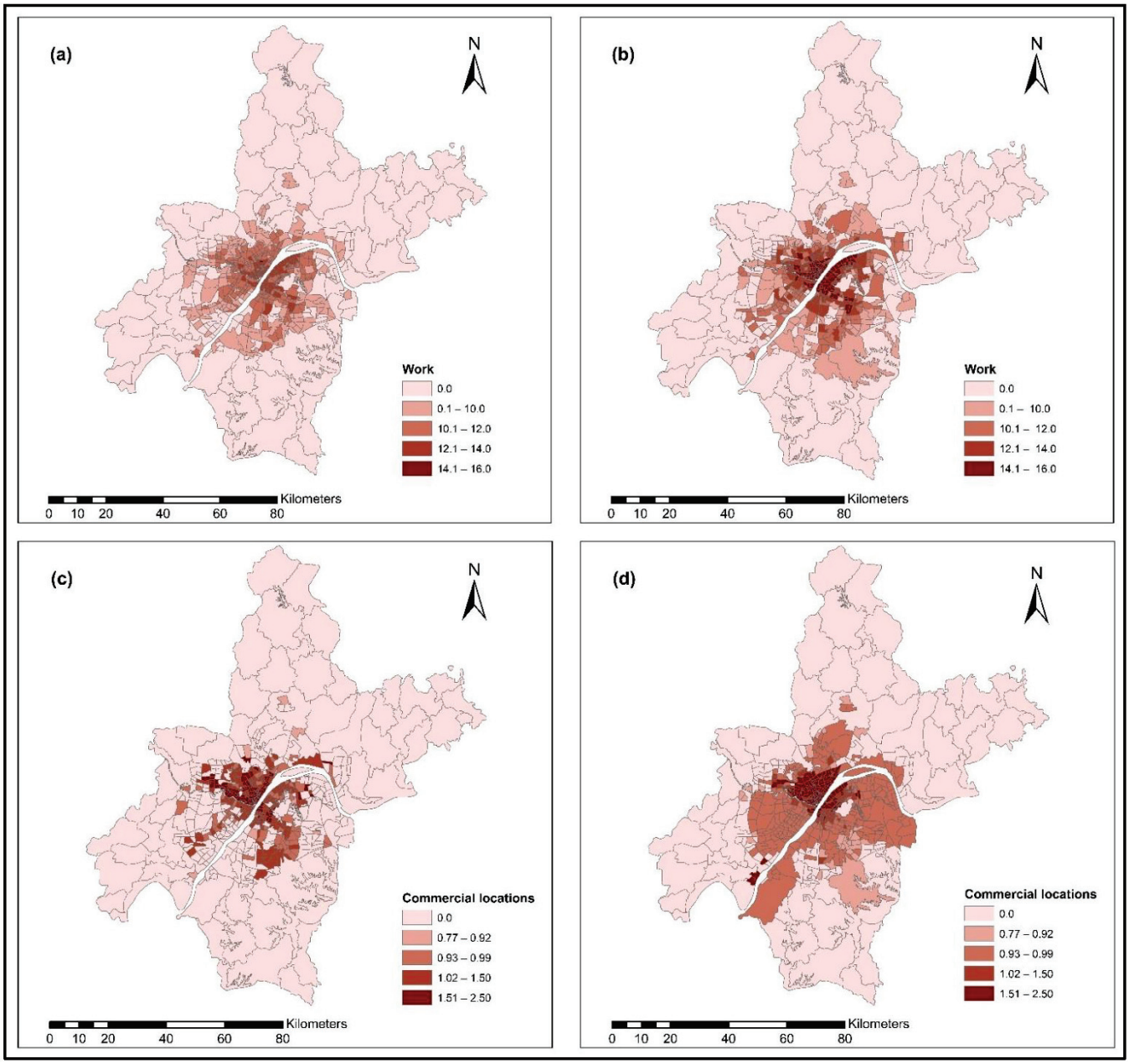

Figure 11. (**a**–**d**) Accessibility to household activities and ISE household locations: (**a**) accessibility using bus for the year 2012; (**b**) accessibility using bus for the year 2015; (**c**) household locations using bus during 2012; (**d**) household locations using bus during 2015.

Meanwhile, accessibility to household activities using bus mode and the ISE-estimated household locations results indicate that areas with a high level of bus accessibility showed a high level of household location and most of the values were related to household locations. Figure 11c,d presents the range of HLI as a result of ISE estimations using bus-based accessibility for the years 2012 and 2015. The HLI ISE-estimated value ranges using bus mode are as follows: no household locations (0.0); low–medium level of household locations (0.1~0.92); medium level of households location (0.93~1.0); medium–high level of household locations (1.01~1.11); high level of household location (1.12~1.33).

Transit (metro and bus) provide interconnected services which provide transfer between these modes. To make this an attractive commuting mode, a discount fare policy is introduced by the local government to encourage the transfer between bus and metro. Transit accessibility results indicate that accessibility to household activities using transit

significantly increased during the year 2015, and most of the AI values are in the range 10–16, especially during the year 2015, due to the updated transit system. Figure 12a,b indicates the accessibility to household activities using transit for the years 2012 and 2015. The range of AI values represents the following: no accessibility (0.0); low–medium accessibility (0.1~10); medium accessibility (10.1~12); medium–high accessibility (12.1~14); high accessibility (14.1~16).

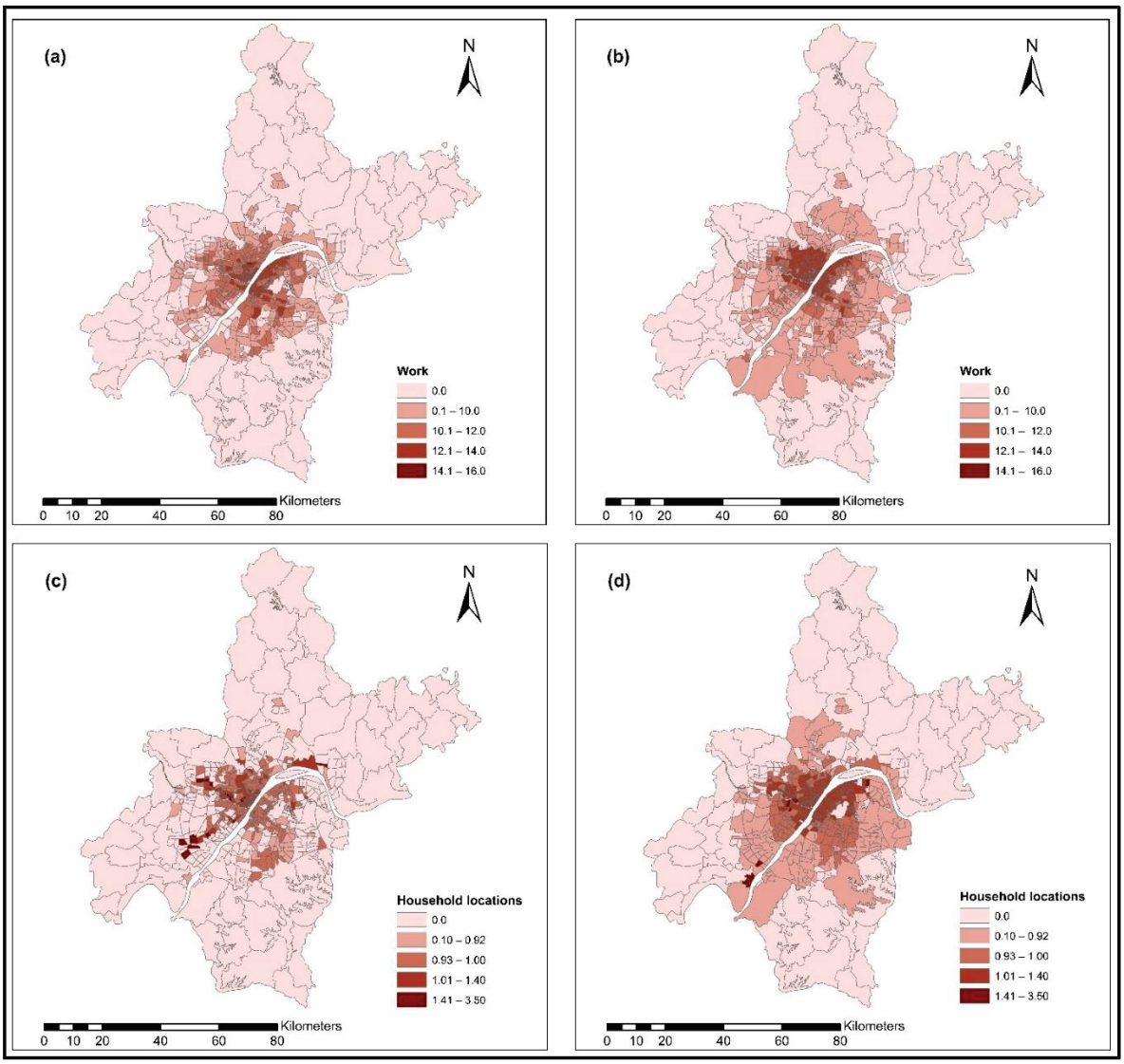

Figure 12. (**a**–**d**) Accessibility to household activities and ISE household locations: (**a**) accessibility using transit for the year 2012; (**b**) accessibility using transit for the year 2015; (**c**) household locations using transit during 2012; (**d**) household locations using transit during 2015.

Meanwhile, the ISE-estimated household locations using transit accessibility indicated that areas with a high level of transit accessibility showed high household locations. During 2015, most of the household location values are in the range 1.01–3.5, due to improved transit accessibility. Figure 12c,d indicates the range of HLI as a result of ISE estimations using transit-based accessibility for the years 2012 and 2015. The HLI ISE-estimated value ranges using transit are as follows: no household locations (0.0); low–medium level of household locations (0.1~0.92); medium level of households location (0.93~1.0); medium–high level of household locations (1.01~1.40); high level of household location

(1.41~3.50). These results indicate that transit accessibility to household activities has a strong relationship with household locations.

The household locations of the ISE model results showed the same trend, namely, as accessibility increases, household activity locations increase, which is presented in Figures 9a–d and 12a–d.

5.1.2. Locational Preferences of Commercial Activities

Commercial activities or services (such as information, retail, hospitality, real estate, technical services, environmental services, and private services), such as household activities, are vital in any economic system. However, in the ISE system, an aggregate 'commercial activity' phrase is employed to represent commercial services.

Figure 8 depicts the commercial activity buying and selling procedure process. Commercial activities typically buy labor and sell services to other activities, including households, and in the process consume a variety of other commodities and services. The enhancement of the road network and transit services increases accessibility and the location choice behavior of commercial services, with better accessibility attracting more commercial activity. Commercial activities (services obtained by households) prefer locations with low transport costs. However, it may vary depending on the nature of the commercial activity; some services are sensitive to auto accessibility, while others are sensitive to accessibility via other modes. It was revealed that the level of auto accessibility to household activities in 2015 was considerably high compared to 2012. Figure 13a,b indicates the range of auto accessibility to commercial activities for the years 2012 and 2015. The AI represents the following: low accessibility (0~8); low–medium accessibility (8.1~10); medium accessibility (10.1~12); medium–high accessibility (12.1~14); high accessibility (14.1~16).

Meanwhile, the ISE-estimated commercial locations are presented in Figure 13c,d. The results revealed that areas with high auto accessibility to commercial services showed a high level of commercial locations. Figure 13c,d shows the range of CLI as a result of ISE estimations using auto-based accessibility for the years 2012 and 2015. The CLI ISE-estimated value ranges using auto are as follows: low commercial locations (0.0~1.0); low–medium level of commercial locations (1.1~1.50); medium level of commercial locations (1.60~2.0); medium–high level of commercial locations (2.1~2.50); high level of commercial locations (2.6~3.0).

Figure 14a,b presents the result of metro accessibility to commercial services during 2012 and 2015. In 2015, metro accessibility to commercial services was relatively high compared to 2012, because of the new metro line, and most of the AI values are in the range 10–14. Figure 14a,b indicates the range of metro accessibility to commercial activities for the years 2012 and 2015: low accessibility (0.0); low–medium accessibility (0.1~8); medium accessibility (8.1~10); medium–high accessibility (10.1~12); high accessibility (12.1~14).

Meanwhile, Figure 14c,d results also reveal that areas with high metro accessibility to commercial services showed a high level of commercial locations, especially in the year 2015. The CLI ISE-estimated value ranges using metro are as follows: no commercial locations (0.0); low–medium level of commercial locations (1.78~1.85); medium level of commercial location (1.86~1.92); medium–high level of commercial locations (1.93~1.98); high level of commercial location (1.99~2.50).

Figure 15a,b presents the results of bus accessibility to commercial services located within the study area. In 2015, new bus lines introduced were added, which eventually provided bus accessibility to a wider area. Results revealed that during 2015, the AIs increased significantly, and most of the AI values are in the range 10–14. Figure 15a,b indicates the range of bus accessibility values for commercial activities for 2012 and 2015: no accessibility (0); low–medium accessibility (5~8); medium accessibility (8.1~10); medium–high accessibility (10.1~12); high accessibility (12.1~14).

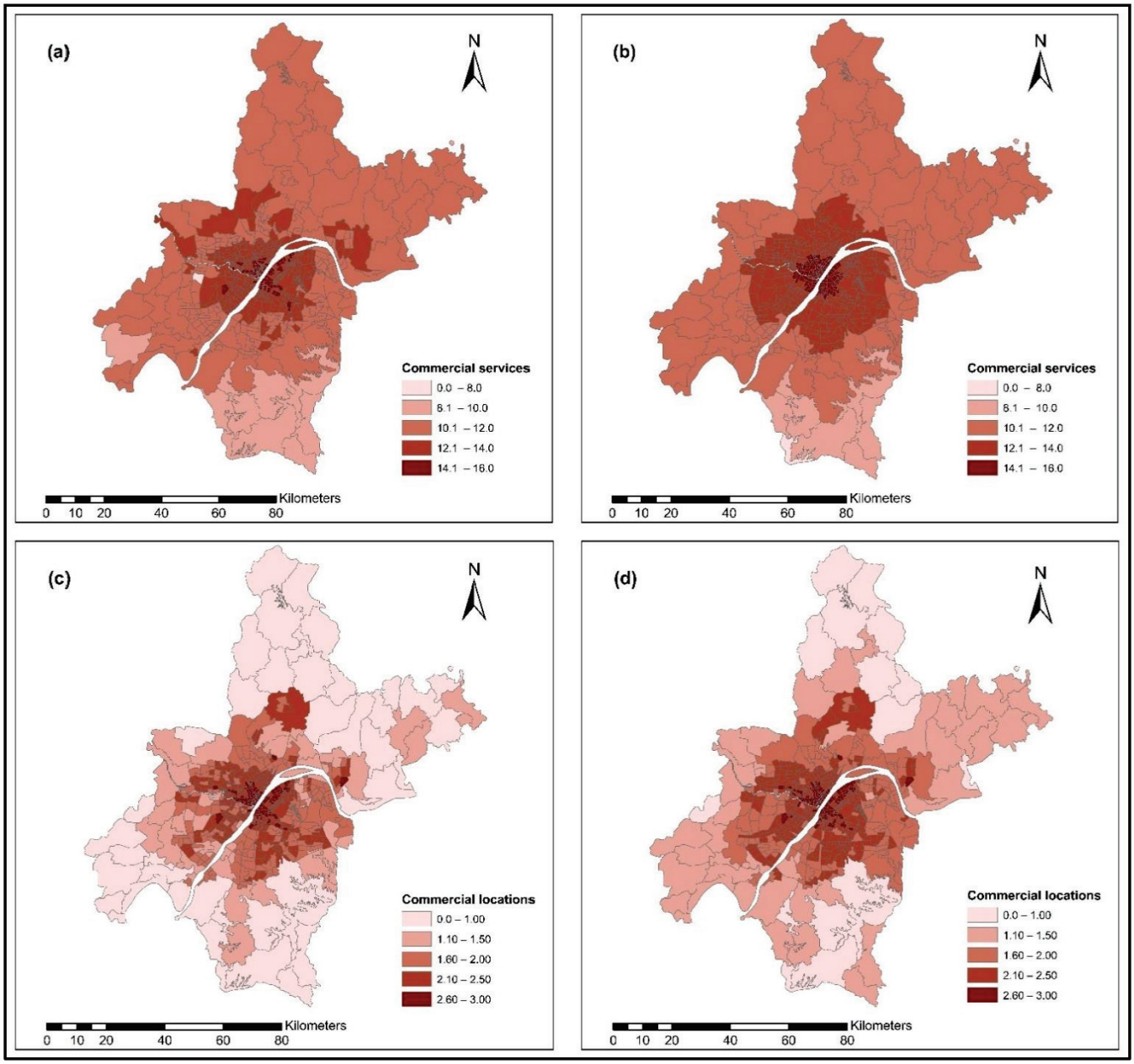

Figure 13. (**a**–**d**) Accessibility to commercial services and ISE commercial locations: (**a**) accessibility using auto for the year 2012; (**b**) accessibility using auto for the year 2015; (**c**) commercial locations using auto during 2012; (**d**) commercial locations using auto during 2015.

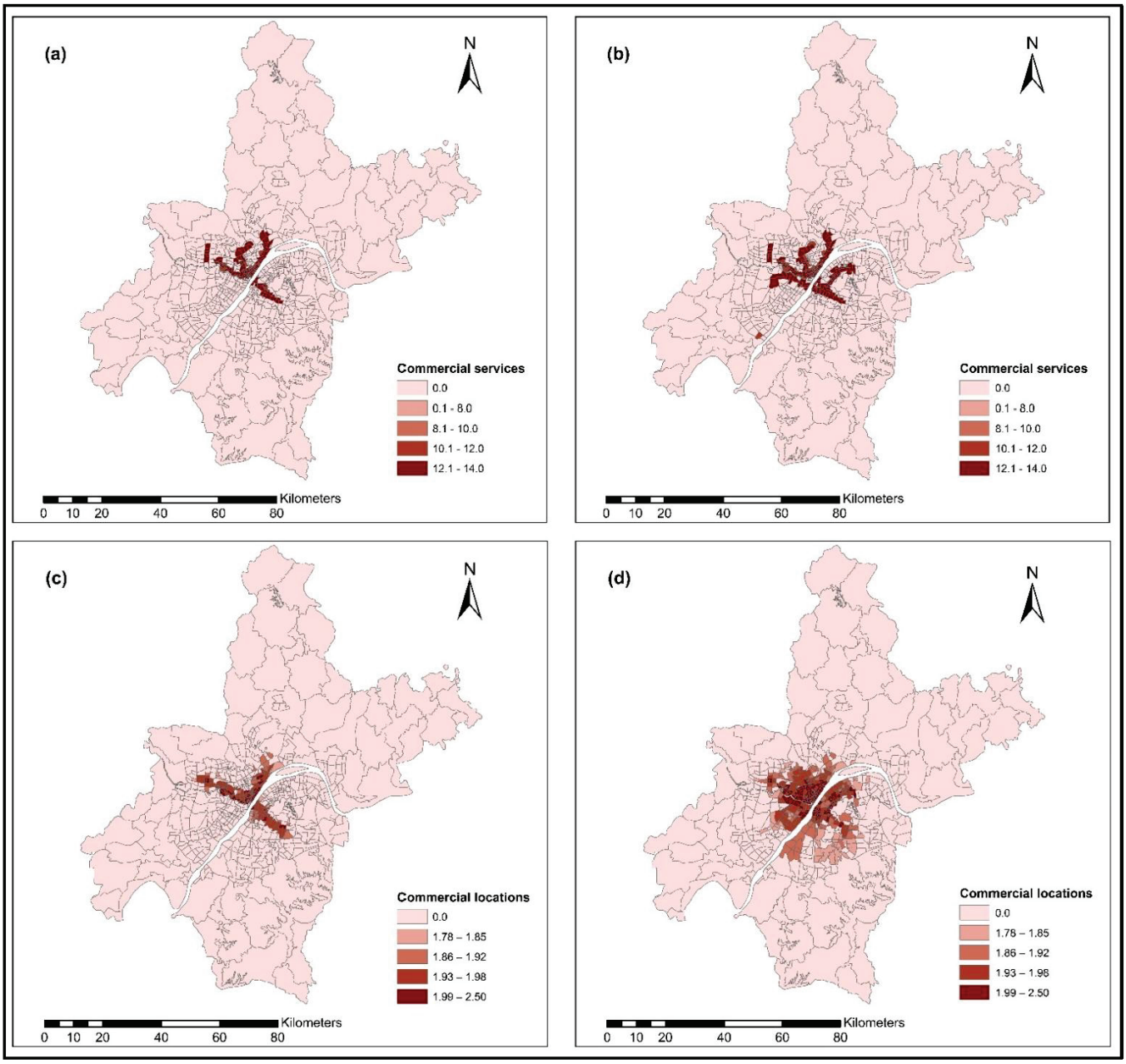

Figure 14. (**a**–**d**) Accessibility to commercial services and ISE commercial locations: (**a**) accessibility using metro for the year 2012; (**b**) accessibility using metro for the year 2015; (**c**) commercial locations using metro during 2012; (**d**) commercial locations using metro during 2015.

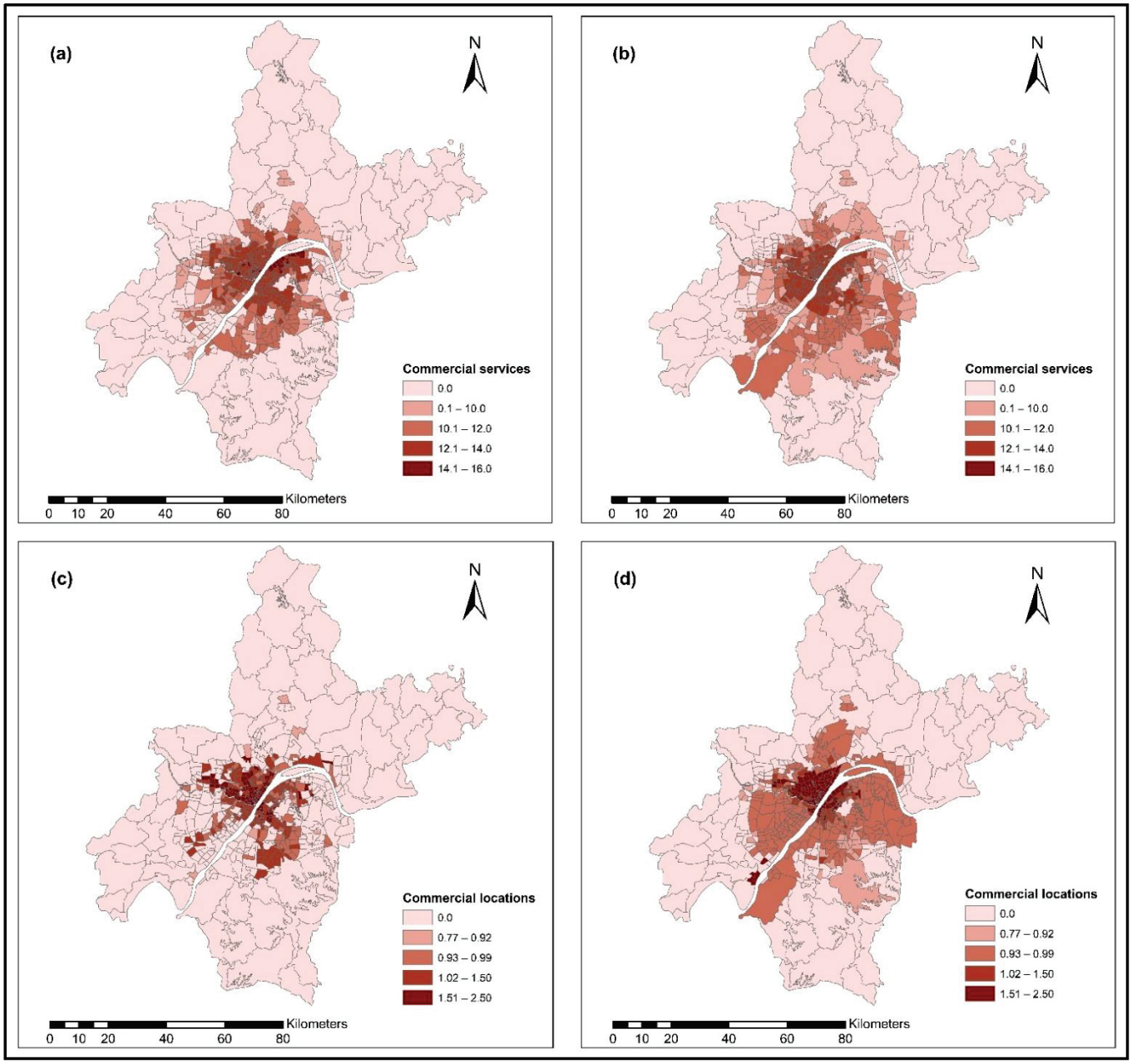

Figure 15. (**a**–**d**) Accessibility to commercial services and ISE commercial locations: (**a**) accessibility using bus for the year 2012; (**b**) accessibility using bus for the year 2015; (**c**) commercial locations using bus during 2012; (**d**) commercial locations using bus during 2015.

Meanwhile, the ISE-estimated commercial location using bus-dependent accessibility during the years 2012 and 2015 is presented in Figure 15c,d. The results revealed that areas with a high level of bus accessibility to commercial services showed a high level of commercial locations, especially during the year 2015. The CLI ISE-estimated commercial locations ranges are as follows: no commercial locations (0.0); low–medium level of commercial locations (0.77~0.92); medium level of commercial location (0.93~0.99); medium–high level of commercial locations (1.02~1.5); high level of commercial location (1.51~2.5).

Accessibility to commercial services using transit as a combined mode is presented in Figure 16a,b for the years 2012 and 2015. Results indicated that areas with a high density of transit lines showed high transit accessibility to commercial services, especially during the year 2015, which was relatively high compared to 2012 because of new bus lines and metro lines introduced in the year 2015. Results revealed that during 2015, the

AIs increased significantly. The range of transit AI to commercial activities in 2012 and 2015 were: low accessibility (0), low–medium accessibility (0.1~10), medium accessibility (10.1~12), medium–high accessibility (12.1~14), and high accessibility (14.1~16).

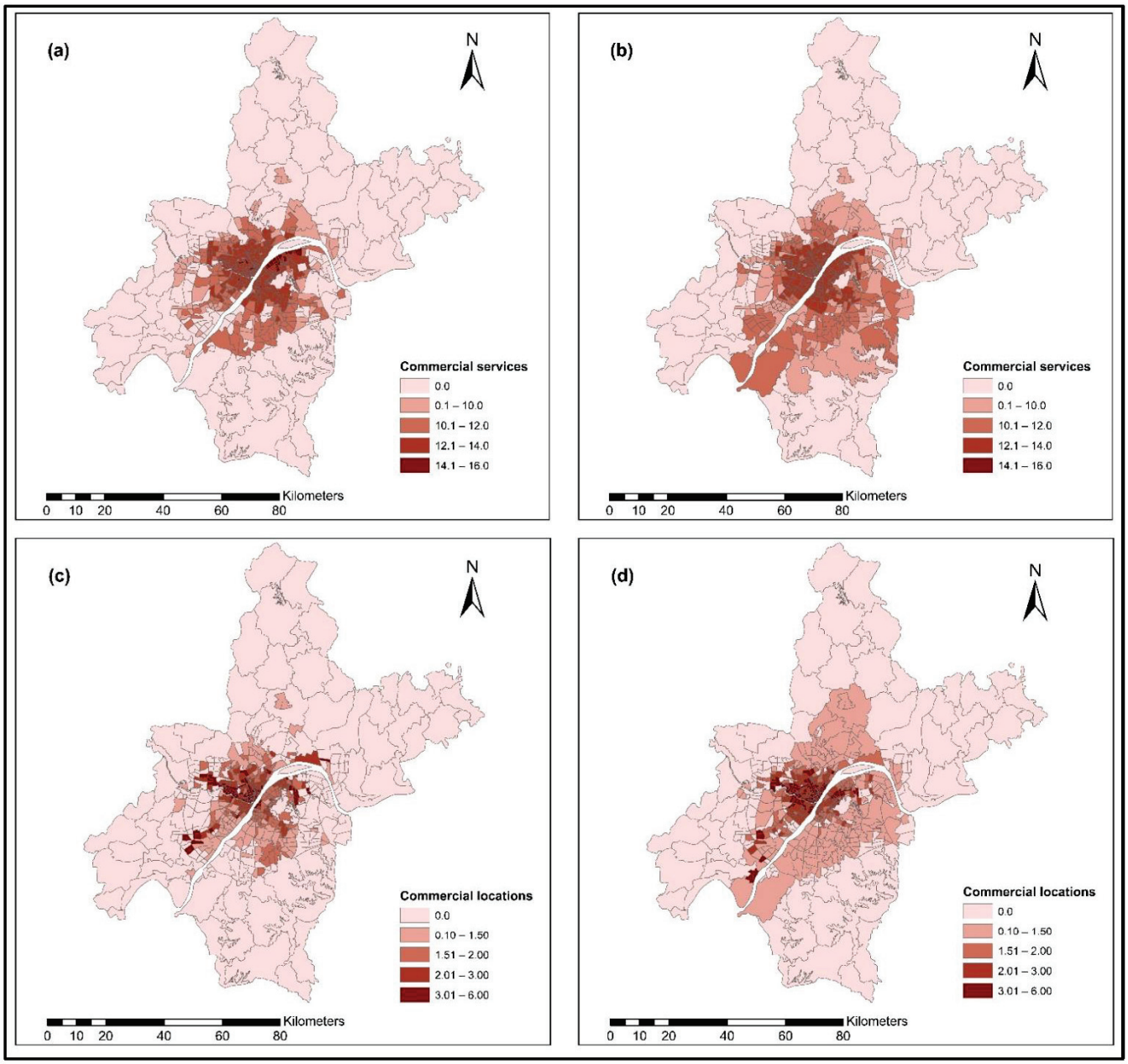

Figure 16. (**a**–**d**) Accessibility to commercial services and ISE commercial locations: (**a**) accessibility using bus for the year 2012; (**b**) accessibility using bus for the year 2015; (**c**) commercial locations using bus during 2012; (**d**) commercial locations using bus during 2015.

Meanwhile, the ISE-estimated commercial locations for the years 2012 and 2015 are presented in Figure 16c,d. Results revealed that areas with high transit accessibility to commercial services showed a high level of commercial locations estimated by the ISE model, and most of the CLI values were in the range 2.0–6. The results indicate the following: no commercial locations (0.0); low–medium level of commercial locations (0.1~1.5); medium level of commercial location (1.6~2.0); medium–high level of commercial locations (2.1~3.0); and high level of commercial location (3.1~6.0).

The ISE commercial services model activity locations results revealed that commercial services were susceptible to MDA rather than static accessibility measure.

5.2. Discussion

Accessibility plays a vital role in the social and environmental aspects. The impact of location rents is poorly known. Activities tend to be located close to high accessibility locations (which in turn influences rents as well). However, it is crucial to understand the actual effect of MDA on location choice behavior of activities and decisions of where to live, where to shop, and where to work. The MDA index provides a synthetic measurement of the ability to reach a particular type of opportunity within a specific time from a place of origin to a specific destination over time and space. Thus, accessibility is defined as a measurement of the capacity to communicate between human activities or settlements using a determined transport system. The usual measurement units are distance, time, mode, and the number of opportunities (activities) available at the destination. These opportunities include jobs, services, etc.; accessibility measures represent the impact that land use distribution and transport systems have on users. It indicates that both concepts, land use and transport, should be related because they allow individuals to participate in activities that take place in different locations. The utility of purchasing a commodity will influence the location utility of an activity that consumes a substantial amount of that commodity.

To understand and distinguish the location choice of various activities, the following two models are developed using ISE models: (i) Household activity location model; (ii) Commercial services activity location model. Location choice behavior of household activities depends on the nature of employment type and access to specific employment locations by a specific time of the day using specific modes. The location preference of household activities may vary depending on the household decision. Working households with no other priorities preferred location, which is within the range of adequate transport accessibility by a specific mode to their job location.

The ISE results revealed that urban households living in the downtown area of the City of Wuhan were sensitive to MDA offered by transit. It also revealed that urban households in the year 2015 showed high household activities estimated by transit-based ISE. This means urban households living in the downtown area are susceptible to MDA offered by the transit system. The results indicated that commercial activities were sensitive to MDA using transit during the years 2012 and 2015. Meanwhile, in the year 2015, when the new transit routes were added and improved the transit accessibility to commercial activities, it was found that commercial activities relocate to a location that offers high transit accessibility. The results also indicated that location decisions of commercial activities are influenced by MDA offered by transit. Nevertheless, the results indicate that commercial and household activities prefer locations with high accessibility offered by different modes.

The static and ISE–MDA models result revealed that household and commercial activities prefer locations that offer high MDA rather than the static accessibility offered, as shown in Table 7. The auto-based ISE–MDA showed an R^2 value of 0.793, and the R^2 value for the static model was lower than 0.727. Meanwhile, transit-based ISE–MDA showed an R^2 value of 0.905 for commercial services, while the static logsum model showed an R^2 value of 0.485. The ISE–MDA models result indicates that location choice behavior of activities has a strong relationship with MDA and has weak relation or causal relationship with static accessibility models. The behavior point, the combined mode (all modes), is not usually considered when choosing the location. Instead, activities are sensitive to specific modes. It is concluded that MDA and ISE models affect the location choice behavior of activities rather than the static logsum models. Hence, for long-term and short-term urban planning exercises, planners and policymakers should consider MDA rather than static logsums.

Table 7. Comparison between static and ISE–MDA models.

	Static Logsum Model (R^2)	ISE–MDA (R^2)			
Activities	**Combined-Mode**	**Auto**	**Bus**	**Metro**	**Transit**
Households	0.727	0.793	0.642	0.642	0.845
Commercial	0.485	0.842	0.530	0.698	0.905

6. Conclusions

This study analyzed the impact of short-term spatial accessibility through Mode-Dependent Accessibility (MDA) on the location choice behaviors of urban activities such as households and commercialin the City of Wuhan, China. This study used auto (private cars and taxis) and public transit (metro, and bus) for measuring MDA. To comprehensively capture accessibility and location choice behaviors of urban activities, this study explicitly analyzed the effects of the metro and bus, as well as their combined effects. The current study used the data from the years 2012 and 2015. These data sets contained household travel survey data, transportation network, transit network, mobile phone signals, and land use data used to develop the land use and transportation interaction model. The study employed the M-TDM model to measure the impact of short-term MDA on household and commercial activities for the years 2012, and 2015. In addition, an advanced integrated spatial economic (ISE) models, i.e., PECAS (Production, Exchange, Consumption, Allocation, System) in order to investigate location preferences of urban activities over space and time. The PECAS approach imitates the spatial economic systems under consideration and has been improved with several distinct features such as an improved representation of socioeconomic systems through a social accounting matrix and microsimulation-based space development. Although locational model methodologies are based on a variety of attributes or characteristics, they all share a common theoretical background based on the random utility theory maximization. Moreover, location models do not function in an isolated way; rather, they are integrated into larger modeling systems such as land use—transport interaction (LUTI) modeling. It is crucial to recognize that the location selection of activities has a strong relationship with the transport system and is influenced by mode-specific accessibility. Accessibility is a dynamic feature of locations that varies in time and mode due to the changes in the transport network and changing patterns of activity distribution at different times of the day.

This study's contribution was to evaluate the short-term MDA for the locational preference of household and commercial urban activities, which could help to capture the effect of MDA under diverse temporal and transport network impedance conditions on the location choice of urban activities. However, the traditional accessibility parameters do not adequately account for the short- and long-term requirements of urban activities. Therefore, it is crucial to create a solution that might provide a more effective planning tool for a thorough understanding of the urban system. This study examined the dynamic short-term accessibility of urban activities, which could be a more effective planning tool than typical "static" accessibility terms. Regarding household and commercial location choice, the ISE modeling results revealed that households and commercial activities are sensitive to MDA, especially using transit. In addition, their findings suggest that highly accessible locations that are well served by automobiles are more appealing for household and commercial activities. The ISE model results estimated that household and commercial location choice models show R^2 of 0.84–0.90 for transit-based accessibility, whereas the logsum-based static models show R^2 of 0.48–0.72. These results from the ISE models revealed that there was a strong relationship between the MDA and the location choice behavior of urban activities.

This study contributes to the existing body of literature with insightful findings, but there are a few limitations that must be acknowledged. This study assessed the short-term MDA for locational preference behaviors for urban activities. However, future studies should examine MDA over various time periods. The current study did not account for nonmotorized modes, which do not affect congestion time but can affect the

accessibility of the first and last miles. Future studies must include nonmotorized modes to comprehensively capture the location choice behaviors. It is believed that data limitations pose the greatest hindrance to the development of such a complex model, especially in developing countries, because it requires large data sets such as economic and demographic data, household travel data, real state data, rent, occupancy, floorspace data, AADT, and mobile phone signal data. Due to the lack of self-reported travel data in developing countries, it is recommended that a survey is conducted to collect the necessary recent data for the model, which may yield useful findings. As time progresses, developments in information technology have provided new opportunities for data and tools to extract the required data. Our forthcoming research aims to address the above inadequacies when the necessary and most current data becomes available.

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Research on the Measurement Method of Benchmark Price of Rental Housing

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Abstract: China's rental housing market has just started to develop in recent years. It is relatively imperfect and lacks a clear reference for the pricing of rents, which is not fully transparent. A study on the rent formation mechanism of rental housing has policy implications for the construction of a guiding price for the rental housing market and the establishment of a reference basis for the pricing of subsidized housing. Referring to the definition of a benchmark land price, we use data from Beijing to innovatively introduce the concept of benchmark rent. Based on hedonic price theory and the driving factors of benchmark rent, a system of indicators is constructed to explore the mechanism of influencing factors at meso and micro levels on the benchmark rent of market-based rental housing. After LaGrange and robustness tests, it is found that the spatial error model (SEM) is more suitable for benchmark rent determination. We conclude that benchmark rents are affected by spatial relationships caused by spatial heterogeneity and dependency, and that there is significant spatial variation in the factors affecting market-based rental housing benchmark rents. The determination of the benchmark rent can be used as a guiding signal for the market, as a clear signal expectation for the market, government, and tenants.

Keywords: rental housing; benchmark rent; spatial differentiation; measurement method; spatial dependence

1. Introduction

Due to the late development of China's real estate market, coupled with the national policy orientation and the influence of residents' cultural concepts, the housing rental market is hugely lagging [1] compared with the housing market. There are shortages of housing, insufficient coverage of affordable housing supply, and mismatches between market supply and demand [2–4]. Due to the lack of regulations related to rental housing, and the incomplete management system, there are still many hidden dangers in the operation of the rental housing market [5], which is not conducive to the formation of a stable rental relationship and market environment [4,6–8]; therefore, the increasing house-leasing market is significant in making up for the shortcomings of China's real estate market, ensuring housing equity, and promoting healthy and intensive economic development [9–11].

However, due to the influence of various factors such as regional conditions, personal preferences, information asymmetry, and so on, the rental housing market is not a completely competitive market, and there is a certain degree of market failure; therefore, it is necessary for the government to intervene to a certain extent to ensure the smooth and efficient functioning of the market [12]. Since 2006, the issue of housing leasing has received continuous attention from the government [13]. The "China Eleventh Five-Year Plan" emphasizes the need to strengthen the regulation of the housing rental market and promote housing gradient consumption, whereas the "China Twelfth Five-Year Plan" proposes a supply system that combines rental housing with the purchase of commercial housing. The most recent "China Thirteenth Five-Year Plan" further proposes a housing

system of "equal rights to purchase and rent". In addition, China also pointed out the need to accelerate the establishment of a multi-subject construction and multi-channel housing system [14]. The intensive policy documents in recent years have revealed the state's emphasis on the housing rental market. Under the policy environment of China's multi-subject construction—renting and selling—the government has not yet implemented unified supervision of the rental housing market; therefore, we believe it is necessary to clarify the concept of benchmark rent as a clear signal of expectations from the market, the government, and tenants to ensure the stable development of the housing rental market and to consider the underlying social and environmental well-being dimensions, as well as the inequality and sustainability indicators that escape GDP accounting [15].

The regulation of prices through a benchmark index system can effectively guide the development of public policy, and has been much studied in the housing market [12,16]; however for large cities with a net inflow of population, rental housing plays a more crucial role in solving the housing problems of the migrant population [17]. In the rental market, the location and transport conditions attached to the housing are important factors that influence the decision, and housing that is easily accessible tends to have higher rent [18,19]. Neighborhood income levels also have a positive effect on rental housing rent, whereas a negative environment can significantly reduce housing rental prices, reflecting the influence of neighborhood characteristics on housing rents [20,21]. In addition, aspects such as the size of the housing stock, the year in which it was built, the design of the house, the floor on which it is located, the degree of decoration, and other infrastructural support are also related to the rent of rental housing [16,22,23]. Considering the transient nature of renter occupancy compared with homebuyers, research has also found that amenity packages have an important impact on rent. There are also additional factors attached by landlords that are likely to have a significant impact on housing rents [24–26].

In general, in past research, the factors affecting housing prices and rent can be divided into macro, meso, and micro factors on a locational scale. Macro influencing factors mainly affect the movement of the overall level of rental housing rent at the city level, and therefore, they influence the differences in rental housing rent levels between cities, such as national macro policies, city and regional policies, the city's level of socio-economic development, demographic conditions, investment in urban infrastructure, and the overall locational characteristics of the city in the country. Meso-influencing factors are the main factors that affect the differences in rental housing rent levels between different locational conditions within a city, such as employment opportunities, locational conditions, and the availability of public service facilities. Micro-influencing factors are factors that affect the rental level of rental housing within a neighborhood, such as green ratio, plot ratio, neighborhood environment, age of construction, floor level of the house, orientation of the house, decoration condition, and so on. Compared with macro-influencing factors, meso-influencing factors and micro-influencing factors are more intuitive in their impact on rental housing rents, facilitating observation, discussion, and analysis within the city; therefore, meso and micro factors will be mainly considered in this work's system of impact factor indicators.

For the research on the benchmark rent measurement method of market-based rental housing, this article attempts to construct an index system of factors affecting market-based rental housing. Based on the hedonic theory, the driving factors are analyzed to construct a system of factors affecting the benchmark rent of market-based rental housing at the meso level, which is then further subdivided into four factor layers and eleven factor layers of neighborhood attributes, location characteristics, public services, and school district characteristics using the characteristic price theory. After the analysis, using the least squares (OLS) model, the spatial regression model was further applied to consider the spatial influence relationship. After the least squares (OLS) model analysis, further spatial regression modeling is applied to analyze the degree of influence and spatial dependency of the influencing factors and to construct a reasonable pricing method and model. The model

is then used to analyze the degree of influence and spatial dependence of the influencing factors and to construct a reasonable pricing method and model.

2. Materials and Methods

2.1. Data Source

The rental transaction data of market-based rental housing in Beijing in 2018 came from the brokers' listings on the website Lianjia.com. A total of 244,050 pieces of rental information were collected, covering 5980 communities (Figure 1). Since the number of houses released by the rental information of each community is quite different, to fully reflect the rental level of the community to a greater extent, in the process of data collection, we tried to ensure that the number of houses in each community were roughly equal. Except for the number of rental listings for individual communities less than 5, the number of rental collections in each community should be controlled as far as possible to 5–10 houses.

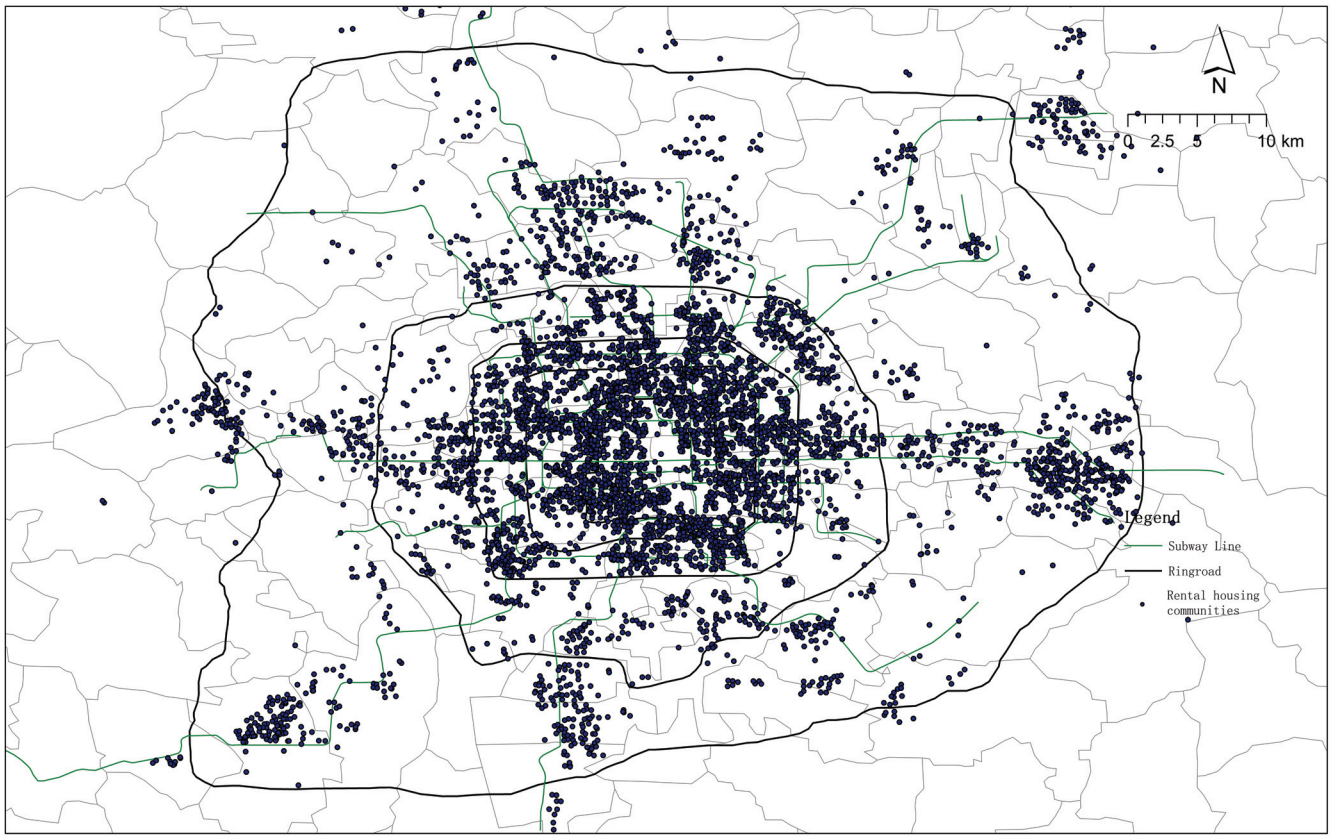

Figure 1. Distribution of market-leased communities in Beijing.

Borrowing the concept of benchmark land prices [27], this article defines benchmark rents as it is defined in the urban planning area, under the set community conditions, location conditions, and supporting facilities, for residential communities with different average values under the current utilization conditions and current development conditions [28]. The regional average rent of housing lease rights at a specific valuation date, in this study, refers to the average benchmark rent of each community and the rent level of specific houses. There are different types of average rent, based on decoration, floor, and house orientation. The main research subject of this article is the benchmark rent for rental housing. The calculation method of the benchmark rent of the community is the average of the unit rent of the residential housing (monthly rent price yuan/m^2), not the total monthly rent of the housing divided by the total area.

It can be seen from Figure 1 that the market-based rental housing is relatively concentrated in the main urban area, and the periphery is extended along the subway line.

The supply and demand of market-based rental housing reflect a complete market behavior [5,17]. The hypothesis of marketers, for the pricing model of market-based rental housing, allows us to apply a characteristic price model and a fixed rent factor.

To better reflect the spatial distribution of rents, when measuring the spatial difference of rent prices, this article uses community as the research unit instead of specific housing as the research unit; therefore, the dependent variable of the rent is the residential communities' rent price, not the rental price of the listing.

2.2. Variables and Methods

Due to the complicated formation mechanism of urban housing prices, various factors comprehensively drive its spatial differentiation [29]. There is no consistent conclusion on the driving force that affects urban residential rental prices. The supply and demand theory [30] and the characteristic price theory [31] construct an index system of influencing factors from different perspectives. From the perspective of equilibrium price with demand, the characteristic price theory emphasizes that housing price is the monetary performance of urban environmental quality [32].

2.2.1. Benchmark Rent Driving Factors

1. Urban planning:

The driving force of urban planning on housing rent is mainly manifested in the following three aspects: (1) Urban planning determines the nature of urban land use, land use function layout, development intensity, and other construction control requirements. Even if the land is of the same nature, different plots have different floor area ratios and building height limits. The economic benefits generated after the development of the plots are also significantly different, leading to an increase in housing rent difference. (2) Urban planning guides the construction and development of new urban areas (or sub-centers). With the increasing severity of urban diseases such as traffic congestion, excessive population density, and air pollution under the urban single-center structure, it is imperative to build and cultivate urban sub-centers or new urban districts, which requires scientific and reasonable urban planning. (3) To determine the new urban area (or sub-center) location problem. Take Beijing as an example [33]; as a suburb of Beijing, in the traditional sense, the rent in Tongzhou is far inferior to those of the six districts, however, after Tongzhou was officially planned as a sub-center in 2015, housing rent in this district has clearly shown a trend of substantial increase.

2. Spatial differences in public goods investment:

Public goods investment includes public goods such as urban rail transit, education, medical care, and green spaces. The spatial difference in public goods investment directly reflects the spatial difference in the convenience and accessibility of public resources and has an essential impact on housing rents. Based on the finiteness of public resources, the difference in the scale, quality, and spatial distribution of public goods resources in different locations make the convenience of life in different communities in Beijing significantly different, leading to the spatial differentiation of housing rents. For example, rail transit will significantly affect the rent of leased housing along the line, and the benchmark rent level will also increase in areas with good infrastructure. Although large-scale communities such as Beijing Huilongguan and Tiantongyuan have a large population and robust rental demand, their rent levels are not high. The reason is that the surrounding supporting public service facilities are insufficient, making it difficult to support higher rents. People with a strong rent payment ability will prefer areas with better urban public goods.

3. Transfer of urban residential land:

The transfer of urban residential land directly affects the location and traffic characteristics of residential quarters. Due to geographical restrictions, residential land available for sale in Beijing will become increasingly scarce in the future [20,25]. No matter what type of residential land, it will be favored by developers. With the increase in land acquisition

costs caused by the shortage of land, developers often build high-end residential quarters on the land to obtain market benefits, thereby raising the level of housing rents in the area.

4. Impact of the urban migrant population:

The first problem facing the migrant population in cities is the housing problem [23]. Due to household registration restrictions and payment constraints, rental housing is their first choice, and they directly reflect the needs of the residential rental market. Among them, migrant workers in Beijing and newly graduated students are the main support groups in the rental housing market in Beijing. Excessive growth of the migrant population has become a problem that must be addressed in the rapid development of Beijing. Although the government has introduced many restrictive policies, Beijing still has many migrant influxes every year, causing its housing rental demand to continuously rise, which can be seen from the housing occupancy rate of each district. In 2016, the average housing occupancy rate of various districts in Beijing was as high as 61% [22]. Moreover, the behavioral characteristics of the migrant population directly affect the rental prices in the rental market. For example, the return home season after the Spring Festival and the job-seeking rental season for college students from June to September each year are the peak demand seasons in the rental market, and rental prices often rise.

5. Urban employment function orientation:

The "Beijing City Master Plan (2004–2020)" defines the two-axis, two-belt, and multi-center spatial development pattern of Beijing, and it is committed to building six industrial functional areas. With the government's support for the construction of infrastructure in multi-center and industrial functional zones, the agglomeration effect of the parks is getting increasingly stronger, the number of jobs continues to increase, and a large amount of capital, funds, and labor are rapidly agglomerated, causing the housing rents in these areas to also increase. Beijing's rent and high-value areas mostly overlap with the multi-center and six industrial functional areas defined in Beijing's master plan, such as the China World Trade Center, Financial Street, Zhongguancun, and Wangjing.

2.2.2. Influencing Factor Index System

The benchmark rent of market-based rental housing is affected by the abovementioned multiple driving factors. The specific performance of these driving factors can be constructed from the four aspects of location transportation, employment accessibility, public services, and community attributes. In addition, rent may also be affected by housing facilities and lease methods. Due to the different housing types, areas, decoration standards, orientation, house facilities, and rental payment methods differ in each community, and thus the variability and randomness in individual housing are relatively large in order to better reflect the rent in a particular space. When measuring the spatial difference of rental prices, this paper uses the benchmark rent of the community as the research unit, rather than the specific housing rent as the research unit; therefore, the dependent variable of the benchmark rent is the residential benchmark rent, not the specific housing source rent. According to the results of literature research by scholars at home and abroad, we can define a four-factor, eleven-factor index system, and descriptive statistics of meso-level variables affecting rent prices as shown in Table 1.

In the above variable indicator system, among the community attribute factors of the rental housing itself, the variables select three indicators: construction age, volume ratio, and greening rate. In terms of employment accessibility, to calculate the actual road network distance from one employment center to another employment center, a total of 15 employment centers were identified based on the characteristics of employment density [28]. From the center to the periphery are the Zhongguancun Center, Financial Street Center, CBD Center, Wangjing-Sun Palace Center, Yangfangdian Street Center, Shuguang Street Center, Datun Center, Jiuxianqiao Center, Shangdi Center, Capital Airport Center, Ten Balidian Center, Ancient City Center, Xincun Center, Yizhuang Center, and Baishan Center.

Table 1. Statistics for Variable Descriptions.

Variable Category	Explanatory Variable	Variable Description	Mean	STd	Expected (+/−)
Dependent variable	R	Average rental price per square meter of the community (yuan/m^2)	31.62	10.07	
Community attributes	Age	Year the community was built	11.08	3.16	−
	FAR	The ratio of the total construction area of the community to the land area	2.13	0.51	−
	Greening	Green coverage of the community (%)	0.31	0.03	+
Employment accessibility	D-job	Distance to the nearest employment center (m)	12,260.47	11,006.81	−
	C-job	Employment opportunities that can be reached within 60 min using public transportation	83.19	123.19	+
Location traffic	Bus	Number of bus stops within a radius of 1 km	415.78	367.87	+
	Subway	Number of subway stations within 1 km radius	2075.69	2177.47	+
Public Service	Park	Distance to the nearest park (m)	1701.08	1179.41	−
	Hospital	Distance to the nearest third-class hospital (m)	5688.15	5245.38	−
	Services	Number of large shopping malls and various supermarkets within 1 km radius	32.7627	27.18	+
	Preschool	Distance to the nearest key elementary school (m)	10,059.38	11,791.42	−

The employment opportunity data comes from the Beijing Employment Accessibility Map [33], which depicts the total number of employment opportunities that people who use the city's public transportation system can achieve in 30, 45, and 60 min travel times across streets, towns, and villages in Beijing's metropolitan area.

This article selects the employment opportunities that can be achieved within 60 min using public transportation. Figure 2 identifies the total number of employment centers in the area that are reached within 60 min (based on the morning rush hour) from the center of each street. The darker the color, the more employment opportunities. The distance from the nearest bus station and subway station to the nearest bus station and the subway station is selected at the level of location and traffic factors. At the same time, in order to make the calculation result closer to the reality of life, the measured distance we use here is the actual road network distance to represent its traffic convenience rather than straight-line distance. For the public service factor level, we chose the distance to the nearest parks, third-class hospitals, and key primary schools. The number of large shopping malls and various supermarkets within 1 km represents the degree of public goods investment. The data for various elementary schools comes from the Beijing "kindergarten to primary school "website (http://www.ysxiao.cn/ (accessed on 31 May 2018)), and measuring other variables (such as the distance to the nearest park, third-class hospitals) is also the actual road network calculated by the near tool distance. The quantity measurement of various variables (such as the number of shopping malls and supermarkets) within 1 km is realized by buffer analysis in Arcgis, which is also the distance of the road network. References to each data source and year are shown in Table 2.

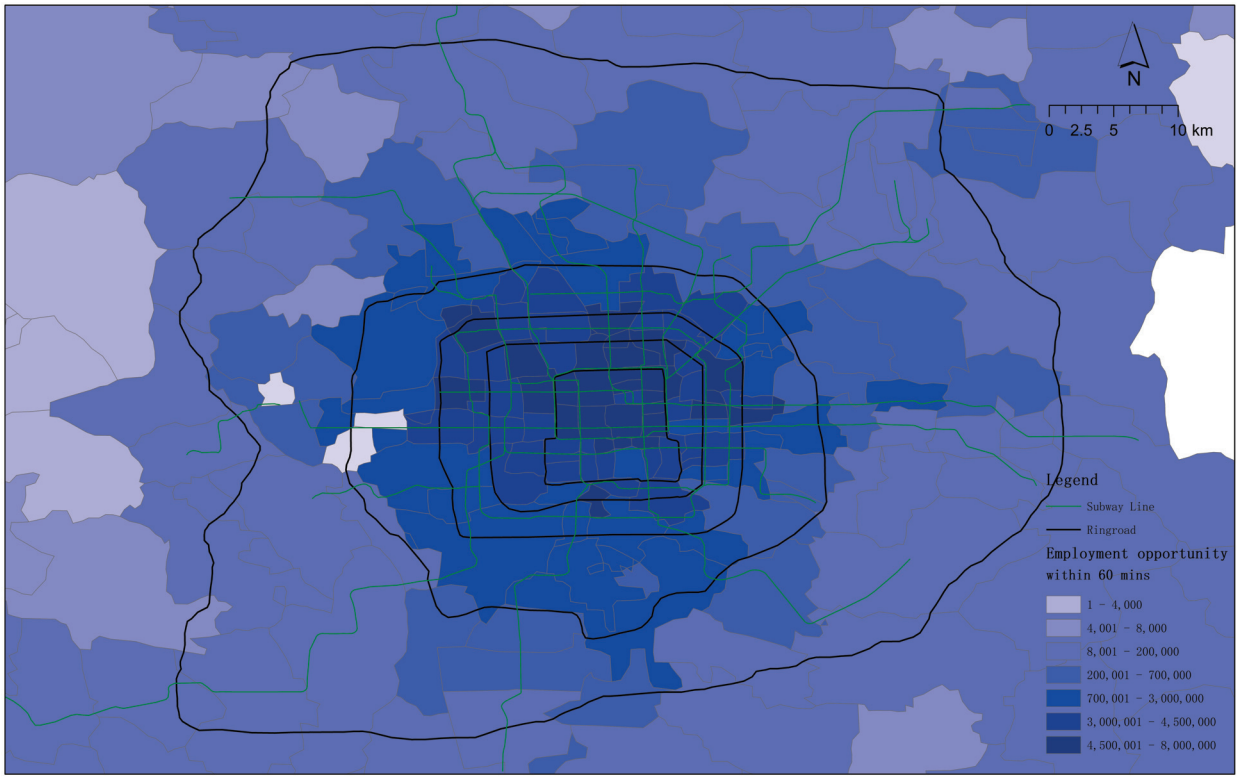

Figure 2. Employment opportunities within 60 min in Beijing.

Table 2. Source for the Statistics of the Variables.

Variable Category	Explanatory Variable	Source of Variable	Reference of Year
Dependent variable	R (Benchmark rent)	/	
Community attributes	Age (Year of construction)	Data from Lianjia website (https://bj.lianjia.com/ (accessed on 1 October 2018))	2018
	FAR (Floor Area Ratio)	Data from Lianjia website (https://bj.lianjia.com/ (accessed on 1 October 2018))	2018
	Greening (Greening ratio)	Data from Lianjia website (https://bj.lianjia.com/ (accessed on 1 October 2018))	2018
Employment accessibility	D-job (Distance to the Job Centre)	Calculated from Beijing Employment Centre Distribution [28]	2016
	C-job (Number of job opportunities)	Calculated from Beijing Job Accessibility Map [34]	2015
Location traffic	Bus (Bus stations within 1 km)	POI data extracted from Baidu Maps (https://map.baidu.com/ (accessed on 31 May 2018))	2018
	Subway (Subway stations within 1 km)	POI data extracted from Baidu Maps (https://map.baidu.com/ (accessed on 31 May 2018))	2018
Public Service	Park (Distance to the nearest park)	POI data extracted from Baidu Maps (https://map.baidu.com/ (accessed on 31 May 2018))	2018
	Hospital (Distance to the nearest third-class hospital)	POI data extracted from Baidu Maps (https://map.baidu.com/ (accessed on 31 May 2018))	2018
	Service (Malls/supermarkets within 1 km)	POI data extracted from Baidu Maps (https://map.baidu.com/ (accessed on 31 May 2018))	2018
	Preschool (Distance to the nearest key elementary school)	Calculated from Beijing "kindergarten to primary school" website (http://www.ysxiao.cn/ (accessed on 31 May 2018))	2018

2.2.3. Methods

Set the latitude and longitude coordinates with the help of Google Maps, import ArcGIS to establish the corresponding point layer, and match the latest Beijing GIS electronic base map to establish a rental housing sample database. Among them, the spatial data includes the latitude and longitude coordinates (X, Y) of the sample rental housing community, the street information of the rental housing, and the supporting public service facilities, such as subway stations, bus stations, parks, and green spaces, top three hospitals, key primary schools, and shopping malls. Attribute data includes transaction time, rental price, living area, construction age, volume ratio, and the sample rental housing communities' greening rate.

Existing studies usually use OLS estimation and extended forms of characteristic price functions (semi-log model and double log model) to estimate the correlation coefficient of explanatory variables. In the characteristic price model, explanatory variables such as location characteristics and public services usually show spatial similarity or spatial dependence, and prices are also affected by unobservable latent variables. When omitted variables and spatial dependence coexist, OLS estimation will make the biased fluctuations have poor inference results, and the spatial measurement model can be used to analyze spatial dependence and spatial heterogeneity and avoid least squares estimation. This is problem of bias.

When choosing a spatial regression model, the specific model setting form must be considered, along with the mutual influence between independent variables and dependent variables. The spatial autoregressive model (SAR) considers the spatial dependence characteristics between the samples of the dependent variable; this model is used based on the belief that the dependent variable will have a certain external effect on the dependent variable of other spatial sample units. For a spatial unit A_i (i = 1, 2, ..., n), regarding the observations of its neighborhood $A_j(i \neq j)$, the expression of the spatial autoregressive model (SAR) model is:

$$\mathrm{y}_i = \rho \sum_{j=1}^{n} \mathrm{W}_{ij} y_j + \sum_{q=1}^{Q} X_{iq} \beta_q + \varepsilon_i, \tag{1}$$

In the formula: y is the dependent variable (benchmark rent); X is the explanatory variable (the index that affects the benchmark rent); W_{ij} is the $(i, j)th$ element of the spatial weight matrix $\mathrm{W}_{n \times n}$; the parameter ρ is the spatial regression coefficient, reflecting the degree of interpretation of the explained variable by the adjacent units in space (the driving influence of the surrounding benchmark rent on the sample area's benchmark rent); β represents the degree of influence of the explanatory variable X on the explained variable y. ε is the random error term which denotes an influence other than the independent variable to represent the uncertainty arising from the presence of other spatial factors.

The spatial error model (SEM) is mainly used to solve the problem of estimation error caused by missing variables in the model, considering that the error term has a certain degree of spatial dependence, and that the spatial interaction is a random process and will not be observable. The spatial perturbation term is correlated with the overall space, and perturbations in one space affect other spaces with spatial effects. The random heterogeneity is placed in the random disturbance term to reflect its spatial correlation. Among them, the spatial error model (SEM) model expression is:

$$\mathrm{y}_i = \sum_{q=1}^{Q} X_{iq} \beta_q + \lambda \sum_{j=1}^{n} \mathrm{W}_{ij} \varepsilon_j + \mu_i, \tag{2}$$

In the formula: the parameter λ is used to measure the spatial dependence characteristics of the disturbance error term; μ is the random error disturbance.

3. Results and Discussion

3.1. OLS

This paper selects the logarithmic form of the benchmark rent of residential quarters as the dependent variable, and follows the analysis framework of characteristic price theory from the attributes of the community. These include employment accessibility, location, transportation, and the four public aspects, including service, which construct the influencing factors of housing benchmark rent. Based on the availability of data, the "community attributes" feature selects three indicators, including construction year, floor area ratio, and greening rate, and "employment accessibility" selects two indicators, such as the distance to the employment center and employment opportunities and "location traffic". Two indicators are selected, including the number of bus stops and subway stations within 1 km. The nearest park, third-class hospital, key primary school, and the number of supermarkets within 1 km are selected for "Public Service" [34].

The residential property variables, location traffic, public services, and school district variables are gradually introduced into the hedonic price model of the benchmark rent [35]. Taking the logarithm of the rental price and use Stata12.0 software (StataCorp. 2011. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP.) for regression analysis, the formula is as follows:

$$\log P_i = a_0 + a_{ni} X_{ni} + \varepsilon_i, \quad (3)$$

In the formula: P_i is the benchmark price of residential areas in Beijing in 2018, and X_{ni} represents the n variable of the i residential sample. ε_i is the error term.

As shown in Table 3, the model's explanatory degree increased from 0.28% to 56.42%, 56.91%, and 60.47%, with the gradual introduction of community attribute variables, location traffic variables, public service variables, and school district variables, respectively. It can be seen that the employment accessibility factor has the most important influence on the benchmark rent, whereas the importance of the community attribute characteristic factor is relatively low.

In the OLS model (4), the construction age, volume ratio, and greening ratio have no significant impact on the benchmark rent, indicating that the tenants do not focus on the community attribute factors. The employment accessibility factor has the greatest impact and is the most important factor for renters to consider. For every 1% increase in distance to the nearest employment center, the benchmark rent decreases by 0.1578%; for every 1% increase in employment opportunities within 60 min, the benchmark rent increases by 0.0884%. Distance to bus and subway stations has a negative impact on benchmark rents, but not to the same extent as employment. For every 1% increase in the distance to the nearest bus and subway station, the benchmark rent decreased by 0.1029% and 0.0136%, respectively. In terms of public services, the distance to parks, third-class hospitals, and key primary schools, have a significant negative impact on the benchmark rent, and the number of supermarkets within 1 km has a positive impact. This is also expected. Relatively speaking, key primary schools and third-class hospitals have a relatively larger impact, whereas parks have no significant impact.

3.2. The Spatial Spillover Effect of Benchmark Rent

This article first calculates the global Moran's I index to measure the degree of spatial autocorrelation of the benchmark rent of the sample rental housing community. Using Matlab software, the Moran's I coefficient of ln P is calculated to be 0.4952, and the p value is 0.0000, which has passed the significant value at the 1% level. The test, and the Z score, is 48.26, which is significantly positive, indicating that the benchmark rent has spatial effects and positive spatial autocorrelation (Figure 3).

There are spatial effects caused by heterogeneity and dependence between spatial data, but the relationship between them is ignored in the classic regression analysis model (OLS). After Moran's I index has verified that there is a certain degree of spatial correlation between the benchmark rent of rental housing and its influencing factors, it is necessary to determine the most appropriate spatial measurement model for analysis. This paper

selects the appropriate model through LaGrange test. As Moran's I test is significant when the maximum likelihood LMLAG test is more significant than the LMERR test, this article chooses the spatial lag model; otherwise, the spatial error model is chosen.

Table 3. Statistics for Variable Descriptions.

Benchmark Rent (Ln-rent)		**OLS**			
		(1)	**(2)**	**(3)**	**(4)**
Community attributes	Age	0.0081 (0.7323)	0.0015 (0.2068)	0.0014 (0.1922)	0.0012 (0.1682)
	FAR	0.0053 (0.5918)	0.0004 * (0.0587)	0.0009 (0.1523)	−0.0007 (−0.1258)
	Greening	−0.5600 *** (−4.0667)	−0.2198 ** (−2.4119)	−0.2142 ** (−2.3744)	−0.0912 (−1.0483)
Employment accessibility	D-job		−0.1739 *** (−26.4884)	−0.1708 *** (−26.1231)	−0.1578 *** (−24.8812)
	C-job		0.1357 *** (44.5667)	0.1344 *** (43.9131)	0.0884 *** (24.9121)
Location traffic	Bus		415.78	−0.0079 (−1.0913)	−0.1029 *** (−12.0154)
	Subway		2075.69	−0.0235 *** (−8.2152)	−0.0136 *** (−4.9147)
Public Service	Park		1701.08	1179.41	−0.0185 *** (−3.7975)
	Hospital		5688.15	5245.38	−0.0400 *** (−8.0251)
	Service		32.7627	27.18	0.0623 *** -8.8087
	Preschool		10,059.38	11,791.42	−0.0659 *** (−13.7354)
Constant		4.4802 *** (68.7265)	3.9936 *** (40.0206)	4.0281 *** (40.2418)	5.4495 *** (44.0041)
R-square		0.0028	0.5642	0.5691	0.6047
Sample size		5980	5980	5980	5980

Note: *, **, and *** are significant at 10%, 5%, and 1% level, respectively.

It can be seen from Table 4 that LMERR > LMLAG, R-LMERR > R-LMLAG for the economic distance spatial weight model, and the test values all pass the significance test at the 1% level, whether it is a LaGrange test or a robustness test. The spatial error model based on the weight of the rental housing price feature is statistically more significant than the spatial lag model, so this article chooses the spatial error model as a method for further research.

At the same time, we compared the estimation results of the spatial lag model (SLM) and the spatial error model (SEM) (Lin Guangping, 2014), as shown in Table 5. In the process of setting the spatial weight matrix, since the sample studied in this paper is a point element, it has the characteristics of wide spatial distribution and local aggregation. The k-order neighbor weight matrix is defined, and the k = 1:20 neighbor matrix result is calculated by the robustness test of the maximum likelihood value sets of the optimal number of neighbors. We uses the maximum likelihood method to estimate the regression model and took k = 13.

Comparing the Log likelihood (LogL) and Lagrange multiplier (LM) values of the spatial lag model (SLM) and the spatial error model (SEM), we can see that the values of the spatial error model (the results of SEM) are better than those of the spatial lag model (SLM), indicating that the factors that affect the benchmark rent of rental housing communities are also potential factors. Compared with the OLS regression model, the spatial error model (SEM) model, after introducing spatial effects, did not impact the significance level

of the variables, parks, and district key points, and public school district housing had no significant impact on the benchmark rent.

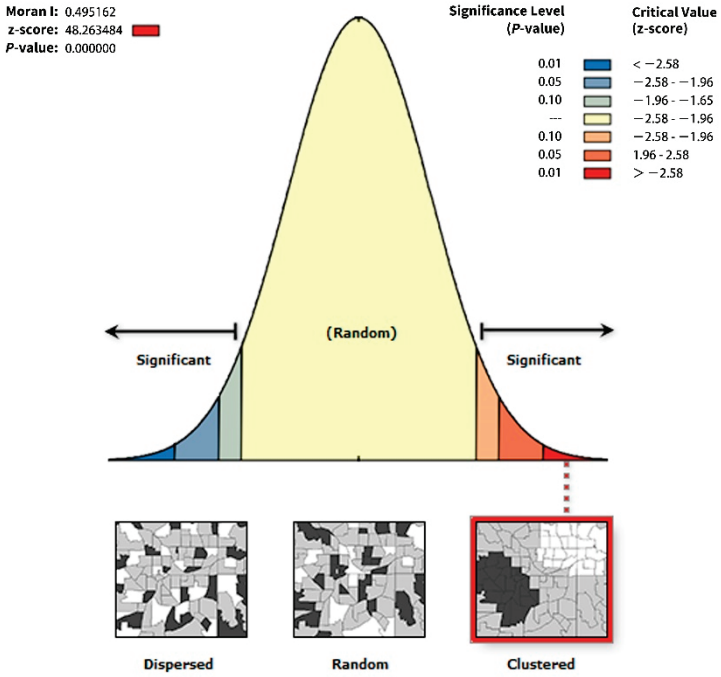

Figure 3. Space autocorrelation report of benchmark rent.

Table 4. LM statistics test results of the housing rent space weight model.

Testing Method	LMERR	LMLAG	R-LMERR	R-LMLAG
Statistics	2989.4869	2617.5919	920.6184	548.8234
p value	0.0000	0.0000	0.0000	0.0000

The regression results show that the community attributes (construction year, plot ratio, and greening rate) have no significant impact on the benchmark rent, indicating that tenants consider community attributes to be critical when choosing a house to rent. The degree of employment accessibility greatly influences the benchmark rent, indicating that tenants should first consider commuting time with their employer when choosing a house. The degree of influence of employment opportunities is greater than the degree of distance to the employment center. Among the location characteristics, the benchmark rent is highly dependent on the bus station, showing that the farther the distance to the nearest bus station, the lower the benchmark rent price, and the influence of the subway station is relatively less obvious. Regarding public service facilities, whether it is the least square method (OLS) model, the spatial lag model (SLM), or the spatial error model (SEM), parks and supermarkets have no significant impact on the benchmark rent, so we will not elaborate on the park variables here. The regression coefficient of the third-class hospitals is negative, indicating that third-class hospitals have a specific role in increasing the benchmark rent, especially due to the fact that society is aging, the elderly are more willing to live nearby to third-class hospitals to facilitate medical treatment, and that the migrant population comes to Beijing for medical treatment, these groups also have a great demand for leasing; therefore, without considering other variables, the benchmark rents of communities near third-class hospitals are often higher. Moreover, in order to facilitate school-age children going to school, many parents tend to rent houses near key primary schools, which has increased the benchmark rent of communities near key primary schools to a certain extent.

Table 5. Spatial lag model (SLM) and spatial error model (SEM) of benchmark rent.

Benchmark Rent (Ln-Rent)		SLM		SEM	
		Coefficient	t	Coefficient	t
Community attributes	Age	−0.034	−0.806	−0.006	−0.146
	FAR	−0.181	−0.332	0.066	0.343
	Greening	−0.161	−0.019	2.948	0.343
Employment accessibility	D-job	−3.232 ***	−5.285	−10.847 ***	−8.145
	C-job	1.805 ***	5.226	4.292 ***	14.897
Location traffic	Bus	−2.443 ***	−2.915	−1.288 ***	−0.98
	Subway	−1.159 **	−2.133	−0.758 **	−1.059
	Park	−0.466	−0.997	−0.373	−0.654
Public Service	Hospital	−1.204 **	−2.512	−2.021 **	−2.628
	service	1.000 *	1.452	0.118 *	0.119
	Pschool	−1.951 **	−4.256	−4.134 **	−5.186
Constant		69.005 ***	5.496	174.284 ***	13.628
ρ/λ		0.676		0.689	
R^2		0.4176		0.5375	
LogL		−25,763.867		−25,827.597	
LM		2617.5919		5172.9086	
Sample size		5980		5980	

Note: *, **, and *** are significant at 10%, 5%, and 1% level, respectively.

3.3. Market Benchmark Rent Measurement Method

The benchmark rent measurement method can be summarized in the following four points:

- The construction year, floor area ratio, and greening ratio have no significant impact on rental housing's benchmark rent.
- The employment center has a relatively large impact on the benchmark rent. The closer to the job center, the lower the commuting cost could be, and the higher the benchmark housing rent.
- The park has no significant impact on the benchmark rent. For renters, most of them are unable to buy with such high housing prices in first-tier cities, and they are struggling to survive. In addition to renting in high-priced housing communities, they should consider the residential function of the house when renting, whereas parks that mainly have leisure functions are not important factors to consider. The impact of living facilities (supermarkets, shopping malls) and other facilities are also not significant, indicating that e-commerce has changed people's lifestyles.
- The housing in key school districts of Beijing can be said to make it easy for children to go to school. Key school districts have a clear positive impact on the benchmark rent. It further confirms that the housing rental market is dominated by residential employment.

Based on the comparative study of several models, the most suitable market benchmark rent measurement method is determined as the spatial error model (SEM):

$$y = \sum_{q=1}^{Q} X_{iq}\beta_q + \lambda \sum_{j=1}^{n} W_{ij}\varepsilon_j + \mu_i, \quad (4)$$

where $\lambda W_{ij} + \varepsilon$ is the disturbance term, which expresses those not included in X (the index system that affects the benchmark rent).

For the missing variable that has an impact on the dependent variable y (benchmark rent), the regression coefficients must be substituted:

$$\begin{aligned} \ln \text{rent}_i = {} & 174.284 - 0.006\text{Age}_i + 0.066\text{FAR}_i + 2.948\text{Greening}_i - 10.847\text{Djob}_i + 4.292\text{Cjob}_i - 1.288\text{Bus}_i \\ & -0.758\text{Subway}_i - 0.373\text{Park}_i - 2.021\text{Hospital}_i + 0.118\text{Service}_i - 4.134\text{Pschool}_i + 0.689W_{ij} + \mu_i \end{aligned} \quad (5)$$

4. Conclusions

The factors affecting the benchmark rent of market-based rental housing have spatial differentiation. In other words, the OLS price feature model ignores the spatial impact, but the benchmark housing rent and its influencing factors are data with spatial mutual influence relationships, which will be affected by spatial relationships caused by spatial heterogeneity and dependence. After LaGrange and robustness tests, it is found that the spatial error model (SEM) is better than traditional models, which finally allows the benchmark rent measurement method for market rental housing to be obtained.

The dominant players in the housing rental market are mainly low- and middle-income groups and a small number of high-income groups. There are a different investment and speculative needs in the housing market [11,17,36]. The rental housing market meets the rigid housing needs of various groups of people, which reflects the crowd's real living demand. Moreover, the benchmark rent can be attributed to four major factors: community attributes, employment attributes, location attributes, and public services. The characteristic price model is based on OLS regression which explains the average sense of influencing factors. The spatial measurement model that introduces spatial effects has a significantly higher interpretation strength than the characteristic price model, indicating that the benchmark housing rent has spatial spillover effects. Community attributes (construction year, plot ratio, greening rate) have no significant impact on the benchmark rent, indicating that most of the tenants are low- and middle-income households and are not sensitive to the community's quality. The benchmark housing rent is very sensitive to commuting costs. The more bus stations and subway stations nearby, the closer the distance to the job center, the more job opportunities there are, the lower the commuting cost, and the higher the benchmark housing rent. Parks have no significant impact on the benchmark housing rent because most renters cannot afford such high housing prices in first-tier cities and are struggling to survive. When renting a house, more consideration should be given to the residential function of the house, whereas parks, which mainly have leisure functions, are not important factors to consider. The impact of key elementary schools on the benchmark rent is relatively obvious, indicating that Beijing's high transportation cost is due to nearby schools' rental demand.

The main groups involved in the rental housing market are mainly low- and middle-income groups and a small number of high-income groups. Unlike the investment and speculative demand that exists in the housing sale and purchase market, the rental housing market caters to the rigid housing needs of various groups of people. The benchmark rent measurement method helps real estate developers to scientifically and reasonably measure the cost-benefit and cost-recovery period of investing in rental housing to a greater extent, and to scientifically and reasonably build and supply rental housing to a greater extent. It also helps residents in the rental housing market to make the most scientific decisions based on their ability to pay, the work–life balance, and amenities. Furthermore, it will help them realize a reasonable and effective screening of rental housing when their income changes. For policy makers, benchmark rents can provide a scientific guideline for the rental housing market, establishing clear standards for rent setting and regulatory controls. We use the Beijing rental housing market as the pilot city for the study, and its benchmark rent determination method for market-based rental housing can be extended further to other cities.

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The Dysfunctional Rental Market in Portugal: A Policy Review

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Abstract: In Portugal, due to the rental market's inability to respond to the constant mismatch between supply and demand over the course of decades, things have become increasingly residual and dysfunctional within the scope of the homeownership market. Through analysis of various laws and legislative changes over the last century, as well as the participant observation acquired by the author's two-and-a-half years of experience as a stakeholder in the sector, this paper aims to review rental policies in Portugal and the multiple impacts they have had on reproducing various weaknesses in the rental market. The paper concludes with some policy recommendations that advocate how government action is decisive in shaping housing and rental policy, establishing a legal and regulatory framework able to transmit credibility, stability and security to the contractual forms between supply and demand, in keeping with an effective right to housing through affordable renting.

Keywords: rent freeze; rent regulation policies; rental regimes; rental market; Portugal

1. Introduction

National housing strategies intentionally promote different ways to consume and provide housing through policy reforms defining housing rights and standards, channelling investment by regulating financial institutions, and providing tax incentives and subsidies, ideally in order to shape fairer market processes and improve access to adequate and affordable housing for all [1,2]. Since the 1970s, many countries have made concerted efforts to promote homeownership, while simultaneously improving the affordability of rental housing. This has, however, led to more households relying on the private rental sector, a factor that temporarily enables regulation of the proper functioning of the housing market. The private rental sector is increasingly viewed by governments across the European Union as a crucial input into the mix of housing services that can provide accessible accommodation for households unable or unwilling to enter homeownership or social rented housing [3,4]

The narratives around rent regulation over decades, on the one hand, incorporate the discourse of private rental market deregulation, advocating the free market and landlord property rights, which in theory increases the housing supply to the market. On the other hand, stricter and more social rent regulations advocate rent controls, longer lease agreements and more rights for tenants to protect them against both rents over the market level and sudden large increases in rent, or, when the aims involve keeping rents permanently below market levels, creating opportunities for affordable housing in keeping with the right to housing [5,6].

The aftermath of the 2007–2008 financial economic crisis demonstrated how many real-estate agents and companies developed the buy-to-rent market, taking advantage of the strangulation of bank credit for homeownership mortgages in the wake of the subprime crisis, to increase rents to speculative values aligned with the increasing demand in the sector [7,8]. Therefore, regulation of the private rental market has become an essential factor for the governance of contemporary cities, for urban redevelopment and for the stabilisation and economic dynamics of real estate. It has assumed a central role in the definition and implementation of urban and social policies through guaranteeing the right

to housing as a prerequisite for access to other rights, as well as strongly influencing the general quality of life of citizens [9,10].

Rent regulation provides an essential component of housing-market governance, fostering a healthy balance and congruence between supply and demand. For instance, Kemp and Kofner [11] demonstrate how on the demand side, security of tenure and softly regulated rents in Germany have helped ensure high levels of demand for rental housing among better-off households who might otherwise have been prompted to consider homeownership. Additionally, despite German landlords eventually complaining about rent regulation and security of tenure having a negative impact on the extraction of surplus value by moderating the levels of rent they can charge, these have largely been compensated for by government-guaranteed tax incentives. However, in comparison, in the United Kingdom, unregulated rents and weak security of tenure are not conducive to long-term renting. Free-market rents and insecurity of tenure are consistent with a sector that has largely focused on short-term tenants and highly mobile households.

The private rental sector is growing in many advanced economies due to declining homeownership and retrenchment in social housing resulting in the coming of age of "generation rent" and "build to rent", with new demand caused by younger individuals excluded from home buying and the traditional routes to homeownership [12–14]. On the contrary, in Portugal, due to the inability of the rental market to respond to the constant mismatch between supply and demand over various decades, all the national scientific and technical studies on housing [15], as well as official statistics, point to a decline in the number of leases in proportion to the scale of the homeownership market in the last decades of the 20th century, although a slight increase will be registered in the first two decades of the 21st century (Figure 1). Sociodemographic and professional changes, as well as greater mutability in the composition of families (new types of households: single parents, singles, couples without children), associated with eventual increases in residential mobility due to employment flexibility and labour market uncertainties, all suggest greater flexibility in the housing market. However, the rental market—by its nature more easily adaptable to individual and family options—attains a much lower proportion than those opting to acquire a home in Portugal. The national rental market, in addition to being scarce, is also very uncertain, fragile and does not return guarantees either for supply or demand [16], in addition to the very high (at around 28%) tax burden on legal lease agreements, which also acts as an invitation to informal leasing in a country where the sector is not subject to any type of inspection or monitoring.

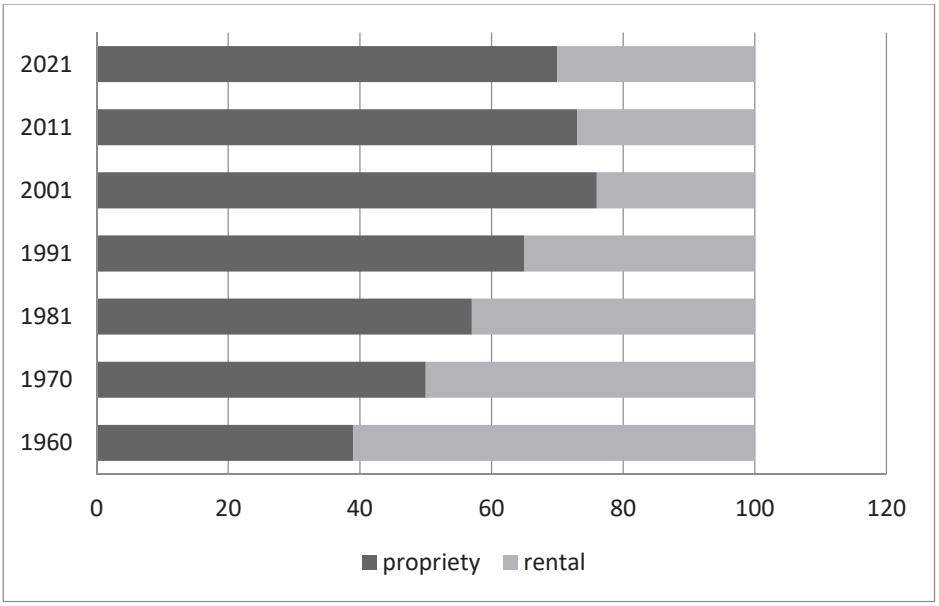

Figure 1. Houses by occupation regime: ownership and rental (1960–2021). Source: [17–23].

In Portugal, the percentage of classic habitual residence family dwellings occupied by tenants and others decreased from 61% in 1960 to 24% in 2001, thereby attaining historic lows. This correspondingly reflects how the property-occupancy regime accounts for three-quarters of the housing market in national terms.

We may explain the slide in rentals recorded between 1960 and 2001 by pointing to government regulations that devalued the rental market and blocked increases in rents and/or any shortening of the duration of contracts; thus, any conditions more favourable to landlords. Simultaneously, around 75% of state housing investment was channelled into subsidising interest on mortgage credit, thus implementing a homeownership policy that boosted the share of homeownership at the cost of the rental sector. The preliminary results of the 2021 Census already indicate a slight increase in the latter and suggest a weighting in the order of 30%. This slight increase in rental properties since the turn of the century is inherently bound up with both the restrictions on access to housing credit imposed since 2011 and the surge in housing prices since 2014, in addition to increasing precariousness and labour flexibility that contribute to greater flexibility in the housing market by slightly increasing the demand for rented houses.

The erosion of the state's role in defining rental policy, leaving it trailing in the wake of private initiative—much of it decapitalised—while simultaneously massively funding banking support for granting mortgage credits for the acquisition of a home ever since the 1980s was associated with the touristification and financialization of real estate in the post-2008–2009 economic crisis period [24]. These factors have combined to produce the rental market situation that Portugal faces today: a country of landowners in which leasing is an increasingly reduced-occupancy regime. Hence, this constitutes a paradigmatic case of mismatch between supply and demand [25] in a market that has historically fluctuated between the freezing of rents, the decapitalisation of owners and other restrictions on the market, and total liberalisation that raises rent values to prohibitive levels and gentrifies the centres of the major cities through the resulting expulsion of tenants. In the Portuguese case, the rental market not only does not work but also does not comply with its economic and social functions in city areas.

Seeking to fill the existing gap in the national and international literature on the Portuguese case, this paper aims to review rental policies in Portugal, especially in the 21st century, and the multiple impacts they have had on reproducing various of the weaknesses in the sector. Thus, the main questions for our study are: How did rental systems evolve in Portugal over the last century? What influence did the successive alternations in rental policies have on the efficiency of the Portuguese rental market? What political measures might bring about positive and balanced growth in the rental market, thereby adjusting supply and demand?

In order to answer these questions, and in addition to a short review of the national and international literature on the housing question and private rental markets, our methodological approach line deployed qualitative methods and techniques. This involved critical content analysis of social media and publicity materials published by both homeowners and tenants' associations, which were then cross-referenced with micro ethnographic fieldwork analysis of the performance of these different associations and movements in the public arena (debates, forums, demonstrations, presence in the press), taking into account the research-action work undertaken by the author as an activist and stakeholder in the last three years. I also performed content analysis of various laws and legislative changes to the private rental sector enabling the macro analysis of their impacts on market functioning.

The structure of this paper is as follows. The first section addresses the beginnings of rent regulation and frozen rents through to the 1990s and analyses some reforms made in the early years of this century that unsuccessfully sought to modernise the private rental market. In the second section, we explore the neoliberal shock to the rental market in the aftermath of the economic and financial crisis of 2008–2009 and the social consequences of these measures, specifically gentrification and the increase in evictions. In the third section, we approach the reactions of the left-wing government that took office in 2015 and

enacted legislative measures to provide additional protection to tenants. The fourth section considers the opportunity for taking advantage of the immense vacant housing stock in Portugal as a means of increasing supply and revitalising the rental market. This article concludes with a summary of its main findings and some policy recommendations.

2. The Beginnings of Rent Regulation and the Subsequent Attempts to Modernise and Liberalise the Rental Market

The right to housing was enshrined in the 1976 Constitution of the Portuguese Republic, along with other social and cultural rights of great importance to the quality of life and social development of the population, such as the rights to social security, health, education, and spatial and environment planning. However, it is now consensual in Portuguese housing studies that this has been one of the most marginalised sectors of the Welfare State throughout the democratic period, whether in terms of budgetary allocations and public expenditure allocation, or the failure to design a strategic vision for public policies capable of consequently producing the concrete actions able to overcome and/or mitigate the structural housing needs experienced by populations. The right to housing is a constitutional right, but is dependent on the financing capacities of successive governments; thus, the legislation passed over the years has taken erratic directions, unfolding into specific programs and piecemeal measures, without any real guidance from the basic and general principles and rules of a uniform Public Housing Policy. Rather, it has run according to the interests and opportunities of the political cycles and powers of the moment and remains hostage to the functioning interests of the markets and banks [26–29].

Along with this lack of coordination over the scales, themes, target audiences and territories that housing policies have experienced in recent decades, which lack overall coherence, the evolution of the right to housing in Portugal was transversally influenced by the characteristics/dynamics of the Portuguese housing market itself, which have themselves not facilitated development. These include the crisis in the welfare state, which is already retarded and with scant provision; the residual weighting of social or public housing compared to other developed countries (2% in total); a very rigid housing market, with little mobility and with high concentration in the homeownership regime; along with a fragile and unreliable rental market, both in terms of supply and demand. Added to these weaknesses, following Portugal's accession to the European Economic Community in 1986, the latter two trends have been strengthened within the scope of the deepening liberalisation and flexibilization of the private rental system and, more recently, the financialization of the housing market in general [30–34].

More specifically, the most significant legal and regulatory framework for the Portuguese rental market took root over a century ago, initiating a process of strong state regulation. However, this has not necessarily always translated into rent regulations or rental regimes capable of contributing to a market adjusted to the needed balance between supply (landlords) and demand (tenants). Rather, it reproduces the structural problems in the sector that have now dragged on for decades.

A century ago, following the proclamation of the Republic and influenced by the context of World War I, Portugal began to enact urban leasing regulations for the entire country, with several legislative initiatives passed between 1914 and 1917. Rents were frozen throughout this period on the grounds of a transitional measure imposed by the economic consequences of the war. Similarly, the terms for resolving lease agreements were limited, alongside the scope for eviction actions and the mandatory leasing of degraded buildings. In short, this phase initiated regulation in two specific areas of great importance to the development of the rental market: the freedom to contract by the landlord and the ability to raise the rents in effect.

The urban leasing regime reform, implemented by Law No. 2030 of 22 July 1948, allowed for rents to be updated even if maintaining this restriction in the two largest urban centres of Lisbon and Oporto. In addition, this limited the terms for terminating leases, endowing them with characteristics of perpetuity. This regime extended beyond

the end of fascism in the mid-1970s. The evolution of urban leasing that accompanied and followed the 1974–1975 democratic revolution took up many of the paths trodden during the 1914–1918 war; however, it did this without learning the necessary lessons. Furthermore, the situation was more serious as it stemmed from a situation that had been gradually deteriorating since 1948. The various legislative changes that followed the 1974–75 revolution against fascism deepened various restrictions on economic freedom within the scope of urban leasing. The rent freeze was again extended to the entire country and assessments to update contracts were all suspended. The right of owners to terminate contracts still remained suspended, and the imposition of leasing agreements took place as a means of legalising the occupations/invasions for housing purposes. We would note that the state's intervention in the rental market, for the first time, reached so far as to establish maximum limits for the rent values of first and new contracts.

There were also several timid initiatives to re-establish the conditions for the normal functioning of the rental market, establishing the criteria for annual rent rises based on coefficients set by the government in order to unfreeze the rental sector. In the 1990s, Decree-Law 321-B/90, of October 15, proclaimed changing the urban rental market to make it more attractive and dynamic as its main objective. This regime proposed, among other aspects, the restoration of the temporary nature of leases, allowing for the signing of limited-duration contracts and combating the degradation of properties by regulating for a renovation works regime. However, this legislation did not come up with any effective solutions for solving the frozen rents problem, essentially maintaining its application to any contracts signed before 1990 [27].

The new urban lease regime (NRAU), approved by Law 6/2006 of February 27, took up the challenge of resolving the problem of the pre-1990 leases with rents now far lower than the market value. In fact, the consensus generated by this law was not based so much on criticism of the old regime, but rather on the sheer need to resolve the issue of old contracts. Thus, this established a system for gradually raising these longstanding rents, with this regime applying to all contracts even while providing a transitional regime to safeguard the legitimate expectations of tenants and landlords in the rent contracts that were entered into before this law came into effect. Furthermore, it also sought to respond to the need to renovate the real-estate stock and, to this end, the need to legislate the terms for carrying out conservation and rehabilitation works.

However, it was effectively Law 30/2012 that brought about the sharp liberalisation of the urban rental-market-to-be, including state-backed evictions for the first time in our country's urban history (See Lisbon Tenants Association bulletin: http://www.ail.pt/Portals/0/pdf/publicacoes/newsletter/AILNoticias14.pdf, accessed on 25 November 2021). One of the important reforms proposed by the Troika's Memorandum of Understanding precisely involved amendments to the 2006 NRAU, resulting in the promulgation of a new NRAU in November 2012. (The rental market reform appeared as an urgent measure within the scope of the economic, financial and budgetary reality resulting from the economic and financial crisis of 2008–2009 as one means of safeguarding the success of the commitments underlying the International Financial Assistance Program in Portugal. The Memorandum of Economic and Financial Policies, also known as the Memorandum of Understanding or the Troika Plan, is an understanding agreement signed in May 2011 between the Portuguese state and the International Monetary Fund, the European Commission and the European Central Bank, and is designed to balance the public accounts and increased competitiveness in Portugal as a necessary condition for the loan of around EUR 80 billion granted to the Portuguese state by these three entities. The memorandum proposed various actions aimed at stabilizing public debt at around 2013 levels.) This regime established that the rent contracts prior to 1990, still a substantial proportion of the Portuguese leases, would be raised, reinforcing the landlord's position in negotiations between the parties and facilitating the transition of the aforementioned contracts to the new regime in shorter periods of time, with the maximum amount stipulated as the annual value corresponding to 1/15 of the lease. This also changed the substantive lease regime,

particularly by attributing the parties with greater freedom to determine the terms relating to the duration of lease agreements. The promulgation of the 2012 NRAU was proof that the 2006 urban lease reform introduced important changes in the sector but did not achieve the expected results as regards the old leases. The continued demand for houses to rent and the lack of market supply at affordable prices demonstrated the need and politically justified the emergence of the 2012 NRAU.

3. The Neoliberal Shock in the Aftermath of the Economic and Financial Crisis of 2008–2009 and the Collateral Social Damage: Gentrification and Evictions

As mentioned earlier, the 2012 NRAU was the subject of vigorous social protest, in keeping with claims that the updated mechanism imposed levels of rent inaccessible to many tenants because the values were established without adequate social support and necessarily impact households with lower socioeconomic levels (see several protests in: https://www.dn.pt/politica/cerca-de-100-inquilinos-manifestam-se-contra-nova-lei-2310040.html, accessed on 25 November 2021; https://www.jn.pt/local/galerias/centenas-em-manifestacao-para-exigir-habitacao-para-todos-9892862.html, accessed on 25 November 2021). Despite the various social countermeasures provided in the law to protect households in economic need, the elderly and the disabled, the truth remains that there were drastic impacts. These were reflected in several waves of eviction, which were particularly felt in the inner-city areas where the pre-1990 contracts and lower rents predominated.

Through the advancing legitimacy of simpler and more expeditious eviction mechanisms for the fulfilment of contracts, especially in the case of default by tenants, the confidence of owners that private rental and short-term rental products would provide safer investments was reinforced. The 2012 law provided the necessary legal lever applied by the market to unblock the tens of thousands of empty buildings in the historic centre and/or those that sheltered needy populations that paid very low rents. This served to prepare the inner city to receive an injection of foreign and private capital that would materialise in the housing stock on the condition of effectively reproducing real-estate capital. These buildings occupy a privileged and central location in noble areas of the city, but are associated with poor conservation, thus creating opportunities for real-estate speculation and the extraction of capital gains. Real-estate developers, following rehabilitation works, sell the buildings at a much higher price than what they paid, and also when they are very degraded. This maximizes the rent-gap principle (the differential between the present ground rent at the date of the lease in an advanced state of degradation and the future and potential rent due to renovation of usage and function).

Following implementation of the 2012 NRAU, the largest impacts on the sector emerged in terms of the duration and type of contracts, in keeping with the transition from old contracts to the new regime and the streamlining of eviction procedures. As regards the duration of contracts, the 2012 law introduced greater flexibility and freedom, effectively favouring contracts of varying durations and shorter contracts without any minimum term in order for supply and demand to adjust more easily. The contract-termination mechanism was reinforced, with tenants incurring a two-month delay in their rent payments subject to a rapid eviction process. On the other hand, in line with fostering the national urban rehabilitation strategy, which was recognised as a key facet in the country's economic recovery, the ending of contracts (even for indefinite periods) is now fast-tracked whenever landlords either wish to carry out demolition or wide-reaching renovation works or whenever they claim to need the housing for themselves or their descendants. These reasons, carrying out in-depth construction works, and the delayed tenant responses to the intentions of their landlords to raise their rents constitute the two main reasons rendering eviction an indisputable feature of this new urban rental law.

In Lisbon, the central district of Santa Maria Maior, for example, has lost almost two thousand inhabitants since 2013. This reflects the departure of more than one inhabitant per day in the four years from 2013 to 2017. Depopulation is not a recent phenomenon in the historic centre of Lisbon, and National Institute of Statistic records indicate how this

demographic bleeding reaches back to the 1960s. Where 160,000 inhabitants resided, 40,000 now reside. During the second half of the last century, this process mainly interrelated with the growing suburbanisation and the consequent formation of the Metropolitan Area of Lisbon. The latest population census figures from 2011 do not capture the aggravated population loss of recent years triggered by the evictions under the new 2012 rent law or the impact of short-term rentals on the local housing market. The number of recent evictions in the historic centre of Lisbon thus remains unknown, and the lack of diagnostic studies prevents the proving of what seems to be clear evidence for those who live or spend their daily lives in the traditional inner-city neighbourhoods but remains invisible to the broader gaze of public opinion and civil society.

However, several residents' associations and campaigners defending the right to housing testify to hundreds of cases in recent years, especially in the central districts of Santa Maria Maior, Misericórdia and São Vicente, which would account for quite a significant proportion in a universe of residents totalling only a few thousand; even more so when dealing with vulnerable populations and those at social risk. Faced with a scenario of increasingly high rents, coupled with the low wages received by most Portuguese workers, the number of evictions has skyrocketed. According to the latest data from the BNA—the National Leasing Bank, evictions have doubled since 2013, and an average of 5.5 tenants are evicted daily across the country. According to data from the Ministry of Justice, the number of evictions in 2016 was 91.7% higher than the number recorded three years earlier, which may reflect evidence of the dynamics described. In the case of Santa Maria Maior, 2000 households were evicted between 2014 and 2018, according to the District Council. This ranks as more than one family a day undergoing eviction from an area of the city that is already greatly underpopulated (see the article in the New York Times: https://www.nytimes.com/2018/05/23/world/europe/lisbon-portugal-revival.html, accessed on 25 November 2021).

There are exceptions to these NRAU 2012 rules in cases where tenants are aged 65 or older or experience disabilities of greater than 60%. In the case of refurbishment and deep restoration works, the landlord must relocate the tenant in the same municipality or provide compensation. In terms of raising rents, this protection guaranteed by age and the degree of disability or even by proven economic need (when the annual household income is less than five times national minimum wage) was only originally to remain in effect for a transitional period of five years, following which the level of rent would be raised to free-market values. However, this five-year term (from 2012 to 2017) has been successively extended, first to eight years (2020) and recently to ten years (2022), thereby protecting the poorest and most vulnerable by delaying the transition from old contracts to this new regime.

Another controversial aspect interrelates with the NRAU 2012 stipulation that, in order to update an old pre-1990 contract, the landlord must notify the tenant in writing and set out a new contract proposal, hence providing a new duration and rent level. The tenant then has 30 days to reply, and should he/she not do so, the proposal is deemed to have been accepted. The contract—which has, in the meantime, expired—is transferred to the NRAU, and may later be terminated. This norm raised many social and political criticisms at the time of enactment due to the reduced amount of time tenants had to answer landlord proposals (30 days), potentially catching people off guard, especially as such tenants are an ageing, often only semi-literate population. Failure to respond within the stated period meant tenants automatically accepted the terms of their landlord's rental proposal, both in terms of the increased rent level and the new contract duration.

We would recall that the Portuguese Constitutional Court declared this NRAU 2012 rule unconstitutional in October 2020, hence coming out against tenants with old rents having their contracts terminated for not having not responded to their landlords in a timely manner whilst being unaware of the effects this lack of response might have. This procedure was considered unconstitutional whenever tenants were not informed of the

alternatives for assistance and when landlords did not warn of the effects associated with the eventual silence of tenants.

4. Legislative Changes by the Left-Wing Government and Additional Tenant Protection

The issue of housing has dominated political debates since late 2016 and became a banner slogan for the second half of the "geringonça" government legislature (2015–2019), visible in the founding of the Ministry of Housing, the State Secretary of Housing and the launch and public discussion of the New Generation of Housing Policies and the Basic Housing Law in 2018 and 2019, respectively. (The middle class was heavily attacked during the post-financial crisis austerity period (2009–2015) but has recovered income since 2015 under a left-wing government backed by the Socialist Party, the Communist Party, and the left-wing Bloc. This recovery has been termed a "geringonça" economic miracle, with this Portuguese slang word meaning something neglected or a poorly constructed and clumsy construction, an apparatus or mechanism of complex construction but that still works and complies with the function for which it was built.)

With the rise to power of the Socialist Party supported by the "gerigonça" left-wing coalition in 2015, this neoliberalisation trend in the rental market, which deepened under the centre-right government of Prime Minister Passos Coelho (2011–2014), ended up slowing down from the perspective of both the norms and the legislation. This happened in the face of strong social pressures applied by urban social movements and tenant associations and in defence of the right to housing, with the housing problem re-entering the political, social and media agenda and since escalating and generalizing through public opinion, especially in 2017, the year of municipal elections.

That year, with the left fully in government, and on the verge of the transitional period of old rents ending (i.e., five years after NRAU 2012), and with a new wave of evictions on the horizon, an extension for eight years was promulgated (another three years in relation to the five years initially established) for the transitional period for updating old rents, through Law No. 43/2017, of 14 June. In this context, the transitional period for updating rental payments established prior to 1990 extended until 2020 and applied to all tenants on very low average incomes, aged 65 years or over or with a disability equal to or greater than 60%. At the same time, there were changes in the Civil Code related to leases, specifically, increasing the duration of contracts (up from two to five years) and raising the period for non-payment of rent (up from two to three months).

The now-introduced restructuring reflects a setback on the path to liberalisation of the rental market as outlined above. Social concerns resurfaced at the centre of the legislators' attention, correspondingly resulting in an increase in the protection attributed to the tenant and, in return, undermining the landlord's position. These changes sought to extend the protection of tenants, who are traditionally perceived as the weakest party in this type of contract. This aligns with a common understanding that tenants are in a more disadvantaged position in such contractual relationships and hence need the law to provide greater protection against abuse by the other party, the landlord.

Further restraining the liberalising momentum from the last national government, one year later, Law No. 30/2018, of 16 July, established an extraordinary transitional regime to protect elderly or disabled persons who are tenants and have resided in the same location for over 15 years, in these cases, proceeding to temporarily suspend the periods of opposition to the renewal and termination by the landlords of lease agreements and alongside the suspension of special eviction procedures and eviction notices.

In the same year, Law No. 64/2018, of October 29, also guaranteed the exercising of a pre-emptive right by tenants in cases of the owner selling the leased property. This reinforced the power of choice of tenants in any sale of properties in which they live, as they hold the power to cancel sales and transactions that fail to respect their right of preference. However, this law was declared unconstitutional about eighteen months later as it is not certain that stability in housing will be effectively protected by the exercise of pre-emptive

rights, in addition to the fact that the balance of interests between owners and tenants is not safeguarded.

Nevertheless, the worsening of the housing crisis triggered by the 2008–2009 economic and financial crisis had already led many landowners to adopt positions of abuse of power in relation to their tenants, exerting pressure to make them leave their homes, which only intensified the urban social movements and right to housing activism. There were several well-known public cases that put pressure on the government. In terms of the media and political agenda, there was talk of "real estate bullying". This was defined as any form of pressure, harassment, intimidation or psychological, symbolic or physical violence that is repeatedly and systemically practiced by the landlord, owner or other hegemonic agent of the real-estate sector over the tenant in order to facilitate the departure of resident tenants perceived as obstacles to the real-estate business. Intentionally degrading the building—removing access stairs, for example—subjecting residents to constant interference, or cutting off electricity, gas and water represent some of the techniques deployed by homeowners in the centre of Lisbon to force tenants out of the house and thus gain higher incomes from their properties.

Precisely this pressure from activists and urban social movements in political forums, coupled with strong media coverage, managed to ensure the enactment of Law No. 12/2019 of 12 February, which again added a new amendment to NRAU 2012, establishing that harassment of the lease or sublease holder is prohibited. This was understood as any illegitimate behaviour by landlords, representatives or third parties interested in the acquisition or commercialisation of the leased property, which, with the aim of bringing about vacancy, disturbs, constrains or affects the dignity of the tenant, subtenant or persons who legitimately reside with the tenant; or subjects them to intimidating, hostile, degrading, dangerous, humiliating, destabilising or offensive environments; or seriously prevents or impairs access and fruition of the leased property.

As regards promoting affordable rent, the highlight thus far came with the Affordable Rent Program (PAA) (Decree-Law No. 68/2019, of 22 May), with its core objective of promoting a greater balance between the rental sector and that of homeowners, focusing on fostering new housing supplied by private owners and making the transition between occupancy regimes more flexible, which, in the long term, is expected to provide greater security, stability and attractiveness to the rental market, on both the supply and the demand sides. This provides tax incentives for public and private entities placing their buildings or urban fractions in permanent housing leases up to the rental limits defined by the program (see Table 1).

Table 1. Rent regimes in Portugal: characteristics and impacts.

Rent Regimes	Main Principles	Impacts
Decree-Law of 11 November 1910	Strict fiscal precepts in the field of urban leasing froze rents for a period of one year and extended the advance notice required for opposing the renewal granted compensation to commercial tenants.	Stabilised rent values due to the strong growth of urbanisation. No evictions allowed, protection of tenants started decapitalisation of the owners. Missing criteria and rules to prevent degradation of the physical conditions of buildings
Decree-Laws of 23 November 1914 and 28 September 1917	Froze rents in existing contracts and in new contracts. New contract should maintain the previous rent. Landlords obliged to lease vacant buildings.	Evictions were prohibited. Decapitalisation of the owners maintained. Still missing criteria and rules to prevent degradation of the physical conditions of buildings.

Table 1. *Cont.*

Rent Regimes	Main Principles	Impacts
Law No. 2030, of 22 June 1948	Sharply limited the situations of contract renewal. Postponed expiry (in case of divorce and/or death of the tenant) and promoted perpetuity. Allowed expropriation for public utility and for surface rights. Rule of automatic contract renewal was maintained under the previous law. Updating rent values only allowed outside Lisbon and Porto. In the two main cities of the country, rents were therefore frozen.	Evictions were prohibited and highly restricted. Perpetuity of contracts protected the main tenant and family. Decapitalisation of the owners maintained. Degradation of physical conditions of buildings worsened.
Decree-Law No. 217/74, of 27 May and Decree-Law No. 155/75, of 25 March	Froze rents on urban buildings for 30 days. Extended the suspension of tax assessments to update rents to all municipalities, previously confined to Lisbon and Porto. Suspended the right of demolition. Established a duty for the owner to lease. Fixed maximum rents for the lease of old buildings. Non-observance of these and other rules was penally repressed. Suspended complaints about leases made on the basis of the expansion of the building or the need for the leased property as the landlord's own house. Legalisation of squatters in dwellings for housing purposes through compulsory lease agreements.	Tight regulation on the freedom to establish the value of rents, evictions and changes in the occupation regime. Landlords' reliance on subsequent tenancy laws ensure financial sustainability in order to maintain the physical quality of leased buildings. Therefore, decapitalisation of the owners visibly worsened the degradation of leased buildings, initiating a process of unsustainability in the rental market, which failed to guarantee habitable conditions. Degradation of physical building conditions further aggravated.
Decree-Law 321-B/90, of October 15 (RAU)	Main objective: to change the urban rental market and make it more attractive and dynamic. Restoration of the temporary nature of the lease. Signing of contracts of limited duration. Combating the degradation of properties, regulating the renovation works regime.	No effective solutions for solving the rent-freeze problem. Maintained the application of contracts concluded before 1990. Degradation of physical conditions of buildings continued. Lack of confidence of landlords/the private sector in the reforms to modernise the rental market and the role of the state. Decrease in the supply of houses for rent.
Law 6/2006 of February 27 (NRAU 2006)	Resolution of the problem of leases prior to 1990 with levels of rent much lower than the market value. Allowed for gradual updating of old rents, calculating the new rents to be based on the value of buildings. Encouraged owners to rehabilitate degraded buildings to improve their property values. For low-income households, the elderly and people with disabilities, an income subsidy was provided when the transitional period ended, to be requested from Social Security.	Allowed for phased updating of old rents. Did not fully liberalise the rental market. Many thousands of the pre-1990 frozen rent contracts were replaced. Degradation of physical conditions of buildings worsened still further. Lack of landlord-sector confidence in the reforms of the state to modernise the rental market. Decrease in the supply of houses for rent.

Table 1. *Cont.*

Rent Regimes	Main Principles	Impacts
Law of 30/2012 (NRAU 2012)	Contracts prior to 1990 were updated, changing the substantive lease regime, specifically by giving the parties greater freedom in stipulating the rules relating to the duration of lease agreements. Created the special eviction procedure and the National Lease Bank so that properties can be vacated more quickly when the tenant does not do so on the scheduled date.	Unblocked tens of thousands of empty buildings in the historic centre and/or those that sheltered needy populations paying very low rents, but by means of eviction procedures. Intense rehabilitation/renovation works in the housing stock of the inner city and attraction of private capital values of rents were established without adequate social support and necessarily affect households at lower socioeconomic levels: gentrification. Confidence of owners in the idea that private rental and short-term rental products would be a safer investment was reinforced.
Law No. 43/2017, of 14 June	Promulgated an extension for eight years (another three years in relation to the five years initially established by NRAU 2012) to the transitional period for updating old rents. Increase in the period for signing contracts (from two to five years). Increase in the period for non-payment of rent (raised from two to three months).	Setback on the path of liberalisation of the rental market previously outlined as social concerns resurfaced at the centre of the legislator's attention. Deepening of the lack of confidence of the landlords sector in the state reforms to modernise and liberalise the rental market. Decrease in the supply of houses for rent.
Law No. 30/2018, of 16 July	Extraordinary and transitional regime for the protection of elderly or disabled people who are tenants and have resided in the same location for over 15 years. Temporarily suspended the periods of opposition to the renewal and denunciation of lease agreements by the landlords. Suspension of the special eviction procedure and eviction action	Another setback on the path to liberalisation of the rental market previously outlined.
Law No. 12/2019 of 12 February	New amendment to NRAU 2012, establishing that real-estate harassment in the lease or subletting sectors is prohibited.	Created difficulties and obstacles to eviction and criminalised real-estate bullying. Lack of confidence of the landlords sector in the state's reforms to modernise and liberalise the rental market. Decrease in the supply of houses for rent. Increase in rent values in new contracts in the private rental market.
Affordable Rent Program (PAA) Decree-Law No. 68/2019, of 22 May	Main objective of promoting a greater balance between the rental sector and homeowners. Attraction of new housing supply from private owners. Making the transition between occupancy regimes more flexible. Tax incentives for public and private entities that place their buildings or urban fractions in permanent housing leases. Rent cap: limit on the rent level defined by the program.	In the long term, expected to provide greater security, stability and attractiveness to the rental market on both the supply and demand sides. Small increase in the supply of houses for rent, which is yet to impact on the increasing rents in new private-rental market contracts.

Source: Author's own elaboration.

Despite the tax incentives granted, the PAA, launched in July 2019, underwent a slow but promising start for landlords and tenants, attracting only a few dozen homes in the first few months. The proposal focuses almost exclusively on the granting of tax benefits to homeowners and launching an insurance package for leasing and does not even begin to tackle the urgent need to regulate the rental market and overheated leasing terms. In fact, the

acceptance of the "market reference value", for rents on which the 20% reduction will then be applied to define the supposed accessible rent, seems to entirely ignore the rampant and speculative escalation that rents have been subject to in recent years (see Figures 2 and 3), with constant and uninterrupted increases as well as generous rates of positive annual percentage increases, always in the order of two digits [26,35].

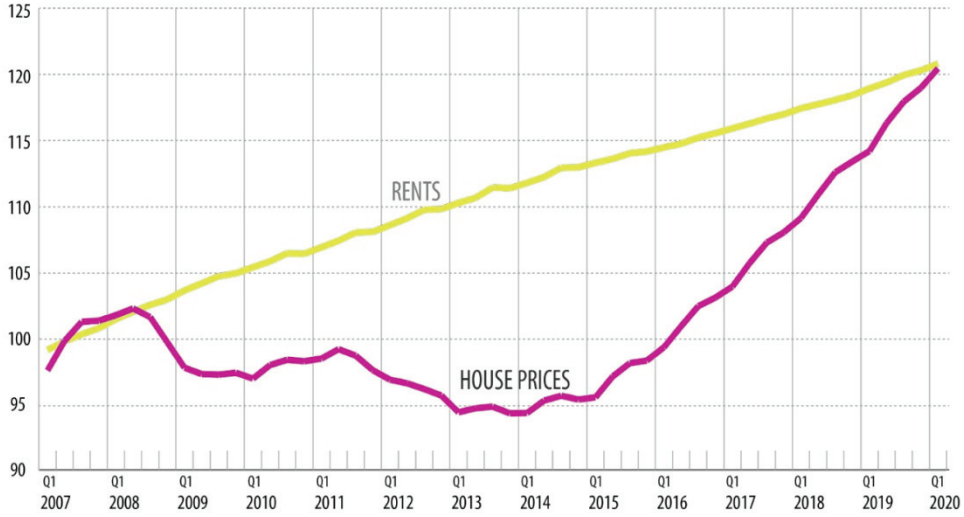

Figure 2. Evolution of rent and housing values indices in Portugal (2007 to 2020) (2007 = 100) Source: [36].

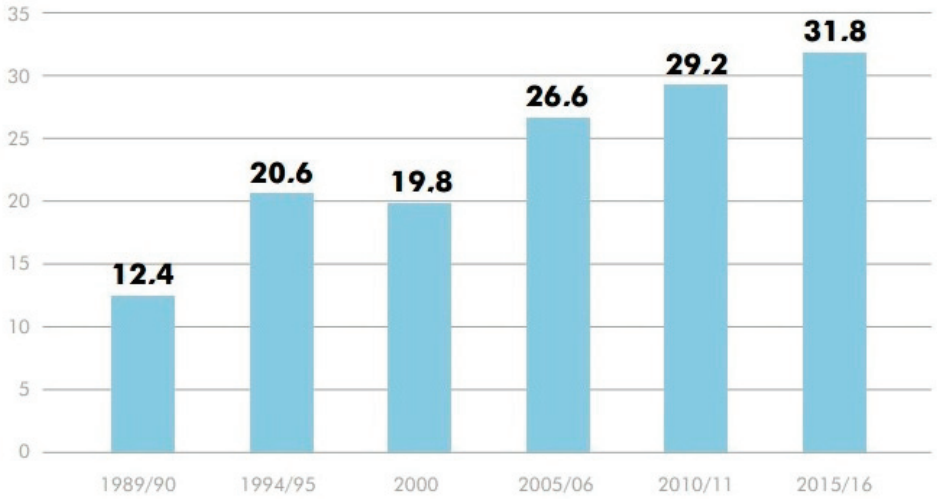

Figure 3. Evolution of average annual household expenditure on housing. (As % of total expenditure.) Source: [37,38].

There is no all-encompassing statutory definition of affordable housing anywhere in the world. Indeed, there remains a good deal of ambiguity around the way the term 'affordable' applies to housing. Aside from covering housing provided through public subsidy, the term is also broadly applied to describe housing of any tenure deemed affordable to a particular household or group by analysing housing costs, income levels and other factors, hence the lack of consensus over what affordability means in housing terms [39]. Affordable housing may refer to housing units that are affordable by the section of society whose income falls below the median household income. Over the past few decades, housing affordability at the household level, and the affordable housing stock more broadly, has gradually declined for most low-, very low- and extremely low-income renters and for some low-income homeowners in many countries, both in the Global North

and the Global South. Housing affordability and affordable housing challenges may have an impact on a household's budget, leaving less to pay for food, utilities, transportation to work, health and childcare expenditures and reducing savings for emergencies, retirement and other opportunities, such as pursuing higher education or starting a small business. These challenges may result in decreased opportunities and a lower overall quality of life [40].

Aalbers [41,42], Madden and Marcuse [43], Wetzstein [44] and many others have explained how the emergent global crisis of urban housing affordability and affordable housing provision results from the way that housing-related household expenses are rising faster than salary and wage increases in many cities and metropolitan areas around the world. This situation was triggered by at least three global post-global financial crisis megatrends of accelerated (re)urbanisation of capital and people, coupled with the financialization of housing, the provision of cheap credit and the rise of intra-society inequality.

Despite improvements in the material and housing conditions of the vast majority of the Portuguese population in the second half of the 20th century, which to a large extent determine well-being and quality of life, the relative weighting of housing expenses in different household consumption expenditures is not uniform. The ratio between the cost of access to housing—that is, the mortgage instalments or the rent value—and the median salary of the household in Lisbon, for example, stands at around 60% [34]. This is more than double the reference benchmarks for effort rates recommended by international organisations as households or individuals should not spend more than 30% of their income on meeting their housing needs. Housing and other associated costs represents one of the final consumption expenditures that weighs most heavily on Portuguese family budgets and has also experienced the most significant upward changes in recent years.

5. Could the Excessive Level of Empty Housing Stock Be an Opportunity for the Affordable Rental Market?

It is difficult to gain any objective and categorical calculation of the total number of vacant houses in the country, as this number is recorded by the population census, and therefore the data we have date back to the last census in 2011, when more than 730,000 properties (approximately 15% of the entire national housing stock) stood empty. Why are so many vacant housing units hoarded and remain off the private rental market?

From the market perspective, the legal and fiscal framework does not provide sufficient incentives for landlords to place these empty houses on the private rental market, which would substantially increase supply and contribute to lower prices. In addition to the successive changes in laws that do not bring stability, confidence and security to market options, there is a poor balance between the respective interests of supply and demand [45]. Roughly speaking, left-wing governments value social protection for tenants; right-wing governments defend the renter interests of landlords, which drives a bipolarised regulatory view with resulting reflections in the dysfunctional market. The most recent political options prevent the total liberalisation of the rental market, delay the necessary reforms to the sector and do not speed up the widespread application of a rent subsidy policy (applied but with very residual effects), placing the social rental market burden on landlords and the private sector. Private property sector agents and actors describe this as a tremendous obstacle to the necessary modernisation of the rental sector and to overcoming the difficulties and lack of confidence of owners in placing their vacant properties on the rental market, which would certainly boost supply.

Furthermore, the number of vacant houses has increased substantially over the last few decades, arising out of a trend towards a housing market greatly oriented towards the construction of new housing, with an increase in the number of vacant properties never designed for habitual residence, but rather for second holiday or temporary/seasonal occupation residence. This also reveals how the Portuguese economy depends on growth generated by the real-estate dynamics linked to new construction (Table 2). This comes at the detriment of the urban rehabilitation of existing buildings, even though the housing

policy targets the paradigm of renovating the existing building stock and attracting vacant buildings back onto the market. Thus, this prioritises progressive transformation in the form of accessing housing: from a model strongly based on the construction of new housing and their acquisition for homeownership to a model in which the rehabilitation of buildings and the private rental market can gain new dynamism.

Table 2. Key housing indicators in Portugal (1970–2011).

	1970	1981	1991	2001	2011
Number of houses per family	1.2	1.2	1.3	1.4	1.5
Homeowners	50%	57%	65%	76%	73%
Vacant houses	373,950	190,331	440,721	543,777	735,128
Precarious housing	—	46,391	27,642	27,319	6612

Source: Pordata and National Statistical Institute.

As the reduction of investment in new building construction, intended for permanent housing, is both understandable and inevitable, urban rehabilitation emerges as an inevitable paradigm for preserving built heritage, revitalising city centres and as a means of guaranteeing employment in the construction sector as the engine of the economy. In addition, from the spatial planning perspective, this ensures containment of the urban perimeter and consolidation of the already built urban environment, preventing excessive (sub)urban expansion that is unsustainable from both social and environmental points of view.

However, the dynamics driving new construction are very persistent and interrelated with the way urbanisation has always been an efficient and easy-to-reproduce "capital deposit" sector in a vicious cycle. Moreover, it is difficult to break at the scale of the municipalities, as new constructions feed local finances through the Municipal Property Tax and other taxes and fees, rendering them sustainable. In addition, this sector generates very significant direct and indirect impacts for the Portuguese economy, employment and wealth creation. Furthermore, according to real-estate and civil-construction professionals, this surplus of empty houses is dispersed throughout the territory and not polarised in the metropolitan or urban areas of greatest pressure where this housing stock is needed to respond to new demand. Especially on the coast and in the main district capitals, where the greatest socio-demographic dynamism is concentrated, this view perceives a continuous and sustained mismatch between supply and demand.

6. Final Considerations and Policy Recommendations

Despite all the reform efforts carried out in the last century (see again Table 1), it was not possible to permanently thaw the old rents, develop mechanisms to support families unable to pay their rents and create a climate of confidence to attract investments and boost the supply of houses for rent in the private sector. Therefore, it was equally impossible to resolve the constant mismatch between supply and demand prevailing in the Portuguese rental market. Public authorities, with a small public housing stock, also decapitalised and have been unable to make the rental market a priority in national housing policy, thus delegating responsibility for creating an affordable rental market to the private property sector.

The government's housing policy is currently subject to widespread debate in Portugal. There is growing pressure for housing policymakers to create more affordable rental housing, a concern that has now been around for over five years, both in national state polices and at the Lisbon and Oporto City Council levels, for instance. Although there are some dissenting voices regarding reintroducing rent regulation as a potential policy instrument to create affordable rental housing, this has not been seriously considered or put it into practice.

The results, in spite of some occasional improvements in the last decade, are very visible: marked deterioration in the housing stock, resulting from the decapitalisation of its

owners due to very low rents and, since the 1980s, major state support for new construction involving massive support for subsidised bank credits to encourage consumers to buy their own home (to the detriment of renting); an increasing number of empty houses in Portugal; a progressive reduction in the supply of houses for rent, both scarce and with rental values inaccessible to most families considering the new, free-market contracts.

In this ongoing and extended housing crisis, which has only worsened over the last few years, it is a categorical imperative that the state makes urban rehabilitation and the affordable rental market an attractive sector for real-estate dynamics, attracting the largest number of private houses possible through more drastic tax exemptions and stimuli at the level of fiscal policy for the private sector, where the overwhelming majority of vacant housing stock is concentrated. In this context, it would even be possible to provide measures to subsidise leasing (directly to the owner) in specific cases of welcoming vulnerable families/individuals or housing emergencies, thus enlarging the stock of affordable public housing.

In this paper, we set out how the huge stock of empty houses may represent an opportunity to mitigate the dysfunctions of the Portuguese rental market, as long as the national government encourages private initiative through a sufficiently attractive fiscal policy that draws these houses into the private rental market. Furthermore, since the beginning of the pandemic, the drop of about 7% in the number of houses assigned to short-term rentals and the migration of many of these to the long-term rental sector, combined with other factors, contributed to rents falling in the city of Lisbon by about 15% in the last six months of 2020 [46].

On the other hand, in areas with high urban pressures, where the percentage of vacancies remains very high, it is the state's obligation to enforce the recently enacted Basic Housing Law, striving to implement the social function of property. Thus, this recommends that more coercive and drastic measures be taken to raise the Municipal Property Tax on unoccupied properties to such an extent that it is not beneficial for owners not to put them to social or economic use. In the event of abandonment motivated by undivided inheritances, a non-existent registration or unknown owner, or the total disinterest of the owner, we would propose the state either takes up administrative ownership or expropriates the property, as happens in other European countries and cities where the housing market is overheated and not adjusting to demand, such as Barcelona, Berlin or Vienna.

A new rental law is necessary to allow for the creation of an environment of trust in the rental market, contrary to the legislation enacted over the last century. This new law should have effective guarantees of protection for landlords, in the case of breach of contracts, but also rights and duties for both parties (landlords and tenants), and this does not, under any circumstances, allow for the eviction of tenants whenever dignified alternatives or sufficient means of subsistence are not duly ensured. In this case of eviction, the family situation must be analysed and the means must be found, whether by the local government or the central state, to adequately support families in the event of their financial inability to maintain housing.

Therefore, it is important to understand how the public problem related to accessible rentals is perceived by the political environment and to compare and contrast this with other experiences and empirical evidence. Government action is decisive and shapes housing policy and forms and regimes of occupation, and is clearly also affecting the private rental market. For example, this might involve the regulation of institutions and the financial market and promoting rent controls through to administrative possession, exercising pre-emptive rights or even expropriation in the case of vacant houses held by large landlords such as real-estate investment trusts, banks or other property developers, especially in areas with strong and unmet demand. However, the state also needs to ensure tax exemptions for property owners who place their houses on the affordable rental market, creating a legal and regulatory framework that transmits credibility, stability and security to the contractual forms between supply and demand, as well as an effective right to housing

through affordable rental, recognising its value as much in economic terms as well as for the social good.

Good governance tools should work together to influence affordability and access to rental market outcomes by: formulating a clear strategy and vision of desired housing outcomes, including adequate supply and access to affordable and adequate rental provision for different household types; acting effectively through legislation and strategic investment and expert administration, while committing to effective rental policy coordination which mediates the many different and contradictory interests, stakeholders and organisations involved in the sector; requiring and enabling all relevant stakeholders in the private and public sectors to play a role in achieving affordable and inclusive housing goals; supporting new housing models promoted through public–common partnerships following the growing trend of third-sector housing in Europe; and establishing and monitoring standards for adequate, affordable and accessible renting across all forms of regime–public rental, private and free-market rental, not-for-profit and co-operative rentals.

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Grey Relational Analysis (GRA) as an Effective Method of Research into Social Preferences in Urban Space Planning

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Abstract: The appearance of urban space is most often determined by planners, urbanists, and officials who fail to consider social preferences in the planning process. According to recent scientific research, spatial design should take into account people's preferences with regard to its shape, as it is they who are the target audience. Moreover, legal regulations in many countries require the public's inclusion into the space planning process. This paper outlines the legal status of the issue of social participation in spatial planning and provides an overview of the methods and techniques applied in the research into preferences. The aim of the article is to determine the strength of the relationship between the features adopted for the study using the grey system theory and to investigate the model's behaviour for varied input data. It also presents the results of a study into the effect of geospatial features on the perception of the sense of security within urban space. The features were extracted using a heuristic method for solving research problems (i.e., brainstorming) and the survey was conducted by the point-scoring method. The survey results were processed by the grey system method according to the grey system theory (GST) of the grey relational analysis (GRA) type to yield a sequence of the strength of dependence between the analysed features. The study was conducted five times, with the order of entering the survey results being changed. The conducted analyses indicated that a change in the order of data from particular surveys applied for calculations resulted in the order of the epsilon coefficients in the significance sequences being changed. The analysis process was modified in order to obtain a stable significance sequence irrespective of the order of entering survey results in the analysis process. The analysis results in the form of a geospatial feature significance sequence provide information as to which of them have the greatest impact on the phenomenon under consideration. The research method can be applied to solve practical problems related to social participation.

Keywords: space user preferences; social participation; safety in urban space; geospatial features; grey system theory (GST); grey relational analysis (GRA)

1. Introduction

1.1. Spatial Planning Model Applied in Practice

Spatial policies and the arrangements of planning documents concern the vital interests of the local community and individual space users. It is planners, who are most often guided in the planning process by the rule of functionality in space and who fail to consider the expectations of the users of a space, who are responsible for the appearance of urban spaces. In spatial planning practice, the rationalistic model [1], also referred to as "technical approach planning", is most commonly applied worldwide [2]. Its basis for planning activities is the full comprehensiveness of operations, with the maximum possible amount of spatial data used and the required procedures followed. In the rationalistic model, public participation in planning work is only guaranteed pursuant to legal provisions. As Hanzl

noted, the consultations held in this model are often regarded by decision-makers as an inconvenient element, and the use of knowledge of the community living in a particular area is often marginalised. A feature typical of the rationalistic model is also citizens' difficult access to the methods and source materials used by planners [3]. In this model, the lack of agreement between planners and the designed space users can be observed. As noted by Jeleński and Kosiński, designs are usually implemented for political reasons, business needs or at the developer's request. It is very rare that a design is the result of a public discussion concerning the creation of good spaces for the benefit of the local community. The spatial development concepts developed by the local community centre around their needs. In most cases, these are very realistic and practical but also contain innovative ideas. Such designs, co-created by space users, are valuable, as the vision included in them is considerably broader than what a single expert or agency can offer [4]. It is worth considering the idea of incorporating social preferences into the planning procedure by including citizens in the process of co-determining the surrounding reality, as it enables both a reduction in social conflicts and the optimisation of the decision-making process in spatial management.

1.2. The Need for Participation in Spatial Planning

Participation (from Latin participo—to participate) means taking part in an enterprise or belonging to a group. Currently, it is understood much more broadly as joint participation in making decisions, co-determination, and active participation in developing the surrounding reality [5]. Social participation in spatial planning refers to a process in which both the authorities and the inhabitants collaborate in the preparation of plans, the execution of a specified policy, and decision-making. This method prevents the emergence of conflicts that are inevitable in spatial planning [6].

Smith believes that the issue of social participation in public management is regarded in Western countries as one of the main political priorities and is very often reflected in the policies implemented at both national and local levels [7].

Many authors note that the dynamics of urban development are changing urban objectives that should be consistent with human needs and experience. The authors stress the need to move away from the paradigms that define idealised spaces, such as Ebenezer Howard's Garden City, Plan Voisin of Le Corbusier's geometric ideal city, or a city following the New Urbanism convention which has, according to the assumptions, a market square in the city centre, city block development in its area and a designed public transport network that marginalises individual means of transport [8,9]. The benefits of incorporating urban development dynamics into spatial planning will allow simplified economic or ecological models to be overcome [10] and initiate productive interactions with psychological tests that examine the individual's needs in the cities [11]. Urban development dynamics should be supported in decision-making with qualitative social research. Following Walmsley's opinion, officials, decision-makers, and planners should respect individuals' needs in the cities by incorporating local communities into the space design process.

There are a growing number of studies that call for a reduction in the role of planners, urbanists, and decision-makers in decisions concerning the design of urban space by incorporating spatial user expectations into the spatial planning process. The current variety of New Urbanism, promoted by the Congress for the New Urbanism Sign-In CNU (a non-profit organisation with its registered office in Washington), is an activity focused on urban planning design for humans. The principles for designing human-friendly public spaces are also presented in a book by Jeleński and Kosiński, who claim that the planning process requires discussion and collaboration with the community at the outset. This approach assumes that professionals extract ideas that are thought up by community members as they track their point of view, actual problems, and even more importantly, local ideas on how to change local public spaces. The role of professionals is then to implement the vision created by the local community [4]. According to Schafran, it is necessary to consider, in the urban environment, that each design is good and should be

accepted by the authorities and to think of how to select any concept, including creativity, entrepreneurship, sustainable development, resilience, and freedom, in which all ideas and aspirations can be very useful [12].

1.3. Legal Status of Participation

The currently observed crisis of representative democracy, and the decrease in citizens' involvement in this area, has prompted local authority representatives to prevent these negative trends and to search for new methods for engaging inhabitants in their local government communities [13].

The incorporation of social preferences into spatial policy can be regarded as a standard whose significance is stressed at the international level in guidelines from individual Earth Summits (Stockholm, 1972; Rio de Janeiro, 1992, 2012; Johannesburg, 2002) or in other supranational agreements, e.g., the Business Charter for Sustainable Development, the UN "Global Compact" system, the UN Declaration "Banking and the Environment", and the Habitat Agenda [14].

Participation has become a standard feature of municipality management, particularly in West European countries and in both Americas. It was in South American countries that both the principles of "social urban planning" based on the inhabitants' participation in the design process and the idea of participatory budgeting were first introduced [15].

In Europe, social participation became a popular issue, resulting from, among others, progressive social and political changes as late as the 1990s [13].

Social participation in spatial planning is well established in Germany, where its protection extends to the very process of considering the planning direction (Abwägungsvorrang) and its effect (Abwägungsergebniß) [16]. Firstly, the planning procedure takes into account the obligation to prevent conflicts (Gebot der Konfliktbeseitiegung) in order to foresee and pre-emptively solve future conflicts and, secondly, an obligation to consider individual interests (Gebot der Rucksichtsnahme). In this case, the municipality is required to protect individual interests because a specific development of a plot affects neighbouring plots, which may infringe the legal and factual interests of other property owners (holders) [17]. Errors in the assessment of interests can, consequently, result in the annulment of the validity of plans, both through inspections and in administrative court proceedings [16].

Protection of private interests under the English system is of a different nature than that under the German system, as it is primarily based on supervisory activities of the state Planning Inspectorate [18,19]. The basic tool is an examination of the draft planning document submitted by the planning authority, in order to compile written comments to the document, collected during the presentation of the initial form of the draft, along with the recorded planning authority's response to the comments made. The collected material, along with the entire planning document, is subject to the Inspector's assessment as to its reliability. Substantive consideration of these comments is an integral part of the draft document [18].

In Poland, participation in the creation of space is strengthened by law and implemented at the local level in the spatial planning process. Nevertheless, the established catalogue of forms in which citizens can become involved in spatial planning is not extensive. Under the current legal structure, the authority is required to consider the comments and has the right to take them into account by introducing changes to the draft plan. However, the authority is not required to justify its decisions on whether or not to take the comments into account [14]. The consultations are limited to providing information and an opportunity for stakeholders to submit proposals and comments and to participate in a public discussion. Their implementation is not part of the idea of including the public in the consultation process but serves to meet the statutory requirement. Most comments are collected at a later stage of the planning procedure when the initial draft is prepared and subject to public access. Moreover, most municipalities do not apply additional forms of consultation [5]. As Buczek argues, these regulations actually specify certain minimum deadlines and requirements for activities related to social participation, as they allow all

stakeholders to take the activities described by these regulations, while being so "imprecise that allow them to be treated pro forma, or even circumvented" [17].

Moreover, as Niewiadomski points out, the incorporation of participation into the spatial planning process is hindered by the NIMBY (Not In My Back Yard) syndrome concerning the behaviour of persons who do not give their consent to the implementation of investments in the vicinity of their place of residence [20].

As follows from the above, the inclusion of social participation in the planning of space is legally empowered in many countries.

Many studies have indicated the problems and limitations related to the implementation of the social preference incorporation process into urban management in the context of social co-decision-making. Participation is most commonly implemented in the form of providing information and consultation but without specific implementation of public expectations. The actual extent of social participation is still very limited, usually to the forms required by law, which are very often implemented by municipalities and designers in order not to actually communicate but to meet legal requirements [21].

The enrichment of planning work with additional studies or predesign analyses, in particular, are in regards to the space users' preferences, can increase the quality and improve the work of the design team, and will enable the application of law in this regard.

1.4. Forms and Techniques of Research on Participation in Spatial Planning

In the decision-making processes, participation comprises three essential elements:

- information exchange—providing information;
- interactions—consultation;
- exercising influence—co–decision–making [22,23].

The state where citizens and social organisations that represent them are given the opportunity to negotiate and co-determine decisions should be regarded as the highest level of participation. This stage, referred to as co-decision-making or authorisation, is a situation in which the administration divests itself of some of its decision-making authority and transfers it to the citizens.

Forms of participation can be implemented using a number of techniques, for example, advisory committees and commissions, task groups, citizens' juries, or public voting. Consultations usually take the form of public discussions, workshops, local referendums, complaints, applications, petitions, opinion polls, qualitative interviews, public hearings, and open meetings [14,23]. Open meetings are held as a series of meetings with designers, thematic workshops, urban planning picnics, debates with experts, neighbourhood consultation points, thematic forums, seminars, questionnaires, and other forms of contact carried out using a variety of techniques (methodologies) and tools [14].

Considering the function of participatory actions, the social participation techniques can be divided into four groups:

1. research: questionnaire survey, qualitative interview, walking survey, and urban prototyping;
2. debates: an open meeting, citizens' café;
3. workshops: Future City Game, Planning for Real®, participatory planning;
4. mixed: citizens' panel, deliberative poll®, World Café, research in action, discussion game, citizens' jury, Charette™ workshop, sentimental map and working group [24].

In the age of the Internet, it is advisable to use, besides the above-mentioned techniques for obtaining social preferences, technologies based on GIS spatial information systems such as geo-survey and geo-discussion.

The aim of the consultation is often to obtain information on the preferences concerning the future development of space with account taken of the aspects addressed during the study (e.g., built-up area density, the nature of public spaces, the presence of service facilities, transport solutions, safety in space, etc.). The data obtained for analysis from research into preferences or during meetings or debates with citizens will not always be

satisfactory. The data quality will be determined by the public interest in the planning process, meeting attendance, public commitment, etc.

1.5. Outline of Data Processing Methods in Participation

The first step of research into preferences is the collection of information during organised meetings, debates, and other methods described in Section 1.4. This step yields the research problem subject to analysis. There are numerous methods of research into social preferences. The data obtained at the first stage of research into preferences, such as the features that have an effect on safety disturbance in space, the features that affect the choice of location of the place of residence in the city, and the features that determine the need for renovation, etc., are the subject of research at a later stage. The obtained information can be elaborated by various methods.

The first group of methods includes statistical techniques that enable the evaluation of features and the determination of the tie relationship between its individual elements accepted for the study. These include correlation methods, variance analysis, quotient transformation in relation to a reference point [25–29], direct comparisons [30], and status value models [31].

The second group involves ranking methods used in research aimed at discovering and measuring a respondent's preferences. They also enable the analysis of data expressed on an ordinal scale. These include, for example, Gerbier's technique, the 0–10 technique, 100 rank point distribution, and multi-criteria evaluations that are applied when the ranking process is based on a few criteria with different ranks [32,33].

Yet another group comprises point-scoring methods (weighted scoring, indicator and scoring method), whose advantage is that they express all the features of the phenomenon under study, being separately assessed as a single number. Point-scoring assessments are one of the scaling method groups. These methods enable the assessment of a few or even several separate qualitative features of the issue under study. They are constructed in such a manner that, for specific qualitative characteristics, individual points on the scale are attributed verbal terms and corresponding conventional numbers/points [34,35].

An alternative to the above-mentioned methods for spatial data analysis, especially point-scoring methods, is the grey system theory developed by Juo-Long Deng. The theory has been developed specifically for the analysis of current systems, while taking into account scarce, uncertain, and incomplete information [36–39].

1.6. Grey Systems in Comparison with Preference Research Methods

Grey systems are an effective method for modelling and forecasting short-term time series that can be applied in all areas based on models with limited, incomplete or uncertain data ranging from social sciences, through economy and economics, to technical sciences [40,41]. The grey system theory has proved itself in economic forecasting [42], agriculture [43], medicine [44,45], tourism enterprise development [46], and noise source location [47]. In practice, the grey relational analysis (GRA) is most commonly used. It uses information on the similarity and differences between series of data describing the objects under consideration that can be ranked [39]. GRA is a method that enables data analysis resulting in the determination of the significance of the features under study. For the studied features with specified ranks or attributed points, the method enables the determination of a significance sequence which indicates those features that have the greatest influence on the phenomenon under study.

Thanks to the application of appropriate procedures, the grey system theory allows, based on information only partially known, additional, previously non-disclosed, useful information to be generated, searched for, found, and extracted. This facilitates both the modelling and monitoring of the behaviour of real systems and a description of the rules that govern their changes [39]. Hence, a GRA-type grey system was applied in order to learn about opinions as to which geospatial features result in the loss of the sense of safety in space. The analysis was conducted based on a small and incomplete group of arbitrarily

selected respondents. The advantage of the grey system method over ranking and point-scoring methods is that a small number of necessary data can be taken for analysis. The minimum number of observations that enables the construction of a grey system model, regardless of the number of features taken for analysis, amounts to four ($n \geq 4$) [48]. It was demonstrated that a stable sequence of tie strength for five features was achieved for 20 observations [49]. The aim of this article is to determine the strength of the relationship between the features adopted for the study using the grey system theory and to investigate the model's behaviour for varied input data. The aim of the present analysis was to examine the relationships between multiple independent variables (geospatial attributes) and the dependent variable (perceptions of safety in urban space). Geospatial attributes that are most likely to contribute to the feeling of insecurity were identified based on the strength of the analysed relationships.

2. Materials and Methods

2.1. Characteristics of the Grey Relational Analysis Method

According to the general system theory, it is rare to have systems that we know everything about, i.e., white box systems. Generally, there are situations where our information is limited, i.e., grey boxes, or where it is only possible to observe the inputs and/or outputs of the system, i.e., black boxes. The basic idea of applying this theory involves obtaining, from accessible, uncertain, and incomplete information, additional information of a "white" and "grey" nature at the expense of "grey" and "black" information, respectively. This is equivalent to a reduction in the proportion of "black", i.e., uncertain information. For discovering information, "whitening" operators are used. "Grey" systems are used to take account of the imperfections of the available information [39].

Having observed and considered the functioning of systems, it can be concluded that, in most cases, a grey system is involved, where information is incomplete (e.g., it is not possible to examine the entire population) and uncertain (e.g., not all behaviours and interactions can be foreseen, i.e., the butterfly effect in forecasting) [50]. Moreover, in the information collecting process (measurements, market research results, opinions, etc.), the problem of scarce data often emerges, with the obtained information on the system behaviour incomplete as well. In addition, based on such incomplete and uncertain information, the system functioning often needs to be assessed, its behaviour needs to be forecast, and various functional, operational, and strategic decisions of great technical and social significance need to be taken [37,48,51–53].

The grey system theory enables the determination of the tie relationship between the variables of the grey relational analysis (GRA) [39,54]. Using the method of grey incidence (relation) analysis, it is possible to determine the absolute degree of grey incidence of the observed system factors and characteristics. The research procedure for GRA is described in [48,54,55].

The starting point of the analysis is the definition of the system observation vector containing information on the system characteristics (X_0) in the following form: $X_0 = (x_0(1), x_0(2), \ldots, x_0(n))$, and of the system behaviour factor vector ($X_1, X_2, \ldots, X_k$) in the following form: $X_k = (x_k(1), x_k(2), \ldots, x_k(n))$. The number of system behaviour factors is determined by the assumed number of observed variables (k). Each vector contains information on a particular variable, obtained from a specified number of respondents (n), for example. The essence of grey modelling is to describe the behaviour of the system observed in reality, in the form of a forecast/endogenous variable: $X_{(0)(k)}$, where $k = 1, 2, \ldots, n$ is a set of explanatory variables that are determinants of the forecast variable condition. Therefore, an endogenous process observable in reality, given as $X_{(0)(k)}$, is explained over time by the number N of independent (explanatory) variables [56,57].

An important step is to calculate the so-called reflection of the observation vectors by zeroing the initial vector values. This operation enables the smoothing of incidental

disturbances and highlights the evolutionary tendency of the grey system behaviour [48]. This operation is performed according to the following formula:

$$X_i^0 = \left(x_i^0(1),\ x_i^0(2), \ldots, x_i^0(n)\right)$$
$$x_i^0 = x_i(k) - x_i(1) \quad (1)$$

where: k = the number of observed variables (system behaviour factors); n = the number of respondents.

The next step is to calculate the behaviour measures s_0 and s_i by means of summing and subtracting the values of reflected vectors [48,49,55].

The essence of the method is the calculation of the absolute degree of grey incidence, i.e., the similarity coefficient ε between the observation vectors X_0 and X_1, X_2, ... , X_n [55]:

$$\varepsilon_{0i} = \frac{1 + |s_0| + |s_i|}{1 + |s_0| + |s_i| + |s_0 - s_i|} \quad (2)$$

Using this measure, one can assess the similarity of behaviour of a pair of vectors and also assess their degree of interrelation if it is known that one of them represents a factor affecting the grey system and the other represents the responses of the system. The properties of the similarity coefficient ε are useful to evaluate the obtained results:

1. $0 < \varepsilon \leq 1$;
2. ε is only related to the geometrical shape of vectors X_0 and X_k, while having no relationship to their spatial arrangement;
3. the more the observation vectors are related (similar), the higher the ε value [48].

2.2. Research into Social Preferences in Terms of the Sense of Safety Disturbance in Space

The data obtained in the social participation process are mostly incomplete and often scarce. The methodology of research using grey systems addresses the analysis of data of such quality. The method enables an analysis that yields reliable results in the form of an ε similarity coefficient significance sequence, even though the data is incomplete—the data is obtained from a small study sample (e.g., when the attendance rate of questionnaire surveys or the public debate is low).

Research into social preferences using the methods described above (Section 1.4) is mostly carried out through organised public debates or questionnaire surveys. In order to collect information, the following research methods are employed: interviews, observations, documentation analysis, and data collection analysis (e.g., interview questionnaires or survey questionnaires). The GRA method allows the data from heuristic methods to be easily applied in the spatial planning process, from the state of cognitive character to the state of knowledge application in practice. The study examined selected geospatial features which, according to the respondents, caused a disturbance in security within urban space.

The features for research into safety disturbance in space were extracted using the brainstorming method [58,59], on an incidental sample of an arbitrarily selected group of students with basic knowledge of safety within urban space [60,61]. The respondents were university students who attended classes and lectures addressing the research problem. During the study program, the students enrolled in a course on designing safe public spaces became familiar with geospatial factors that influence perceptions of security/insecurity in space. The study was conducted on a sample of 60 respondents.

For the research into the preferences for the sense of safety within urban space, the following variables were adopted:

X_1—vacant buildings, ruins;
X_2—uncontrolled greenery;
X_3—narrow passages between buildings;
X_4—protruding staircase entrances without door intercoms;
X_5—pedestrian tunnels, bridges, etc.

After determining the features for the research, a questionnaire survey was conducted on the same group of respondents. In order to grade the features, a point-scoring method was applied [35], using a seven-point scale including quality levels for the assessment of each of the safety disturbance features that the respondents identified. For each feature for perceptions of insecurity in space, on a scale of 1 to 7, a score of 1 denoted an attribute that was least important and a score of 7 denoted an attributes that was most important. The results of the survey were implemented in a GRA-type research procedure:

- very high safety disturbance = 7 points;
- medium-high safety disturbance = 6 points;
- high safety disturbance = 5 points;
- medium safety disturbance = 4 points;
- low safety disturbance = 3 points;
- very low safety disturbance = 2 points;
- no safety disturbance = 1 point.

The data obtained from the survey on a sample of 60 respondents, in the form of a certain number of points assigned to each variable, was applied to the procedure described in Section 2.1. Based on the data, general system observation vectors (formula 1) were created. The number of the system's behaviour factors is determined by the adopted number of the variables observed. Each vector contains information on a particular variable, obtained from a specified number of respondents: $X_{(0)(k)}$, for $k = 1, 2, \ldots, n$, where k = the number of variables observed and n = the number of respondents.

3. Results

The results obtained from the survey were analysed by the GRA-type grey system method. The calculations were made for 4, 10, 20, 30, 40, 50, and 60 input data. The data was calculated five times, with the order of entering the survey results being changed each time. The similarity coefficient values were presented for the observed system characteristics: (X_0)—the sense of safety in space with the system behaviour factors and (X_1, X_2, X_3, X_4, X_5)—the features adopted for the study. The conducted analyses yielded the epsilon similarity coefficient values shown in Table 1.

Table 1. ε similarity coefficient values depending on the number of observations included in the model.

Number of Analysis	Number of Observations							
	Epsilon Values	4	10	20	30	40	50	60
Analysis 1	ε_1	0.611111	0.646154	0.575472	0.592050	0.593558	0.593824	0.596000
	ε_2	0.527778	0.576923	0.540881	0.550209	0.547546	0.551069	0.552000
	ε_3	0.526316	0.507143	0.531447	0.543933	0.538344	0.532067	0.548000
	ε_4	0.520833	0.506098	0.502404	0.501656	0.501202	0.500947	0.500792
	ε_5	0.518519	0.505495	0.502370	0.501587	0.501188	0.500924	0.500761
Analysis 2	ε_1	0.692308	0.638462	0.575472	0.589796	0.593558	0.614458	0.596000
	ε_2	0.653846	0.546154	0.540881	0.548980	0.547546	0.539759	0.552000
	ε_3	0.653846	0.507143	0.531447	0.536735	0.538344	0.518072	0.548000
	ε_4	0.525000	0.506024	0.502404	0.501623	0.501202	0.500951	0.500792
	ε_5	0.520833	0.505435	0.502370	0.501558	0.501188	0.500949	0.500761
Analysis 3	ε_1	0.954545	0.884615	0.928105	0.888446	0.892537	0.899761	0.909182
	ε_2	0.909091	0.820513	0.816993	0.792829	0.774627	0.778043	0.781437
	ε_3	0.750000	0.634615	0.705882	0.685259	0.702985	0.713604	0.710579
	ε_4	0.613636	0.615385	0.640523	0.629482	0.614925	0.606205	0.609780
	ε_5	0.521739	0.505952	0.503106	0.501859	0.501433	0.501139	0.500928

Table 1. *Cont.*

Number of Analysis	Number of Observations							
	Epsilon Values	**4**	**10**	**20**	**30**	**40**	**50**	**60**
Analysis 4	ε_1	0.620690	0.574324	0.565359	0.593617	0.593168	0.607053	0.608081
	ε_2	0.603448	0.574324	0.562092	0.574468	0.557453	0.560453	0.552525
	ε_3	0.534483	0.540541	0.526144	0.508511	0.501488	0.501222	0.500967
	ε_4	0.514286	0.505747	0.502717	0.501812	0.501351	0.501092	0.500883
	ε_5	0.513889	0.505435	0.502604	0.501618	0.501171	0.500954	0.500767
Analysis 5	ε_1	0.766667	0.645833	0.566038	0.593617	0.591195	0.947072	0.610548
	ε_2	0.533333	0.534722	0.556604	0.574468	0.556604	0.607053	0.556795
	ε_3	0.516129	0.506173	0.525157	0.508511	0.501511	0.501176	0.500967
	ε_4	0.514286	0.505814	0.502674	0.501812	0.501381	0.501092	0.500887
	ε_5	0.513158	0.505814	0.502500	0.501618	0.501182	0.500984	0.500769

4. Discussion

The obtained values were sorted in descending order to obtain an ε similarity coefficient significance sequence. The obtained results of the epsilon coefficient values in individual analyses are provided in Table 2.

Table 2. The order of ε similarity coefficient relationships depending on the number of observations included in the model.

Order of Strength of Relationships	Number of Observations						
	4	**10**	**20**	**30**	**40**	**50**	**60**
Analysis 1	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 2	$\varepsilon_3 > \varepsilon_1 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_1 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 3	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$
Analysis 4	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_5 > \varepsilon_2 > \varepsilon_4 > \varepsilon_3$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$
Analysis 5	$\varepsilon_3 > \varepsilon_4 > \varepsilon_1 > \varepsilon_2 > \varepsilon_5$	$\varepsilon_3 > \varepsilon_4 > \varepsilon_5 > \varepsilon_1 > \varepsilon_2$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$

In the third analysis, the sequence is stable for all observations. In the fourth and fifth analysis, sequence stability is achieved with 20 observations, while in the first and second analysis, stability is achieved with 30 observations. The results indicate that stable sequences are obtained for all analyses with 30 observations, but the order of ε similarity coefficient is different when the order of input data is changed. For the first and second analyses with 30 observations, the order of ε in the significance sequence is $\varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$; for the third analysis, it is the sequence $\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$; and for the fourth and fifth analyses, it is the sequence $\varepsilon_5 > \varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4$. Therefore, it is difficult to determine, based on the obtained results, which features have the greatest effect on the disturbance of the sense of safety in space.

In the next step, the research procedure was modified at the stage of calculating the reflection of the observation vectors by zeroing the initial vector values. In formula 1, in each case, a maximum number of points to be scored for each feature (seven points) was assumed to be $x_i(1)$. Again, the analysis was conducted five times while maintaining the order of entering data from previous analyses to obtain the epsilon coefficient values shown in Table 3.

Table 3. ε similarity coefficient values depending on the number of observations included in the model at $x_i(1)$ equal to 7.

Number of Analysis	Number of Observations							
	Epsilon Values	4	10	20	30	40	50	60
Analysis 1	ε_1	0.512500	0.504854	0.502463	0.501730	0.501285	0.501016	0.500859
	ε_2	0.510000	0.504237	0.501873	0.501292	0.500967	0.500765	0.500644
	ε_3	0.509615	0.503937	0.501799	0.501220	0.500904	0.500708	0.500607
	ε_4	0.509434	0.503731	0.501667	0.501152	0.50085	0.500676	0.500566
	ε_5	0.509091	0.503497	0.501650	0.501119	0.500843	0.500664	0.500550
Analysis 2	ε_1	0.516129	0.504854	0.502463	0.501695	0.501285	0.500973	0.500859
	ε_2	0.511364	0.504202	0.501873	0.501272	0.500967	0.500791	0.500644
	ε_3	0.511111	0.503817	0.501799	0.501193	0.500904	0.500720	0.500607
	ε_4	0.510417	0.503704	0.501667	0.501136	0.500850	0.500678	0.500566
	ε_5	0.509615	0.503472	0.501650	0.501104	0.500843	0.500677	0.500550
Analysis 3	ε_1	0.511111	0.504587	0.502591	0.501629	0.501241	0.501010	0.500859
	ε_2	0.509259	0.503623	0.501916	0.501222	0.500943	0.500768	0.500640
	ε_3	0.509259	0.503378	0.501880	0.501208	0.500891	0.500718	0.500603
	ε_4	0.508621	0.503311	0.501779	0.501144	0.500849	0.500675	0.500567
	ε_5	0.508333	0.503226	0.501712	0.501087	0.500833	0.500667	0.500549
Analysis 4	ε_1	0.511111	0.505155	0.502660	0.501825	0.501319	0.501080	0.500867
	ε_2	0.508929	0.504132	0.502101	0.501374	0.500984	0.500805	0.500650
	ε_3	0.507937	0.503597	0.501812	0.501225	0.500923	0.500746	0.500611
	ε_4	0.507813	0.503472	0.501761	0.501134	0.500843	0.500692	0.500569
	ε_5	0.507692	0.503247	0.501645	0.501131	0.500835	0.500679	0.500553
Analysis 5	ε_1	0.511111	0.505556	0.502564	0.501825	0.501330	0.501080	0.500876
	ε_2	0.508929	0.504587	0.502049	0.501374	0.500994	0.500805	0.500650
	ε_3	0.507813	0.503876	0.501792	0.501225	0.500936	0.500746	0.500613
	ε_4	0.507813	0.503788	0.501712	0.501134	0.500846	0.500692	0.500571
	ε_5	0.507576	0.503623	0.501618	0.501131	0.500840	0.500679	0.500554

The epsilon coefficients were sorted again in descending order to obtain tie strength sequences. The obtained results show that a rather stable sequence is obtained for all analyses at 20 observations. For the fourth and fifth analyses, complete sequence stability occurs for 40 observations ($\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$), but starting from the 20th observation, the differences are only noticeable for the two last epsilons ($\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$). In all conducted analyses, the ε coefficient order is maintained in the significance sequences (Table 4).

Table 4. The order of the ε similarity coefficient relationship depending on the number of observations included in the model at $x_i(1)$ equal to 7.

Order of Strength of Relationships	Number of Observations						
	4	10	20	30	40	50	60
Analysis 1	$\varepsilon_1 > \varepsilon_2 > \varepsilon_5 > \varepsilon_3 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 2	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 3	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_3 > \varepsilon_2 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 4	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_4 > \varepsilon_3 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$
Analysis 5	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4 > \varepsilon_1$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$	$\varepsilon_1 > \varepsilon_2 > \varepsilon_3 > \varepsilon_5 > \varepsilon_4$

The conducted analysis result is a tie strength sequence that enables the determination of which features adopted for analysis have the greatest effect on the disturbance of the sense of safety in space. As indicated by a tie strength sequence that is stable due to the epsilon order for all analyses performed after the modification of the calculation process, the disturbance of safety in space is most contributed to, according to respondents, by features X_1 (vacant buildings, ruins), followed by X_2 (uncontrolled greenery), and X_3 (narrow passages between buildings). According to respondents, the sense of safety in space is affected the least by features X_4 (protruding staircase entrances without door intercoms) and X_5 (pedestrian tunnels, bridges, etc.).

The GRA-type grey system method applied for the analysis is an alternative to point-scoring methods, as it enables information on the most significant features in the aspect under study to be obtained in a simple manner based on an incomplete and scarce sample.

5. Conclusions

Many authors point out that there is a need to implement the results of social preferences surveys in the space design process. The literature review outlined the problem of participation that is legally empowered in many countries. Moreover, the limitations and problems related to the implementation of participation were described. This leads one to reflect on the need for a more in-depth look at this issue.

This study presented the advantage of the GRA-type grey system methods over the methods commonly applied to assess social preferences. The GRA method is more effective than other methods of research into social preferences (e.g., point scoring or ranking), as it enables an analysis based on incomplete and scarce data while maintaining the reliability of the obtained results. As a result of the analysis, knowledge is gained as to which features under study are most important in terms of the phenomenon being analysed.

The study into the sense of safety within urban space demonstrated that the feature of vacant buildings, ruins, and uncontrolled greenery was most significant, while pedestrian tunnels and bridges had the smallest effect.

The described methodology can be applied to other urban areas. The required information relates to a given place and time. An evaluation of social preferences in any area of research is a costly and time-consuming process. This study proposes a simple method for acquiring information that can be used in any area of research. The criteria selected for a research study should be validated in a survey with the use of a points method and the results inputted into a GRA-type grey system.

The method presented can be applied in research into social preferences in a variety of areas. The method is effective in all cases where points or specified ranks are attributed to the characteristics under study. The performance of a GRA-type analysis based on such points or specified ranks will provide knowledge on which features are the most relevant for the phenomenon under study. The application of the GRA-type grey system method will streamline the application of the results obtained from research into preferences in urban space planning and does not require great effort to yield reliable results. The analysis is conducted based on scarce and incomplete data, with the knowledge gained in the form of a similarity coefficient tie strength sequence streamlining the process of social participation implementation in urban spatial planning and management.

The aim of the analysis was to construct a reliable model of the grey system to predict its behaviour and make decisions concerning the present or future based on the obtained order of the similarity coefficient ε relationship strength. The analyses conducted determined the strength of the relationships between the features adopted for the study and indicated the model's behaviour for various numbers of input data. The application of the grey system-based method is supported by the fact that it requires no quantitative limitations on representative data samples, with no need to comply with the formal requirements imposed by statistical samples. Potential users of space have different perceptions of safety. Urban structures and spaces also differ in terms of management and maintenance. Analyses of public perceptions of safety require information that pertains to a given location and point

in time but surveys of social preferences are expensive and laborious. This study proposes a simple method for generating data that can be used in numerous fields of research. The GRA approach facilitates the determination of the relationships between various factors and their influence on the examined system. The processed data can be used to evaluate the interdependencies between observation vectors, to predict the system's responses to various situations, and make optimal decisions without the need for complex statistical analyses. With the GRA approach, analyses of scarce, incomplete, and uncertain data produce reliable results.

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Residents' Demands for Urban Retail: Heterogeneity in Housing Structure Characteristics, Price Quantile, and Space

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Abstract: A thorough understanding of residents' demands plays an important role in realizing the rational distribution of urban retail (*UR*) and promoting the habitability of cities. Unfortunately, these demands for *UR* are currently under-researched. To solve this problem, this study aims to quantify the capitalization effect of *UR* on housing prices and explores the impact of heterogeneity in housing structure characteristics, price quantile, and space on the residents' demands for *UR* according to the hedonic price model, quantile regression, and geographically weighted regression in Chengdu. The results of these models show the following: (1) good property management and building sound insulation can reduce the negative influence of *UR* on residents' lives; (2) only the owners of low-price houses are willing to pay a premium for *UR*; and (3) residents' demands for *UR* increase from the central area to the peripheral area of Chengdu, and an inverted U-shaped relationship was found between housing prices and the *UR* level. A comprehensive analysis of the heterogeneity of residents' demands for *UR* can provide a reference for planning departments, real-estate developers, and *UR* owners and promote the sustainable development of *UR*.

Keywords: housing price; urban retail; residents' demands; hedonic price method; quantile regression; geographically weighted regression

1. Introduction

There is an increasing integration of commercial activities in the marketplace, and the term urban retail (*UR*) refers to all consumer-related activities, including the following categories: shopping for personal and household goods and services; dining out; engaging in recreation; and attending sports, entertainment, and cultural events [1]. Many studies, while only adopting *UR*-related variables as control variables, have confirmed *UR* to be an important determinant for residents' expected housing prices [2–5]. The results of these studies showed positive and negative effects on housing prices simultaneously. This phenomenon may be caused by the double impact on residents' welfare and quality of life.

On the one hand, *UR* has a positive impact on residents' welfare and quality of life. The development of urban retail plays an increasingly important role in improving urban economic performance and residents' welfare. At the urban level, *UR* can also drive the production activities of other sectors, improve the urban employment rate [6], promote the construction of urban support infrastructure, and optimize urban planning and layout [7,8]. In terms of residents' quality of life, an improvement in *UR* improves the accessibility and availability of commercial services [9], which help meet residents' growing entertainment demands as a consequence of an increase in their incomes [8,10], while simultaneously reducing their travel time and costs [11,12]. These positive impacts provide the positive capitalization effect of *UR* on housing prices and lead to increased residents' demands for *UR*.

On the other hand, *UR* has negative effect on residents' welfare and life quality. Increased *UR* density would lead to a massive influx of people and vehicles into a region, which could lead to severe noise and air pollution, garbage, more congested roads [9,10,13], and an increase in crime rates [14]. As a result, an increase in *UR* has a negative effect on housing prices and can reduce residents' demands for *UR*, pushing some residents to even reject *UR*.

Furthermore, because of the heterogeneity in housing structure characteristics, price quantile, and space, different residents may have different attitudes towards the negative and positive impacts of *UR* and have different demands degree and expected prices on *UR*. Previous studies have supported this argument for other public services or infrastructure. However, few studies have focused on *UR* [14–16]. Therefore, analyzing the capitalization effect of *UR* on housing prices and further exploring the residents' demand for *UR* in heterogeneous conditions (housing structure characteristics, price quantile, and space) are important and interesting issues to explore.

In this study, we assume that residents' demands for *UR* are primarily impacted by heterogeneity in housing structure characteristics, price quantile, and space. In other words, the capitalization effect of *UR* on housing price is not constant. This study helps answer the following questions:

(1) How are the capitalization effects of *UR* on housing prices and residents' demand for *UR* affected by heterogeneity in housing structure characteristics, price quantile, and space?
(2) How should the *UR* layout of the city based on heterogeneity in housing structure characteristics, price quantile, and space be adjusted?

The answers to the above questions can provide a reference for the government's urban planning decisions and the formulation of housing development targets by real-estate developers. To answer these questions, this study aims to quantify the capitalization effect of *UR* on housing prices by using the hedonic price model, quantile regression, and geographically weighted regression based on second-hand housing transaction data from a Chengdu real-estate intermediary website in 2019 and to further examine residents' demands for *UR* in heterogeneous conditions.

The remainder of this paper is organized as follows. Section 2 summarizes the relevant studies. Section 3 introduces the research data and methods. Section 4 presents the main results and discusses them. Section 5 summarizes the study's conclusions, practical implications, and limitations.

2. Literature Review

Housing prices are closely related to cities' development and residents' quality of life. According to the hedonic price model, scholars base housing prices on several implicit housing characteristics and explore residents' demands for those housing characteristics. Previous studies have divided these characteristics into three categories: (1) structural characteristics, such as the age of the house [17], size, floor [16], and orientation [18]; (2) location characteristics, such as education resources [19], transportation [2], and landscape [20]; and (3) environmental characteristics, such as noise [21], afforestation [3], crime rate [22], and pollution [23]. *UR* is an integral component of urban vitality and residents' lives and has a significant impact on housing prices. However, its impact is seldom discussed in the literature.

In many studies, *UR*-related factors have been employed as control variables [2–5]. These results are significantly different and show negative and positive capitalization effects of *UR* on housing prices, while simultaneously suggesting potential and different residents' demands for *UR* in heterogeneous conditions. In recent years, some scholars have begun to focus on the capitalization effect of *UR*-related factors. Song et al. [1] have discussed the premium of retail accessibility on housing prices. Yu et al. [24], Sirpal [25], and Sale [26] have investigated the impact of shopping mall accessibility on housing prices. Some have contended that considering the relationship between *UR* and housing

prices solely based on accessibility is inappropriate since the nearest *UR* center is not the only choice available to customers [27]. They may shop elsewhere on their way to work or anywhere else "as long as it suits their lifestyle" [28]. Jang and Kang [9] have examined the gap of the relationships between housing prices and different retail stores such as department stores, shopping centers, hypermarkets, supermarkets, and convenience stores. Zhang et al. [13] have classified shopping malls according to the size, age, and structure of the tenants and discussed the influence of different types of malls on housing prices. Chiang et al. [14] studied the impact of convenience stores on housing prices from the perspective of density and availability in Taipei city. As more *UR* stores provide more choices for consumers in accordance with their different lifestyles, this study analyzes the residents' demands for *UR* based on the number of *UR* stores surrounding houses. This is the first study to undertake such an investigation.

Previous studies have found that the capitalization effect of *UR* and residents' demands for *UR* are not constant. Song and Sohn [1] previously investigated the impact of retail accessibility on housing prices. The positive impact of retail channels on housing prices was found to decrease rapidly with distance. Simultaneously, when the distance between retail stores and the house is reduced to a certain level, a further reduction in distance decreases housing prices. Some scholars have obtained similar results for the impact of shopping malls' accessibility on the externalities of housing prices [10,13,25,26,29], and have attributed the results to the spatial distribution [13] and two-way influence of *UR*: increasing convenience in the residents' lives and the damage to the environment (noise, traffic congestion, and pollution) [29]. The negative influence of *UR* on the comfort of residents' lives may be the core reason for the negative effect of *UR* on housing prices. Hence, reducing residents' perceptions of the adverse influence on the environment (for instance, by increasing sound insulation capacity through better construction technology) may have a positive impact on their demand for *UR*. Generally, the heterogeneity of housing structure characteristics may have a moderating effect on the residents' demands. This has been confirmed in some studies that focus on other factors. For example, Xiao et al. [16] explored the moderating effect of vertical heterogeneity at different floor levels on the residents' demands for landscape. Liu et al. [30] also confirmed that community population density can reduce the negative influence of COVID-19 on housing prices. Li et al. [31] analyzed the moderating effects of built-environment factors on rail transit proximity premiums. However, few studies have discussed the moderating effects of housing structure characteristics on the residents' demands for *UR*. This study aims to address this gap.

For the price quantile effect, the residents' income levels and total assets largely determine their demands. Bayer [32] has provided empirical evidence on families from different social classes and indicated that the marginal willingness to pay increases with income. This effect cannot be observed directly using a traditional hedonic price model [33]. Many scholars have adopted quantile regression because it provides a comprehensive estimate of the entire housing price distribution based on different regression curves [34]. Based on Hong Kong's housing market, Mak et al. [35] have confirmed a substantial difference in the preferences of owners of houses with different values. Wen et al. [36] found that residents' demands for educational resources (such as the presence of a primary school, middle school, and college) differ across quantiles in Hanzhou (China). The owners of high-price houses represented higher presence for a college and a high school. Using Quantile Regression, Chiang et al. [14] noted that the regression coefficients on convenience store density show a non-linear trend, revealing a positive effect in low-price communities and an inhibiting effect on high-price neighborhoods. Wang [37] combined the spatial and the quantile regression approach and found the influence of the subway on all levels of housing rents to be negligible. In addition, some scholars have studied the quantile effects of other characteristics on housing prices, such as wildfire likelihood [38], household attributes [39], flood risk [40], tourism [41], and natural environment features [42]. However, the quantile effect is rarely considered in studies investigating the

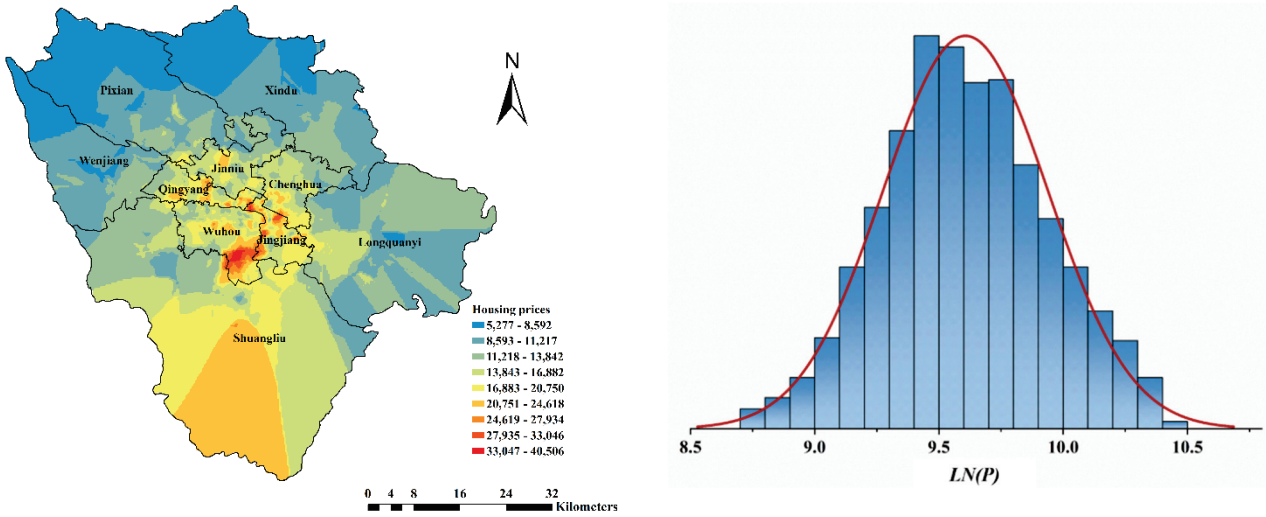
capitalization effect of *UR* on housing prices and identifying the residents' demands for *UR* in heterogeneous housing structure characteristics, heterogeneous price quantile, and heterogeneous space.

This study makes an important contribution to the literature. In contrast to previous research, this study is the first to use the number of *UR* stores as a *UR*-related variable and consider the heterogeneity of housing structural characteristics, price quantile, and space to study the capitalization effect of *UR* on housing prices and residents' demands for *UR*.

3. Materials and Methods

3.1. Study Area

Chengdu, the capital of Sichuan province, is the study area. Chengdu is one of the political, financial, and transportation centers of Southwest China and had a GDP of 1700 billion yuan and a population of 16 million in 2019 [43]. The exciting culture, pleasant environment, and abundant presence of historical sites attract a large number of tourists to Chengdu every year. The solid economic foundation and the developed tourism industry have promoted *UR* development in Chengdu. The study area includes nine municipal districts of Chengdu: Wuhou, Qingyang, Shuangliu, Qingyang, Wenjiang, Pidu, Longquanyi, and Jinniu (Figure 1a).



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

Figure 1. Study area and housing price distribution. (**a**) the spatial distribution of housing prices; (**b**) the normal distribution of logarithm of house prices.

3.2. Data and Variables

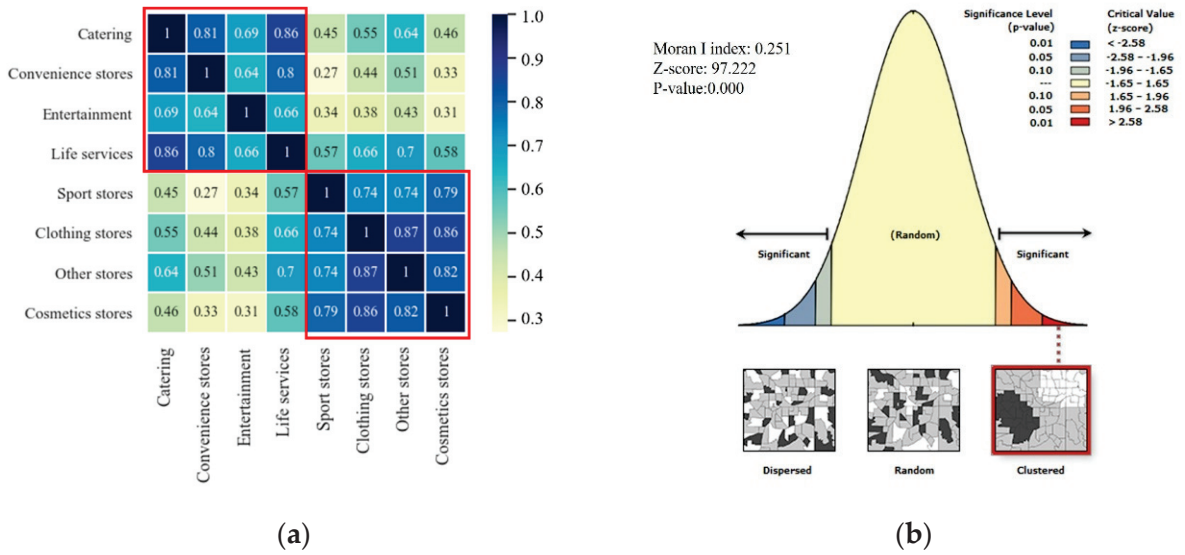
3.2.1. Dependent Variables

As the second-hand housing market exhibits a considerably more dispersed and large-scale housing supply compared with the new housing market [44], this study obtains second-hand house transaction data from Fangtuanxia (fangtianxia.com), one of the largest house intermediary platforms in China. This dataset reports information regarding housing prices, housing size, the presence of elevators, the floor area ratio, and the level of property management. To make the data comparable, this study does not consider villas and townhouses, which command an obviously high housing price and only account for 2.3% of the total samples and selects the multi-layer and high-rise housings as the major research object. In addition, differences within a residential community are ignored, and the data of houses attributed to the same community are merged [45]. Therefore, the average housing prices of residential neighborhoods are used

as the dependent variables. After the above treatment and removing abnormal values, the final dataset includes 73,889 houses and 2286 residential communities. The Kriging method [46] is used for the spatial interpolation of housing prices. The results are split into nine levels based on the Jenks classification. Figure 1a represents the spatial distribution of Chengdu housing prices, which is characterized by a circular distribution. The housing prices decrease from the city center to the city boundaries; the highest housing prices are in the city center area, and lower price houses are mainly distributed in Northwest Chengdu. The housing prices of Tianfu New District show a rapid growth trend due to policy support. The housing prices of Chengdu have begun to shift from a unipolar distribution centered on Tianfu Square to a bipolar distribution. In addition, the logarithm of Chengdu housing price ($LN(P)$) is approximately normally distributed (Figure 1b), and the mean of $LN(P)$ is 9.61.

3.2.2. Independent Variables

Urban retail refers to all consumer-related activities. Based on the classification rules of the Gaode Map, this study selected eight urban retail store categories, including catering stores, convenience stores, entertainment stores, life services stores, sport stores, clothing stores, cosmetics stores, and other stores (Figure 2a), and uses a number of these stores within 500 m of the house. Meanwhile, mega markets (e.g., shopping malls) are broken up into multiple independent urban retail stores, to be counted separately.



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

Figure 2. Pearson coefficients and Moran I Index of *UR*. (**a**) represents the Pearson correlation coefficient among different urban retail types; (**b**) represents the Moran I index of urban retail.

A correlation analysis (Figure 2a) reveals that the different *UR* types are significantly correlated, and all the correlations are positive (most values exceed 0.4). Catering, clothing stores, and other stores are strongly correlated with almost all other *UR* types. In addition, there are two clusters: (1) catering, convenience stores, entertainment, and life services, and (2) sport stores, clothing stores, other stores, and cosmetics stores. When the *UR* density of an area reaches a certain level, the area may be considered a commercial area. Meanwhile, the Moran I index of *UR* is 0.251 and is significant at the 95% level (Figure 2b), which indicates a space-clustered distribution of *UR*. Furthermore, excessive correlation generates multicollinearity in the regression analysis. Therefore, the total number of stores of different *UR* types is used as a *UR*-related variable.

For control variables, consumers' demands for the functional characteristics of a house affect their willingness to pay [36]. Therefore, based on past research and residents' demands, we employ control variables from six dimensions (housing structural characteristics, education, transport, medical, environment, and others). Independent

variables are divided into structural variables, surrounding variables, and environmental variables [47]. Property management (*PM*) and school district (*SD*) are the scores assessed by real estate agency websites (Fangtianxia). The assessment of property management follows the standard of property management service grade of residential building, which classifies property management into four grades depending on the degree of building management, maintenance of shared facilities and equipment, maintenance of public order, and cleaning services. The assessment of school districts is decided by the rank of the supporting primary school and junior middle school of the house. A higher number indicates a better quality of property management and school district. The distances between houses and independent variables may take two forms: real distances (in the road network) and Euclidean distances. Among them, the distances to senior high school (*DSHS*), university (*DUN*), subway station (*DSUB*), hospital (*DHOS*) and park or square (*DG*) are real distances. The distance to the urban center (*DUC*) is based on Euclidean distance; *DUC* is not used in this study to describe the accessibility of the facility but the location of houses. Table 1 lists the community-level independent housing variables and relevant descriptions.

Table 1. Independent variables and descriptions.

Category	Variable	Abbreviation	Description
Dependent variable	Residential housing prices	*P*	Price per square meter (yuan/m^2)
Structural variables	Size	*SIZE*	Area of structure (m^2)
	Year	*YEAR*	The age of the house
	Elevator	*EL*	If the residence is equipped with elevator, 0 = no; 1 = yes
	Plot ratio	*PR*	Floor Area Ratio/Volume Fraction (%)
	Property management	*PM*	0 = Needs improvement; 1 = Low; 2 = Mid; 3 = High
Location variables	Urban Retail	*UR*	The number of relevant stores within 500 m
	School district	*SD*	0 = Low; 1 = Mid; 2 = High
	Kindergarten	*KG*	The number of kindergartens within 1000 m
	Distance to senior high school	*DSHS*	The real distance (not Euclidean distance) to the nearest public senior high school
	Distance to university	*DUN*	The real distance (not Euclidean distance) to the nearest university
	Bus station	*BUS*	The number of bus stations within 500 m
	Distance to subway station	*DSUB*	The real distance (not Euclidean distance) to the nearest subway station
	Distance to hospital	*DHOS*	The real distance (not Euclidean distance) to the nearest comprehensive hospital
	Distance to urban center	*DUC*	The distance (Euclidean distance) to Tianfu Square

Table 1. *Cont.*

Category	Variable	Abbreviation	Description
Environment variables	Distance to park or square	*DG*	The real distance (not Euclidean distance) to the parks or squares

3.3. Methods

The hedonic price model is typically used to analyze the relationships between housing prices and housing characteristics. It may take different forms: linear, semi-log, and log–log. No theory determines the choice of the functional form. A previous study suggests that log-form models reduce heteroscedasticity [48]. In this study, the discrete variables (*EL*, *YEAR*, *PM* and *SD*) adopt the original form, and other variables are logarithmized (Equation (1)).

$$LN(P) = \beta_0 + \beta_1 LN(UR) + \beta_4 LN(S) + \beta_5 LN(L) + \beta_6 LN(E) + \beta_7 Z + \varepsilon \quad (1)$$

where P indicates housing prices, UR is the UR level surrounding the house, β indicates the regression coefficient, S comprises continuous structural variables, L indicates continuous location variables, E comprises continuous environment variables, Z indicates other continuous-discrete variables, and ε is the error term.

In Chinese, the design of urban residential buildings must follow the standards of sound insulation. These standards of sound insulation have been revised many times to improve sound insulation performance. For example, non-standard before 2000, codes for sound insulation design of residential buildings were introduced in 2010 and 2020. Therefore, we assume building age has a positive relationship with building performance of sound insulation and use $YEAR$ to characterize building performance of sound insulation. The interaction items ($LN(UR) \times PM$, $LN(UR) \times YEAR$) are introduced in the model to explore the moderating effect of housing structural characteristics (Equation (2)).

$$\begin{aligned} LN(P) = {} & \beta_0 + \beta_1 LN(UR) + \beta_2 (LN(UR) \times PM) + \beta_3 (LN(UR) \times YEAR) \\ & + \beta_4 LN(S) + \beta_5 LN(L) + \beta_6 LN(E) + \beta_7 Z + \varepsilon \end{aligned} \quad (2)$$

Quantile Regression is used to test the residents' demands on UR from price quantile. Quantile Regression estimators are calculated based on asymmetric absolute residual minimization. Compared with the hedonic price model, quantile regression has some advantages: (1) it does not require strong assumptions for the error terms and the estimation results are robust to outliers; and (2) it describes the whole conditional distribution of explained variables more comprehensively [36]. The regression coefficients across different housing price levels are obtained as follows:

$$LN(P) = \beta_{0(q)} + \beta_{1(q)} LN(UR) + \beta_{4(q)} LN(S) + \beta_{5(q)} LN(L) + \beta_{6(q)} LN(E) + \beta_{7(q)} Z + \varepsilon \quad (3)$$

where q indicates housing price quantiles; $\beta_{0(q)}$, $\beta_{1(q)}$, $\beta_{4(q)}$, $\beta_{5(q)}$, $\beta_{6(q)}$ and $\beta_{7(q)}$ are the qth quantile coefficients to be estimated; and the remaining variables are the same as in Equation (1).

An urban housing market, which usually comprises various submarkets, is too complex to be described as a spatially homogeneous unit [13,49]. Tobler's First Law of Geography indicates that there are more similarities between adjacent geographical entities. Due to the uneven distribution of urban retail resources and other housing characteristics, there may be spatial heterogeneity in the resident's demands for UR. The global regression of the hedonic pricing model is not detailed enough to explain the local conditions. The geographically weighted regression model uses the local smooth processing method to solve the problem of spatial heterogeneity. Considering spatial heterogeneity, geographic coordinates and core functions are utilized to carry out local regression estimation on the adjacent individuals of each group. Therefore, this study tests the spatial heterogeneity of the capitalization effects of UR on housing prices based on the result of the geographically weighted regression model, as follows:

$$LN(P_i) = \sum_j \beta_{ij}(\mu_i, v_i) X_{ik} + \varepsilon_i \quad (4)$$

where (μ_i, v_i) indicates the spatial location of sample house i, and $\beta(\mu_i, v_i)$ is the regression coefficient on sample house i. In contrast with the hedonic price model, a weighted matrix W_i is used to indicate the influence of different observation points with different spatial locations on the estimation of the coefficient of sample house i [50]. In this study, we use the Gaussian function to calculate the weighted matrix, as follows.

$$W_{ij} = e^{-\frac{1}{2}\left(\frac{d_{ij}}{b}\right)^2} \quad (5)$$

where d_{ij} indicates the Euclidean distance from sample house i to observation house j, b indicates the bandwidth, and the selection of b follows the AICc criterion [50].

4. Results and Discussion

4.1. Hedonic Price Model Results

Table 2 represents the baseline hedonic price model results for the capitalization effect of *UR* on housing prices in all districts. Model (2) introduces the two interaction items. All the adjusted R^2 values exceed 0.5, indicating that the model explains over 50% of the variation in housing prices. Most regression coefficients are significant at the 5% level. Hence, the proposed hedonic price model has adequate explanatory power.

Table 2. Baseline hedonic price model results.

Variable	Model (1)				Model (2)			
	Coefficient	**SE**	***p* Value**	**VIF**	**Coefficient**	**SE**	***p* Value**	**VIF**
LN(*UR*)	−0.051 ***	0.009	0.000	1.897	−0.053 ***	0.008	0.000	1.985
LN(*UR*)×*PM*					0.020 **	0.013	0.092	2.357
LN(*UR*)×*YEAR*					−0.003 **	0.002	0.042	2.357
PM	0.085 ***	0.011	0.000	2.927	0.083 ***	0.012	0.000	3.003
YEAR	−0.014 ***	0.001	0.000	3.745	−0.014 ***	0.001	0.000	3.755
EI	0.080 ***	0.014	0.000	2.108	0.081 ***	0.014	0.000	2.128
LN(*BUS*)	0.051 ***	0.016	0.002	2.491	−0.035 ***	0.006	0.002	2.492
LN(*DSUB*)	−0.036 ***	0.006	0.000	1.227	−0.035 ***	0.006	0.000	1.233
LN(*DUC*)	−0.279 ***	0.008	0.000	1.881	−0.281 ***	0.008	0.000	1.917
LN(*DG*)	0.004	0.006	0.478	1.190	0.005	0.006	0.449	1.193
LN(*DHOS*)	0.042 ***	0.006	0.000	1.411	0.042 ***	0.006	0.000	1.413
LN(*KD*)	0.132 ***	0.019	0.000	3.210	0.130 ***	0.019	0.000	3.221
LN(*DUN*)	0.037 ***	0.006	0.000	1.270	0.037 ***	0.006	0.000	1.271
LN(*DSHS*)	−0.024 *	0.014	0.088	1.014	−0.024 *	0.014	0.081	1.015
SD	0.034 ***	0.009	0.000	1.078	0.034 ***	0.009	0.000	1.079
PR	0.010 ***	0.003	0.001	1.222	0.010 ***	0.003	0.001	1.224
LN(*SIZE*)	0.163 ***	0.016	0.000	1.113	0.161 ***	0.016	0.000	1.116
Intercept	10.903 ***	0.189	0.000		10.551 ***	0.274	0.000	
Adjusted R^2		0.560				0.564		

Note: ***, **, and * represent 1%, 5%, and 10% significance levels, respectively. SE represents standard error of regression coefficient. VIF represents variance inflation factor, which is used to quantify the degree of multicollinearity.

The results of Model (1) indicate that *UR* had a negative effect on housing prices in all districts. The regression coefficient of *UR* is −0.051 at the 1% significance level, indicating that a 1% increase in *UR* is associated with a 0.051% decrease in housing prices. This result indicates that residents were more sensitive to the negative influences of *UR* compared to the convenience of *UR*, which makes them reject the increase in *UR* density.

For the results of Model (2), the regression coefficient of *UR* is similar to that of Model (1). The regression coefficient of the interaction item of *UR* and property management is at the 10% significance level (p-value = 0.092) and the value is 0.020. This indicates that property management has a positive moderating effect on the capitalization effect of *UR* on housing prices. Generally, the negative effect of *UR* on housing prices decreases as the quality of property management increases. For the interaction item of *UR* and building age, the coefficient is −0.003 at the 10% significance level, indicating that the negative effect of *UR* on housing price decreases with improvements in performance

of building sound insulation (as the building age decreases). These results are consistent with the fact that property management and performance of building sound insulation (*YEAR*) can reduce the residents' perception that *UR* has a negative influence on environment and society [51,52]. The negative impact of *UR* on residents' quality of life usually decreases residents' preference for *UR*, which leads the demand curve to move to the left and the premium of *UR* to decrease. However, greater property management means better security, which can keep the community isolated from strangers to the maximum extent possible and decrease the potential probability of crime [52]. Furthermore, new buildings usually adopt better construction technologies and construction materials to improve performance of building sound insulation, which effectively insulate residents from adverse environments and create a more comfortable living experience for residents [53]. Therefore, compared with the owners who have housing with bad sound insulation, the demand curve of owners having houses with good sound insulation is further to the right. In other words, they are willing to pay a higher premium for *UR*.

Meanwhile, the coefficient of *PM* is 0.083 at the 1% significance level (the results of Model 1 and Model 2 are approximately the same), which means that property management and building have a direct capitalization effect on housing prices. Further, the coefficient of *YEAR* is −0.014 at the 1% significance level, indicating that newer housing with better performance of building sound insulation are preferred by home-buyers. Therefore, considering the double effect of property management and performance of building sound insulation, developers can achieve higher premiums by adopting better property management services and construction techniques, particularly for houses in areas with high *UR* density. Moreover, there is little difference in the control variables' regression coefficients of Model (1) and Model (2), confirming their robustness.

4.2. Quantile Regression Results

The baseline results of the hedonic price model are reported in Column 1 of Table 3 for comparison. The full quantile regression includes eight estimates from the 20th quantile to the 90th quantile and specifies the capitalization effect of *UR* on different levels of housing prices.

Table 3. Quantile regression results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Global	**Q10**	**Q20**	**Q30**	**Q40**	**Q50**	**Q60**	**Q70**	**Q80**	**Q90**
LN(*UR*)	−0.051 ***	0.012 ***	0.006 **	−0.028 ***	−0.045 ***	−0.057 ***	−0.063 ***	−0.079 ***	−0.076 ***	−0.093 ***
	(0.008)	(0.004)	(0.003)	(0.010)	(0.010)	(0.009)	(0.010)	(0.011)	(0.012)	(0.017)
EI	0.080 ***	0.094 ***	0.080 ***	0.079 ***	0.079 ***	0.079 ***	0.074 ***	0.079 ***	0.093 ***	0.071 **
	(0.014)	(0.024)	(0.019)	(0.018)	(0.017)	(0.016)	(0.017)	(0.020)	(0.022)	(0.030)
YEAR	−0.014 ***	−0.007 ***	−0.012 ***	−0.015 ***	−0.015 ***	−0.014 ***	−0.016 ***	−0.015 ***	−0.015 ***	−0.016 ***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
LN(*BUS*)	0.051 ***	0.047 *	0.046 **	0.049 **	0.048 **	0.038 **	0.051 **	0.042 *	0.067 ***	0.055
	(0.016)	(0.028)	(0.022)	(0.021)	(0.020)	(0.019)	(0.020)	(0.023)	(0.025)	(0.035)
LN(*DSUB*)	−0.036 ***	−0.047 ***	−0.038 ***	−0.031 ***	−0.031 ***	−0.035 ***	−0.048 ***	−0.047 ***	−0.046 ***	−0.030 **
	(0.006)	(0.010)	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)	(0.009)	(0.009)	(0.013)
LN(*DUC*)	−0.279 ***	−0.243 ***	−0.264 ***	−0.277 ***	−0.284 ***	−0.290 ***	−0.291 ***	−0.286 ***	−0.286 ***	−0.303 ***
	(0.008)	(0.013)	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)	(0.011)	(0.012)	(0.017)

Table 3. *Cont.*

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Global	**Q10**	**Q20**	**Q30**	**Q40**	**Q50**	**Q60**	**Q70**	**Q80**	**Q90**
LN(*DG*)	0.004	0.015	0.019**	0.016**	0.013*	0.007	−0.001	−0.004	−0.013	0.011
	(0.006)	(0.011)	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)	(0.009)	(0.010)	(0.013)
LN(*DHOS*)	0.042 ***	0.030 ***	0.041 ***	0.041 ***	0.045 ***	0.048 ***	0.043 ***	0.051 ***	0.045 ***	0.041 ***
	(0.006)	(0.010)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.009)	(0.013)
LN(*KD*)	0.132 ***	0.086 ***	0.105 ***	0.129 ***	0.157 ***	0.168 ***	0.153 ***	0.153 ***	0.133 ***	0.130 ***
	(0.019)	(0.032)	(0.025)	(0.024)	(0.023)	(0.022)	(0.023)	(0.027)	(0.029)	(0.041)
LN(*DUN*)	0.037 ***	0.041 ***	0.033 ***	0.037 ***	0.039 ***	0.037 ***	0.037 ***	0.032 ***	0.047 ***	0.045 ***
	(0.006)	(0.011)	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)	(0.009)	(0.010)	(0.013)
LN(*DSHS*)	−0.024 *	−0.033	−0.014	−0.010	−0.011	−0.009	−0.011	−0.021	−0.025	−0.033
	(0.014)	(0.023)	(0.018)	(0.017)	(0.016)	(0.016)	(0.017)	(0.019)	(0.021)	(0.030)
SD	0.034 ***	0.030 *	0.022 *	0.030 ***	0.032 ***	0.030 ***	0.028 **	0.043 ***	0.044 ***	0.045 **
	(0.009)	(0.016)	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)	(0.013)	(0.014)	(0.020)
PR	0.010 ***	0.007	0.007*	0.008 **	0.007 **	0.010 ***	0.010 ***	0.010 **	0.009 *	0.010
	(0.003)	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.005)	(0.006)
PM	0.085 ***	0.089 ***	0.072 ***	0.063 ***	0.078 ***	0.086 ***	0.086 ***	0.077 ***	0.095 ***	0.086 ***
	(0.011)	(0.019)	(0.015)	(0.014)	(0.014)	(0.013)	(0.014)	(0.016)	(0.018)	(0.025)
LN(*SIZE*)	0.163 ***	0.088 ***	0.106 ***	0.150 ***	0.168 ***	0.157 ***	0.184 ***	0.186 ***	0.194 ***	0.248 ***
	(0.016)	(0.026)	(0.021)	(0.020)	(0.019)	(0.018)	(0.019)	(0.022)	(0.024)	(0.033)
_cons	10.903 ***	10.780 ***	10.734 ***	10.613 ***	10.540 ***	10.699 ***	10.940 ***	11.031 ***	11.082 ***	11.026 ***
	(0.189)	(0.319)	(0.249)	(0.237)	(0.224)	(0.219)	(0.232)	(0.265)	(0.288)	(0.403)
Pseudo R^2	-	0.347	0.357	0.360	0.364	0.368	0.367	0.360	0.351	0.326
Adjusted R^2	0.563	-	-	-	-	-	-	-	-	-
N	2286	2286	2286	2286	2286	2286	2286	2286	2286	2286

Note: ***, **, and * represent 1%, 5%, and 10% significance levels, respectively.

Table 3 lists the quantile regression results. The pseudo R^2 of all the quantiles is between 0.326 and 0.368, indicating that all models have adequate explanatory power. All the regression coefficients of *LN*(*UR*) are significant at the 1% level, indicating that *UR* has a capitalization effect on all levels of housing prices. However, the capitalization effect on different levels of housing prices is significantly different in heterogenous price quantiles. Specifically, with the increase in housing prices, the coefficients decrease from 0.012 to −0.093. *UR* also shows a positive and negative effect on low-price houses (Q10 and Q20) and medium-/high-price houses (Q30–Q90), respectively. In other words, the owners of low-price houses represent positive demands on *UR*, and the owners of high-price houses resist the increase in *UR* density.

This result be due to various reasons. First, compared to high-price houses, *UR* development is lower in the surroundings of low-price houses. Those living in low-price houses may not be as mobile as the residents of high-price neighborhoods [53]. For example, the owners of high-price houses usually own more private cars and are less sensitive to increases in transportation costs [42]. Therefore, there might be lower demand from the owners of high-price houses for the convenience of *UR* service near their houses. In addition, wealthier residents tend to be more concerned about the privacy and comfort

of their homes [20]. More *UR* stores imply increased adverse impacts on the environment, such as noise pollution, large crowds, trash accumulation, and increased crime rate due to the presence of strangers [13]. The owners of high-price houses will show less tolerability to the negative influence of *UR* than those who own low- and medium-price houses. In addition, more job opportunities from high density *UR* areas may also lead to gaps between the demands of the owners of low-price and high-price houses [6]. The above reasons meant that the demand curve of high-price house owners were more to the left than the demand curve of low-price house owners. In other words, high-price house owners are willing to pay a lower premium for *UR*.

4.3. Geographically Weighted Regression Model Results

Before building a spatial econometric model of Chengdu housing prices, we test the spatial autocorrelation of the logarithm of housing prices. The Moran I index of logarithm of housing is 0.576 at the 1% significance level (p-values < 0.01), indicating that Chengdu housing prices are characterized by positive spatial autocorrelation and spatial aggregation (the high-price houses are clustered together, as are the low-price houses). Hence, the geographically weighted regression model is used to estimate the spatial heterogeneity of the impact of the above-mentioned explanatory variables on housing prices in Chengdu. Because the regression of coefficients of distance to park or square are not significant in global and all price quantiles, we remove distance to park or square in the geographically weighted regression model.

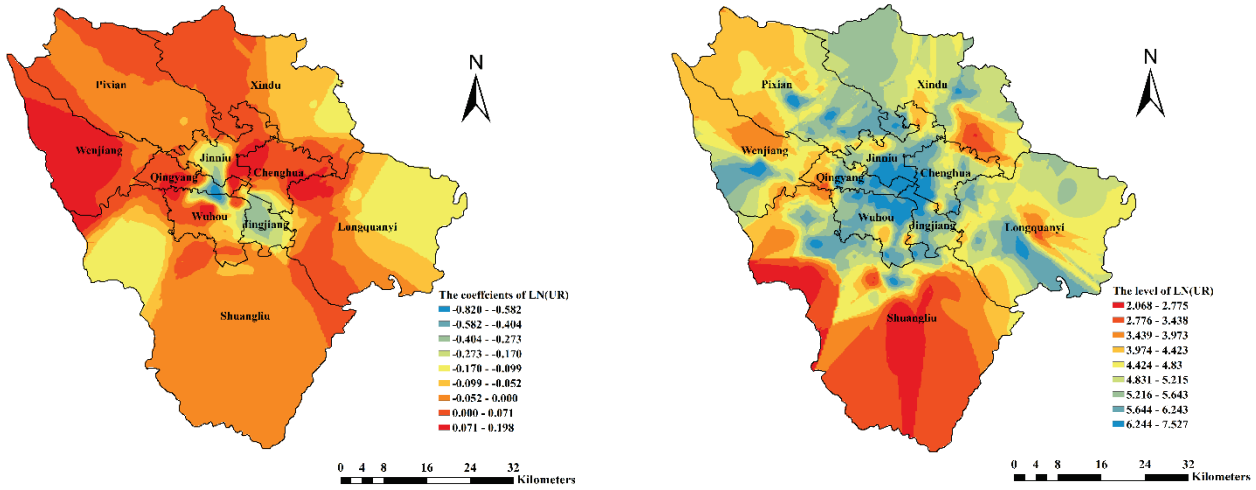
Table 4 presents the minimum, median, maximum, and mean of geographically weighted regression model results. The adjusted R^2 of the geographically weighted regression model is 0.775, significantly higher than the hedonic price model (0.560), indicating superior explanatory power. Spatial heterogeneity has a significant impact on the capitalization effect of *UR* on housing prices. The regression coefficients of *LN*(*UR*) show both positive and negative values, indicating that residents' demands for *UR* are significantly different in different regions and represents demand and rejection simultaneously.

Table 4. Results of geographically weighted regression model.

Variable	Max	Median	Min	Mean
LN(*UR*)	0.2009	−0.0407	−0.8097	−0.0779
EI	0.2613	0.1276	−0.0526	0.1289
YEAR	0.0098	−0.2566	−0.8356	−0.2699
LN(*BUS*)	0.3468	0.0585	−0.2544	0.0562
LN(*DSUB*)	0.1343	−0.0415	−0.3572	−0.0392
LN(*DUC*)	0.5170	−0.6877	−2.4070	−0.6817
LN(*DHOS*)	0.7616	0.1374	−0.6634	0.1034
LN(*KD*)	0.2712	0.0114	−0.2021	0.0171
LN(*DUN*)	1.5305	0.0077	−1.6244	0.0519
LN(*DSHS*)	0.2499	0.0281	−0.4133	0.0203
SD	0.2027	−0.0037	−0.2645	0.0011
PR	0.4484	0.1332	−0.1476	0.1350
PM	0.2955	0.1254	−0.0812	0.1196
LN(*SIZE*)	1.9464	0.2349	−0.7878	0.2602
Intercept	0.2009	−0.0407	−0.8097	−0.0779
Bandwidth		60		
N		2286		
Adjusted R^2		0.775		

To further examine the influence of spatial heterogeneity, we employ the Kriging method (Figure 3a) to perform spatial interpolation on the coefficients of *LN*(*UR*). Negative coefficients were observed in the core area of Chengdu, with Tianfu Square as the center, while positive coefficients were observed in the peripheral area of Chengdu, particularly in Wenjiang and Pixian districts, which are in the northwest area of Chengdu. In general, the coefficients of *LN*(*UR*) show significant spatial heterogeneity and reflect a

nearly circular distribution, which gradually increases outward from the city center (from −0.8097 to 0.2009). In other words, residents in the periphery area need an increased *UR* intensity to realize convenience from *UR*, and residents in the core area reject the increase in *UR* intensity to protect their habitable environment and life equality.



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

Figure 3. Spatial distribution of *LN*(*UR*) and coefficients. (**a**) the spatial distribution of coefficients of logarithm of urban retail; (**b**) represents the spatial distribution of logarithm of urban retail.

Furthermore, we plot the spatial distribution of *LN*(*UR*) (Figure 3b) and assign a reverse color direction (the blue part indicates higher ownership *LN*(*UR*)) for ease of comparison with Figure 3a. We find that the *LN*(*UR*) coefficients have a similar spatial distribution to *LN*(*UR*). Hence, we assume that the regression coefficient of *LN*(*UR*) is related to the level of *LN*(*UR*). This hypothesis is supported by the scatter diagram (Figure 4) between the *LN*(*UR*) and coefficients of *LN*(*UR*). Figure 4 shows that *LN*(*UR*) has a negative impact on the regression coefficients of *LN*(*UR*), which implies that the positive capitalization effect of *LN*(*UR*) on housing prices gradually decreases with the increase in the level of *LN*(*UR*). The fitting straight line indicates that the impact of average *LN*(*UR*) on housing prices shifts from promotion to inhibition when average *LN*(*UR*) reaches 3.441, where the attitude of residents changes from demand to resistance. This shows that there is an inverted U-shaped relationship between *LN*(*UR*) and housing prices. To directly confirm this deduction, we established a new hedonic price model, which introduced the square of *LN*(*UR*). The result is shown in Table A1. From Table A1, we can see that the regression coefficients of the square of *LN*(*UR*) was −0.015 at the 5% significance level, confirming the inverted U-shaped relationship between *LN*(*UR*) and housing prices. Generally, before *LN*(*UR*) reaches the inflection point, *LN*(*UR*) has a positive capitalization effect on housing prices, which decreases with the increase of *LN*(*UR*). After reaching the inflection point, the positive capitalization effect changes to a negative effect on housing prices. This might be due to two reasons: (1) with the increase in *UR*, the demand for the convenience of *UR* eventually plateaus, which leads to a reduction in the willingness to pay for the increase of *UR* convenience and (2) the increase in *UR* will attract more consumers and negatively affect the comfort of the living environment [10,13].

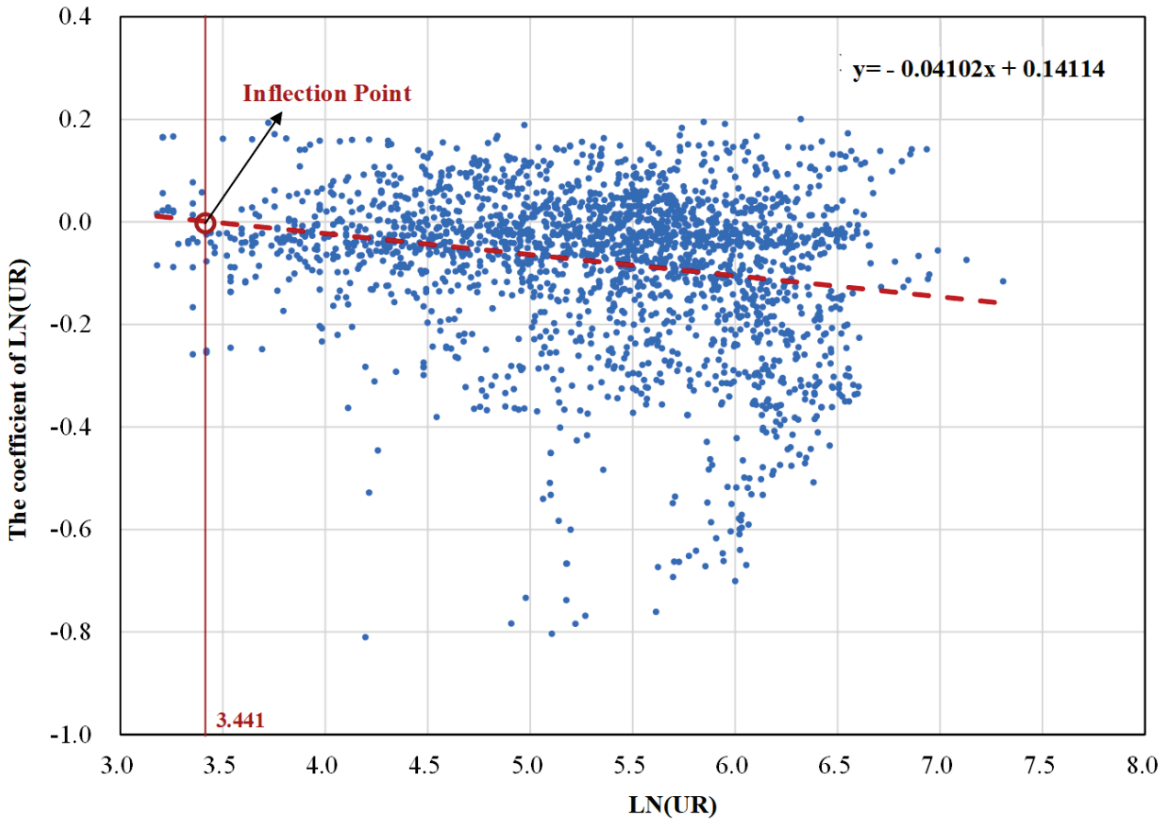


Figure 4. The relationship between *LN*(*UR*) and coefficients.

5. Conclusions

An accurate understanding of the residents' demands for *UR* in heterogeneous conditions is crucial for the *UR* layout of cities. Based on the second-hand housing transaction data of Chengdu, this study employed the hedonic price model, quantile regression, and geographically weighted regression to explore the capitalization effect of urban retail on housing prices and the gap between residents' demands for *UR* in heterogeneous housing characteristics, heterogeneous price quantiles, and heterogeneous space. The main results are as follows: (1) The level of property management (*PM*) and house age (*YEAR*) have a moderating effect on the capitalization effect of *UR* on housing prices. Specifically, good property management and good sound insulation can decrease the negative influence of *UR* on residents' lives; (2) The owners of high-price houses have a lower demand for *UR* compared to the owners of low-price houses; (3) The capitalization effect of *UR* on housing prices is spatially heterogeneous and decreases as we move outward from the Chengdu central area to the Chengdu peripheral area; (4) There is an inverted U-shaped relationship between *UR* and housing prices.

In contrast with previous studies, this study is the first to discuss the inverted U-shaped relationship between housing prices and *UR* and to analyze the moderating effect of housing structure characteristics on residents' demand for *UR*. These research perspectives can provide some reference for further studies on housing prices, such as the relationship between transportation infrastructure and housing prices. For practice, this study also provides several policy implications for real-estate developers and city planning departments. First, considering the negative impact of *UR* on residents' lives, the city planning department should prevent excessive urban retail development in developed areas, which, with a high *UR* intensity or older houses, focuses on regional security and environmental management to offset the negative impacts of *UR*. Specifically, the results of geographically weighted regression indicate that Wenjian and Xindu are more appropriate for *UR* development. On the contrary, Wuhou, Jingjiang and Jinniu should try to decrease their *UR* density. Furthermore, because of the local regression of

geographically weighted regression, according to the regression coefficients of houses with similar environments and location variables, planer can find the *UR* development limitation of a specific region. The inverted U-shaped curve indicates that the *UR* intensity of a dwelling district should not be more than $125/km^2$ ($\exp(3.441)/0.5^2$). Meanwhile, actively developing the *UR* in boundary areas that have lower *UR* intensity can improve the quality of life of local residents and relieve the pressure on existing commercial areas. Second, real-estate developers should fully focus on consumers' characteristics and adopt different real estate development strategies. Specifically, for consumers with high incomes, real-estate developers should pay more attention to the establishment of a livable and private living environment, since these consumers are not sensitive to the convenience derived from *UR*. On the contrary, the convenience derived from *UR* and reducing the travel cost should be the focus of real-estate developers for consumers with low incomes as the major target consumer group. In addition, by considering the direct and indirect positive impacts of suitable property management and the performance of building sound insulation on housing prices, real-estate developers should consider adopting better property management and sound insulation to increase housing prices, especially in areas with high *UR* intensity.

This study has some limitations. First, it only focuses on the real-estate market in 2019 without considering changes in the capitalization effect of *UR* on housing prices over time. Therefore, residents' demands for *UR* at different times remains unclear. For example, in the past, residents needed to reach retail stores for accessing *UR* activities. Now, residents can enjoy various services without leaving their homes through online shopping platforms such as Meituan and Taobao. Online *UR* reduces the need for physical *UR* resources. Future studies should employ a space–time econometric model and consider variables related to online business. Second, given the strong correlation between different types of *UR*, this study merges all *UR* types. Hence, the impacts of different *UR* types on housing prices and residents' demands for different *UR* types (such as catering, auto service, and clothing sales, among others) are not considered. Finally, because of the limitations of our data, this study does not further discuss the relationship between the residents' demand for urban retail and the employment capacity created by retail, especially for rural areas. These may have some implications for government retail layout plans. Future research should discuss these questions, providing guidance for the optimization of regional internal *UR* structures.

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Appendix A

Table A1. The results of the hedonic price model with $LN(UR)^2$.

Variable	Model (1)				Model (3)			
	Coefficient	SE	*p* Value	VIF	Coefficient	SE	*p* Value	VIF
LN(*UR*)	−0.051 ***	0.009	0.000	1.897	0.107	0.068	0.117	134.689
$LN(UR)^2$					−0.015 **	0.007	0.020	133.717
PM	0.085 ***	0.011	0.000	2.927	0.085 ***	0.011	0.000	2.928
YEAR	−0.014 ***	0.001	0.000	3.745	−0.014 ***	0.001	0.000	3.745
EI	0.080 ***	0.014	0.000	2.108	0.079 ***	0.014	0.000	2.113
LN(*BUS*)	0.051 ***	0.016	0.002	2.491	−0.051 ***	0.016	0.002	2.491
LN(*DSUB*)	−0.036 ***	0.006	0.000	1.227	−0.035 ***	0.006	0.000	1.228
LN(*DUC*)	−0.279 ***	0.008	0.000	1.881	−0.282 ***	0.008	0.000	1.905
LN(*DG*)	0.004	0.006	0.478	1.19	0.004	0.006	0.520	1.191
LN(*DHOS*)	0.042 ***	0.006	0.000	1.411	0.042 ***	0.006	0.000	1.412
LN(*KD*)	0.132 ***	0.019	0.000	3.21	0.127 ***	0.019	0.000	3.247
LN(*DUN*)	0.037 ***	0.006	0.000	1.27	0.037 ***	0.006	0.000	1.27
LN(*DSHS*)	−0.024 *	0.014	0.088	1.014	−0.024 *	0.014	0.085	1.014
SD	0.034 ***	0.009	0.000	1.078	0.034 ***	0.009	0.000	1.079
PR	0.010 ***	0.003	0.001	1.222	0.010 ***	0.003	0.001	1.228
LN(*SIZE*)	0.163 ***	0.016	0.000	1.113	0.163 ***	0.016	0.000	1.113
Intercept	10.903 ***	0.189	0.000		10.551 ***	0.244	0.000	
Adjusted R^2	0.560				0.561			

Note: ***, **, and * represent 1%, 5%, and 10% significance levels, respectively.

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Research on the Evaluation of Real Estate Inventory Management in China

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Abstract: Inventory management not only determines the health of the real estate market development, but also affects the regional economy and the capacity of sustainable social development. In this paper we use the DPSIR framework to integrate multi-dimensional influence factors, such as economic, social, and environmental factors, to construct a real estate inventory management performance evaluation and obstacle diagnosis model, and conduct an empirical study on 31 Chinese provinces and cities. The results show that: first, China's real estate inventory is huge in size, with significant spatial heterogeneity and agglomeration; second, China's real estate inventory management performance is unsatisfactory and still shows no improvement despite the strong policy intervention of the central and local governments; third, the obstacle factors of real estate inventory management are becoming increasingly diversified and complicated, with great differences among provinces—significantly, Profits of Real Estate Enterprises, Disposable Income of Urban Residents, Financial Revenue, Per Capital GDP, Resident Population, Gross Domestic Product, Total Retail Sales of Social Consumer Goods, Financial Expense, and Loans Balance of Financial Institutes are critical obstacle factors; and fourth, it is suggested that, on the basis of mastering the actual conditions of supply and demand in the real estate market, differentiated and precise response strategies should be formulated by integrating near-term and long-term goals, direct and indirect forces, and administrative and market instruments.

Keywords: inventory management; housing market; performance evaluation; China

1. Introduction

1.1. Background

Inventory is an important part of the material security of enterprise production and sales, having a high place in enterprise operations and remaining a hot topic of concern for business managers and researchers [1,2]. A certain amount of inventory helps enterprises ensure normal, continuous, and stable production, and also helps to respond and meet customer needs in a timely manner, maintain a corporate reputation, and consolidate market share. Real estate is a leading industry in most countries of the world, featuring a large investment scale, high product value, high risk, and high return. Against the background of high inventory and high housing prices, the level of inventory management has become an important index reflecting the competition of real estate enterprises, the development of the industry, and the health of market operation, and has a significant impact on the sustainable development of cities and regions, and even

the national economy and society. It has received attention from researchers in different disciplines such as land management, spatial planning, human geography, real estate economics, and business management [3].

China's real estate market is huge in scale, and with the continuous increase in inventory in recent years, financial, market, economic, and social risks continue to accumulate, making it a typical representative in the world [4]. After decades of rapid development, China's real estate has experienced a decline in investment growth and oversupply in the market. Especially since 2010, China's real estate market has fallen into the dilemma of an increasing inventory. High inventory and high housing prices have become a great threat to the healthy development of the economy and social harmony and stability. In 2015, the Central Economic Work Conference made real estate "destocking" one of the government's five key tasks, indicating that real estate destocking has officially risen to a national task. Local governments at all levels have issued special policies on real estate destocking, such as *Opinions of Shaanxi Provincial People's Government's on Real Estate Destocking and Structure Optimization*, *Implementation Opinions of Qinghai Provincial People's Government on Promoting Real Estate Destocking*, *Implementation Opinions of Anhui Provincial People's Government on Destocking and Promoting Stable Development of Real Estate Market*, *Opinions of General Office of Chongqing Municipal People's Government on Promoting the Stable and Healthy Development of the City's Commercial and Commercial Real Estate Market*, *and Opinions of Guangzhou on Further Promoting the Stable and Healthy Development of the City's Real Estate Market*.

The central government and local governments at all levels have successively implemented a number of real estate destocking policies and achieved certain results after years of management, but the achievement has failed to meet expectations and there is still a big gap to fill to reach the ultimate goal [5]. China's real estate inventory is huge, and there is a significant spatial difference in destocking pressure, making the task of inventory management arduous and complicated. As indicated in the *Market Size Report on Global Real Estate*, China has grown to be the fourth largest real estate market in the world, with global representation. Therefore, it is of great theoretical significance and practical value to carry out research on the inventory management performance evaluation of China's real estate market and analyze the main obstacles and coping strategies for destocking.

1.2. Literature Review

Inventory management is a difficult issue of long-term and continuous concern for industry, politics, and academia. The current research focuses on inventory management technology innovation and application, development of inventory management strategies for multiple scenario models, and exploration of specific enterprise and product inventory management methods [6]. It should be noted that real estate inventory management is receiving more and more attention as an emerging field.

1.2.1. Research on Technology Innovation and Application of Inventory Management

The research foci on inventory management technology innovation and application in different fields, industries, and enterprises include inventory management model and system development, method innovation and application, and index and index construction [7]. For example, Yan [8], Melikov [9], Preil [10], and Drakaki [11] developed inventory management models and systems based on System Dynamics, Markov Model, Artificial Intelligence, and Colored Petri Net-based modeling methods. Mamani [12] and Borgonovo [13] conducted a robustness and sensitivity analysis of inventory management models. Hill [14] developed a forecastability quotient index for inventory forecasting. Subramanian [15] developed a supply chain inventory management control model, and Perez [16] proposed an optimization method for inventory management algorithms. Borgonovo [17] developed a new inventory management model sensitivity measure using differential importance (D) and the comparative statics (CS) techniques. Almaktoom [18] developed a method of quantifying the reliability of an inventory management system,

and Jonsson [19] conducted a comparative study of different methods of safety inventory management (SIM). Lei [20] analyzed the dynamics of the Nonlinear Inventory Management System by means of the eigenvalue trajectory, bifurcations, chaotic attractor, and yjr the largest Lyapunov exponent diagram, Fractional-Order Approximate Entropy, finding the equilibrium of the inventory management system. Rahaman [21] analyzed the synergy of inventory management in uncertain environments based on memory and learning effects. In general, the existing research focuses on the development technology of models, systems, and algorithms, but pays little attention to the performance evaluation and application effect of inventory management. Technology innovation is a front-end research topic, while technology application and effect evaluation is a back-end research topic. In the enterprise development practice, more emphasis is placed on the latter, as enterprises are eager to know what state and problems of inventory management are when using a certain system or model. However, the existing papers give little attention to inventory management performance evaluation methods and problem diagnosis technology, which does not match the practical needs and restricts the application and reinvention of inventory management technology.

1.2.2. Research on Multi-Scenario Inventory Management Strategies

As a complex, non-linear, and systematic project, inventory management is greatly influenced by various external environment and internal factors, so scholars pay close attention to the research of differentiation strategy of inventory management in different scenarios. For example, Bendavid [22], Steinker [23], and Katehakis [24] argued that the goal of inventory management models is to achieve a continuous balance between costs and sales by effective strategies, and it is necessary to consider the constraints of working capital. Sharma [25] analyzed inventory management models in the context of order constraints; Fu [26] and Buzacott [27] analyzed inventory management methods in inventory-dependent financing scenarios; Herrmann [28] analyzed inventory management models during high-frequency trading in imperfectly competitive environments; Xu [29], Chen [30], and Mokhtari [31] analyzed inventory management technology in the context of joint pricing; Guo [32] studied inventory management schemes under the condition of mass customization; Chen [33], Xiao [34], and Transchel [35] analyzed inventory management strategies under dynamic price effects; Park [36] analyzed optimal inventory management schemes under buy-one-give-one conditions; Xie [37] and Muharremoglu [38] analyzed measures to achieve inventory management robustness in the presence of multiple supply sources; Mascle [39] developed an inventory management system with integrated sales volume forecasting; and Nenes [40] and Cao [41] provide a case study of inventory management in irregular and non-smooth demand scenarios. In summary, to improve the competitiveness and adaptability of enterprises, scholars have analyzed inventory management models in many situations from different perspectives, mainly focusing on case and qualitative studies, with less attention to quantitative and empirical studies, thus impairing the accuracy and practicability of the research conclusions.

1.2.3. Research on Inventory Management of Specific Enterprises and Products

The current research focuses mainly on the inventory management of industrial manufacturing, retail, and supply chain service companies, while the inventory management for special products, such as oil, disaster relief supplies, and shared bicycles, is attracting increasing attention [42]. In the field of industrial production, the focus is placed on spare parts inventory management in the manufacturing industry. For example, Muniz [43] and Turrini [44] analyzed spare parts inventory management in the Brazilian mining industry and German renewable energy industry, Kranenburg [45] analyzed service differentiation of spare parts inventory management, and Dendauw [46] proposed the critical state of spare parts inventory management. Furthermore, remanufactured product inventory management [47], supply chain inventory management in Industry 4.0 [48,49], and indus-

trial inventory management in China [50] and India [51] have also received some attention, and there are many empirical research papers. In the supply chain and services sector, the main focus is on retailer inventory management. Jaksic [52] analyzed optimal inventory management in the context of supply backorders for retailers; Agrawal [53] analyzed optimal inventory management models for retail chain stores in the context of demand differentiation (differences in economic conditions, culture and demographics, and store formats); Ehrenthal [54] analyzed inventory management solutions in different seasonal demand differentiation scenarios; Turgut [55] studied retail inventory management models with back-office effects; Saputro [56], Sarkar [57], and DeCroix [58] analyzed inventory management methods in the context of supply disruptions; and Hasan [59] proposed an inventory management scheme for e-commerce retailers. In the field of special product inventory management, Raviv [60] and Swaszek [61] analyzed inventory management technology for shared bicycles; Chuang [62] analyzed inventory management solutions for General Motors, Mostafaei [63], Siddiqui [64], and Dimas [65] analyzed inventory management strategies for oil; Toyasaki [66], Loree [67], and Natarajan [68] analyzed the inventory management model for humanitarian relief materials; and Paam [69] and Golas [70] analyzed the inventory management methods for agriculture.

1.2.4. Research on Inventory Management in Real Estate Market

Real estate inventory management has been on the rise. Geman [71] was the first to introduce the inventory management concept into the real estate and conducted an empirical study of the UK. Pham [72], based on an analysis of dynamic panel data of Vietnamese real estate companies for the 2011–2018 period, believes that inventory size, installment payment, and financing policies are the main factors affecting sales growth. Bian [73] studied the effect of inventory size on residential prices and liquidity and concluded that real estate inventories bear obvious externality. Caplin [74] constructed a joint model between real estate inventories, prices, and sales, arguing that high inventories lead to higher prices. Ott [75] found high inventories of real estate in the US, particularly in cities such as Atlanta, Las Vegas, and Orlando, and proposed an optimal staging and inventory decision model for large residential developments. Wen [76], based on the real estate practice in China, proposed an inventory management model in the context of demand uncertainty and dynamic price changes. Kwoun [77] introduced system dynamics to analyze unsold new housing stocks, and developed Causal Loop Diagrams and Stock-Flow Diagrams for quantitative simulation. Morales [78], Jiang [79], and Muczynski [80] provided a brief analysis of real estate inventories in Brazil, China, and Poland. Yoo [81] and Nam [82] conducted an in-depth case study of the factors influencing real estate inventories and their management responses in Gyeonggi Province, South Korea. Real estate inventory management research is generally still in its infancy, and the existing research is fragmented significantly, lacking a systematic and mature research framework and methods.

1.3. Aim and Question

The change trends in real estate inventory levels vary across countries and industries, and the factors affecting inventory management are also very different. China is a global representative in real estate inventory management, so the empirical study of China can provide experience and decision-making reference for countries and regions with similar conditions. China's real estate development is characterized by significant spatial heterogeneity, with uneven destocking pressure in different provincial and municipal governments. To reveal the current status, changing trends, performance levels, major obstacles, and management strategies of China's real estate inventory, this paper is devoted to answering the following three questions: (1) What are the characteristics of the spatial and temporal evolution of China's real estate inventory, including the time series change trend and spatial pattern characteristics under different measurement indexes? (2) How does one construct the performance evaluation index system of China's

real estate inventory management, including the index composition, weight scheme, and result grading? (3) What is the optimization strategy for real estate inventory management in China, including the analysis of the influence factors of inventory management, identification of the main obstacle factors, and policy design suggestions?

2. Research Design

2.1. Study Area: China

The study area of this paper covers 31 provinces, autonomous regions, and municipalities directly under the central government of China, excluding Taiwan, Hong Kong, and Macao due to a lack of data (Figure 1). According to the data released by the National Bureau of Statistics, China's real estate inventory showed a rapid rise in scale in 2010, and a decline only after 2015 under the strong policy intervention. However, it currently is still at a high level. Significantly, the scale of China's long-term real estate inventory (staying on the market for 3 years or more) has continued to grow rapidly over the same period, with a surge in growth in the last two years in particular (Figure 2). At the same time, from the perspective of population and land scale in the study area, the characteristics of unbalanced development and inequality are prominent, which should be properly considered when studying the spatial differentiation of real estate inventory (Figure 3).

Figure 1. Study area.

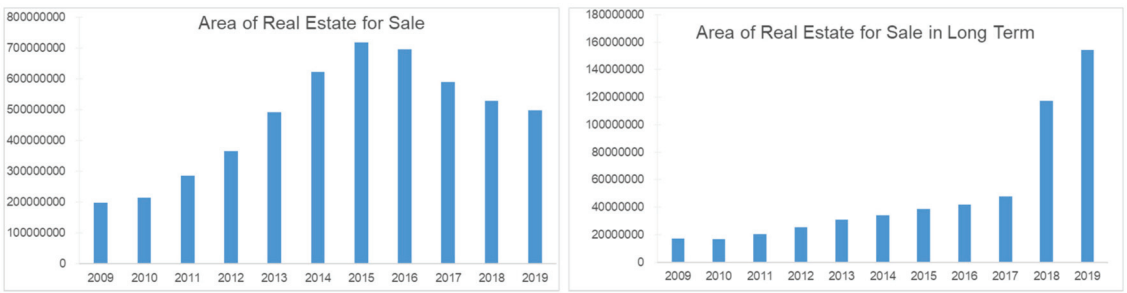

Figure 2. Analysis of the inventory of real estate in China.

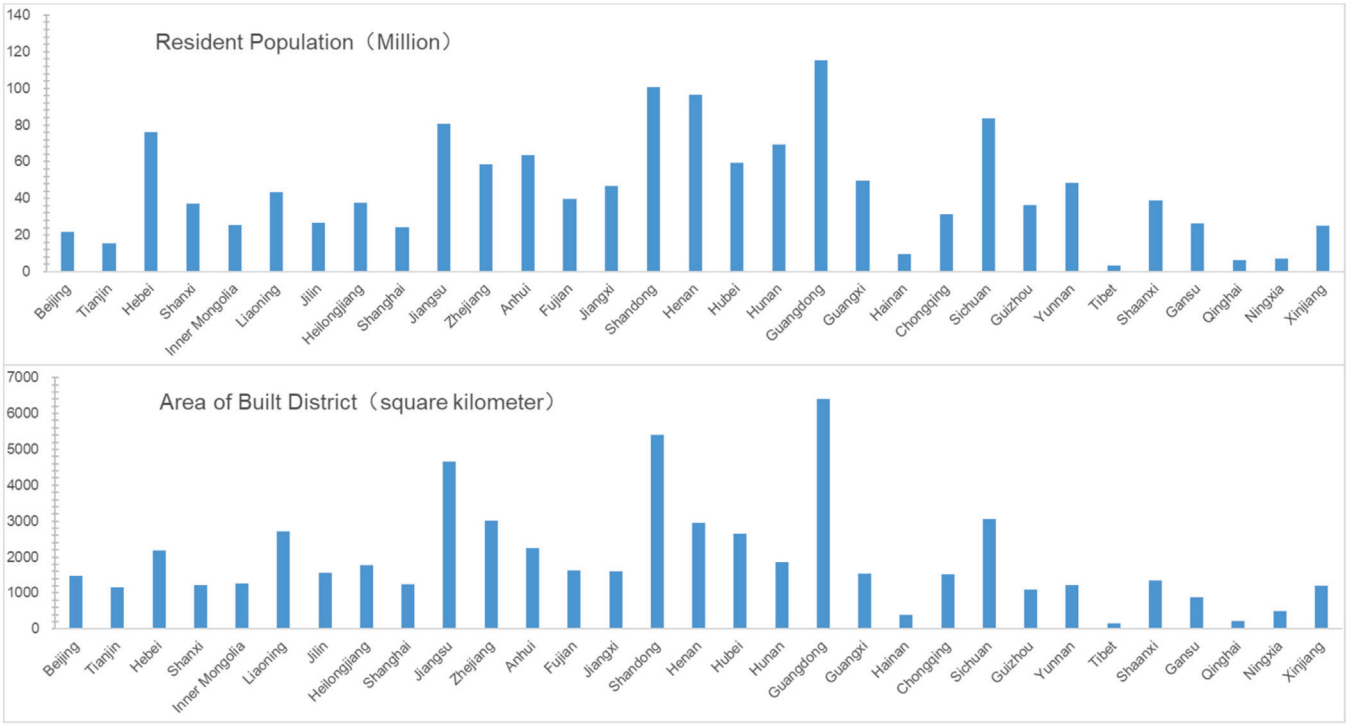

Figure 3. Analysis of the urban population and land scale in the study area.

2.2. Research Methods

2.2.1. DPSIR Model

The Driver–Pressure–State–Impact–Response (DPSIR) model, created by the European Environment Agency, serves as a comprehensive model dedicated to the study of environmental issues [83]. It is a combination of the advantages of the Pressure–State–Response (PSR) model and Driver–State–Response (DSR) model, characterized by comprehensiveness, systematism, integrity, and flexibility, and containing the causal relationship of "what happens, why it happens, and how to respond". It provides a technical framework for comprehensive analysis of the relationship between society, economy, resources, and environment in urban and regionally complex systems [84,85]. The model has been widely used in recent years in regional ecological safety and environmental management [86], resource utilization evaluation [87], urban and regional sustainable development [88,89], and industrial and economic high-quality development evaluation [90,91], and has gradually become an effective tool for judging the causal relationship between development performance and problems. Real estate inventory management involves a wide range of corporate, governmental, market, social, economic, and environmental factors, which are interconnected and constrained at multiple levels.

The DPSIR model offers a framework that helps decompose, simplify, and then effectively synthesize complex problems, providing a technical route for the study of real estate inventory management problems [92] (Figure 4). The Driver is the potential factor causing real estate inventory—that is, the deep-seated reason or fundamental driving force that leads to the oversupply of real estate—and represents the behavior and demands of multiple participants, such as the government, enterprises, and citizens. Pressure is the direct cause that acts directly on real estate inventories and drives changes under the influence of driving forces. State describes the inventory status and changing trends in the real estate market under the driving force and pressure, including product and raw material inventory and long- and short-term inventories. Impact reveals the state of the real estate inventories and the consequences of their changes on the economy, society, and the environment. Response is the countermeasure taken by the stakeholders

in the real estate market to the abovementioned state, impact, and changes, including government policies, corporate investments, and citizens' decisions. Based on the research needs, some indexes were selected to represent each part of the model separately, and a quantitative approach was adopted to obtain the empirical data in this study (detailed in Section 2.3).

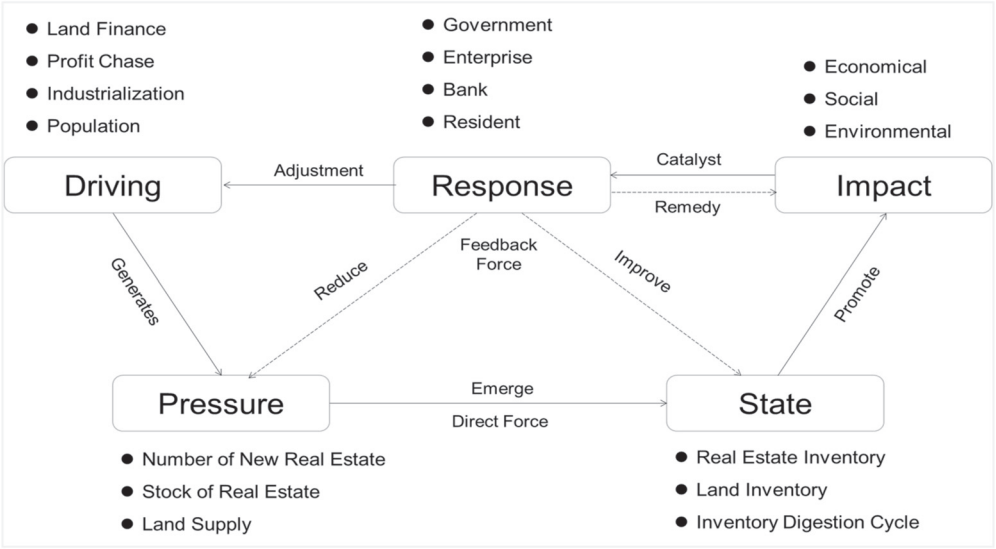

Figure 4. DPSIR analysis framework of real estate inventory management.

The DPSIR model is a method initiated by the United Nations Organization for Economic Cooperation and Development (OECD) and the United Nations Environment Programme (UNEP), specifically designed for sustainable development evaluation. It reveals the causal relationships and feedback mechanisms among social, economic, demographic, environmental, and policy elements, and is widely used in sustainable development assessment and governance. Real estate inventory management is not only an important part of achieving sustainable development of the real estate market, but also a complex system involving many fields and subjects, such as society, economy, environment, as well as government, residents, and enterprises. The DPSIR model helps capture the "action–feedback–reaction" cycle of real estate inventory management from the perspective of sustainability, describing and demonstrating the causal chain between the domains of real estate inventory management performance evaluation. It is applicable to this study. Of course, it must be noted that there are many methods to analyze the imbalance between supply and demand in the real estate market, such as regression analysis or machine learning, which have great advantages in influencing the factor analysis and future prediction. In this study, we choose the DPSIR model based on two main rationales. First, for real estate inventory management, an emerging research area, the influencing factors are still unclear, the variable selection is highly uncertain when using regression analysis and machine learning, and the multicollinearity among indicators is also a big challenge. Second, when choosing research methods, we should focus more on "useful" than "better" or "newer", and the potential to achieve our research goals (sustainability) is the primary principle for the selection of different methods.

2.2.2. Obstacle Factor Diagnosis

To further explore the constraints of real estate inventory management in China, this study introduces the obstacle degree model and uses it as a basis to propose targeted and applicable optimization strategies [93,94]. In this paper, we calculate the obstacle index intensity of each factor with the help of the obstacle degree model and find out the key constraints based on comparative analysis, so as to find out the countermeasures to solve the real estate inventory problem in each place. With X'_j standing for the standardized

value of the index j, n standing for the number of evaluation indexes, D_j standing for the difference between the standardized value of the index j and the ideal value, W_j standing for its weight, and O_j standing for the obstacle degree of the index j to the efficient management of real estate inventory, the obstacle degree is calculated as follows [95]:

$$D_j = 1 - X'_j \tag{1}$$

$$O_j = \frac{D_j \times W_j}{\sum_{j=1}^{n}(D_j \times W_j)} \tag{2}$$

2.3. Index Selection

According to the framework diagram of the DPSIR model, 23 indexes were selected to build a comprehensive evaluation system of real estate inventory management performance based on the connotation of real estate inventory management and the characteristics of its influence factors, as well as the relevant research results, in line with the principles of scientificity, representativeness, comparability, and operability of the indexes (Table 1). Indexes include positive and negative categories. A positive index with a larger value has a greater positive effect on the evaluation results; a negative index with a larger value has a smaller positive effect on the evaluation results. In Table 1, we use positive and negative signs to represent them, respectively. The management of inventories at high levels not only requires reasonable destocking measures to reduce the pressure and impact of risks, it also needs to discourage the emergence of new inventory; that is, weaken the force that drives inventory formation. Therefore, the construction of the performance evaluation index system around the process and needs of real estate inventory management should integrate multi-dimensional indexes such as response, motivation, pressure, and impact, with status indexes as the core. For the state of inventory, the current total housing inventory and the long-term inventory are two important indexes to consider, which present the severity of the inventory risk. In addition, it is necessary to take into account the digestion period and land inventory. The former indicates the potential for future inventory resolution, while the latter reflects the scale of new inventory in the future. It should be noted that inventory is negative while performance is positive, so a smaller value of the performance index represents a higher inventory risk, indicating that the market oversupply is more serious.

Based on historical information, development status and trends, and criteria widely used in the relevant research literature [96,97], this paper classifies real estate destocking management performance into five levels. The index value of the Lower level is 0~0.2 and the indicator lamp is red, representing very poor inventory management performance and a huge risk; the index value of the Low level is 0.2~0.4 and the indicator lamp is orange, representing poor inventory management performance and a big risk; the index value of the Mean level is 0.4~0.6 and the indicator lamp is yellow, representing medium inventory management performance and an average risk; the index value of the High level is 0.6~0.8, and the indicator lamp is blue, representing good inventory management performance and a low risk; the index value of the Higher level is 0.8~1.0 and the indicator lamp is green, representing very good inventory management performance and basically no risk. By multiplying the standardized values of each index with the weights and then summing all indexes, we can calculate the real estate inventory management performance index for each region. Taking X_j as the raw data for the index j, X_{max} as its maximum value, and X_{min} as its minimum value (all provinces of the study area in a year, not all years), the data normalization and inventory management performance index is calculated by the following equations:

$$\text{Positive index}: \ X'_j = \frac{X_j - X_{min}}{X_{max} - X_{min}} \tag{3}$$

$$\text{Negative index}: \ X'_j = \frac{X_{max} - X_j}{X_{max} - X_{min}} \tag{4}$$

$$\text{Performance management index}: \ P_{index} = \sum_{j=1}^{n} (X'_j \times W_j) \tag{5}$$

Table 1. Index system based on the DPSIR framework.

Code		Name	Attribute
Driving	X_1	Financial Revenue	+
	X_2	Profits of Real Estate Enterprises	+
	X_3	Per Capita GDP	+
	X_4	Resident Population	+
Pressure	X_5	New Construction Area of House	-
	X_6	Building Construction Area of House	-
	X_7	Completed Construction Area of House	-
	X_8	Land Area Purchased by Real Estate Enterprises	-
State	X_9	Area of Real Estate for Sale	-
	X_{10}	Inventory Digestion Cycle of Real Estate	-
	X_{11}	Area of Real Estate for Sale in Long Term	-
	X_{12}	Land Area Waiting for Construction	-
Impact	X_{13}	Gross Domestic Product	+
	X_{14}	GDP Growth Rate	+
	X_{15}	Total Retail Sales of Social Consumer Goods	+
	X_{16}	Disposable Income of Urban Residents	+
Response	X_{17}	Financial Expense	+
	X_{18}	Area of Land Requisitioned	-
	X_{19}	Loans Balance of Financial Institutions	+
	X_{20}	Urbanization Rate of Population	+
	X_{21}	Investment of Real Estate Enterprises	-
	X_{22}	Average House Price	-
	X_{23}	Number of Real Estate Enterprises	-

At the Driver level, real estate destocking policies have catered to land finance to some extent and led to lucrative profits for real estate developers, represented by Financial Revenue and Profits of Real Estate Enterprises, and representing the micro driving forces for government and market entities. In the stage of economic development, especially in the industrialization process, new urbanization, especially the transformation of "semi-urbanization" population, is the macro driving force of real estate destocking, which can be represented by the Per Capita GDP and Resident Population. To achieve real estate destocking, it is necessary to reduce blind investment by developers, and also to control the expansion of government land finance at a deep level, to coordinate the game of interests between local governments' land finance and real estate developers' corporate profits, and to promote the scale of the real estate supply to meet the population demand and be in balance with the stage of economic development [98,99].

At the Pressure level, New Construction Area of House, Building Construction Area of House, and Completed Construction Area of House represent the area of houses built and under construction in the current real estate market, reflecting the direct inventory pressure in the real estate market. The New Construction Area of House refers to the building area newly started in the current year, and the Building Construction Area of House refers to the total building area constructed in the current year. The Completed Construction Area of House refers to the sum of the building area of all types of houses

fully completed in accordance with the design requirements in the current year, which meet the requirements of use, pass the appraisal, or reach the completion and acceptance criteria, and can be officially handed over for use. The Land Area Purchased by Real Estate Enterprises represents the area of land acquired by real estate companies through various means of access, reflecting the potential pressure on the real estate market inventory [100].

At the State level, the Area of Real Estate for Sale refers to the portion of commercial properties completed for sale or lease in the current year that have not yet been sold or leased, including those completed in previous years and those completed in the current year. It does not include the construction completed after demolition, houses built in a systematic or agent way and public supporting buildings, nor does it include the real estate company's self-use rooms, relocation housing, and other unsellable or other building areas that cannot be sold or leased. The Inventory Digestion Cycle of Real Estate reflects the time required to digest real estate inventory, and it is calculated using the ratio of real estate area for sale to sales area [101]. The Area of Real Estate for Sale in Long Term refers specifically to the area of houses staying on the market for three years or more, which reflects the real estate destocking is a long-term and arduous task. The Land Area Waiting for Construction represents the area of land that real estate enterprises have obtained the right to use by a variety of means with the approval of government but have not yet been put into construction, which reflects the potential level of the real estate inventory [102].

At the Impact level, real estate destocking is not only an economic but also a social and livelihood issue. It is an important means for the government to cope with the new normal of economic development (China's macroeconomic development has shifted from high-speed growth to medium-speed growth, and from factor-driven and investment-driven to innovation-driven), expand domestic demand, upgrade consumption, and raise residents' income. Gross Domestic Product and GDP Growth Rate represent the impact of real estate destocking on economic development with focus on the economic dimension [103]; Total Retail Sales of Social Consumer Goods and Disposable Income of Urban Residents represent the impact of real estate inventory on urban residents' consumption and income, focusing on the social dimension [104,105].

At the Response level, Financial Expense represents the government's ability to digest real estate inventory through purchase and investment [106], Area of Land Requisitioned represents the government's ability to resolve real estate inventory at source by controlling land supply [107], Loans Balance of Financial Institutions represents the ability of the government and banks to solve real estate inventories by adjusting credit policies [108], and Urbanization Rate of Population represents the ability to solve real estate inventories through urbanization [109]. They together represent government actions and their feedbacks. Investment of Real Estate Enterprises represents the control of business investment in the context of high inventory, Average House Price and Number of Real Estate Enterprises represent the response of the real estate market and industry in the context of high inventory, and together they reflect the market behavior of real estate enterprises and their feedbacks.

2.4. Research Steps and Data Sources

This study consists of three steps (Figure 5).

The first step is the raw data processing; that is, to create complete raw data tables using data published on statistical sites. Since the scale units of each index are different and the indexes cannot be directly compared with each other, Equations (3) and (4) were applied to standardize the positive and negative indexes, respectively. As the research on the performance of real estate inventory management using the DPSIR model is still an emerging field, we currently only know that there should be differences among indexes, but we are still unable to determine the degree of differences in importance between them. It is very simple and convenient to calculate the weight based on the information content method. Using the information content within the data to identify the index weights

applies to both large and small samples of data. For an exploratory study of real estate inventory management performance evaluation in this paper, to calculate the weights by the information content method is a good solution to open the "black box". The coefficient of variation of each index is first calculated, then it is normalized, and the new value obtained is used as the weight. The coefficient of variation is the core of the method, and generally the weight assigned is greater when the coefficient of variation is larger. In this paper, we calculate the weights by information content, and calculate the weighting results using the software SPSSAU.

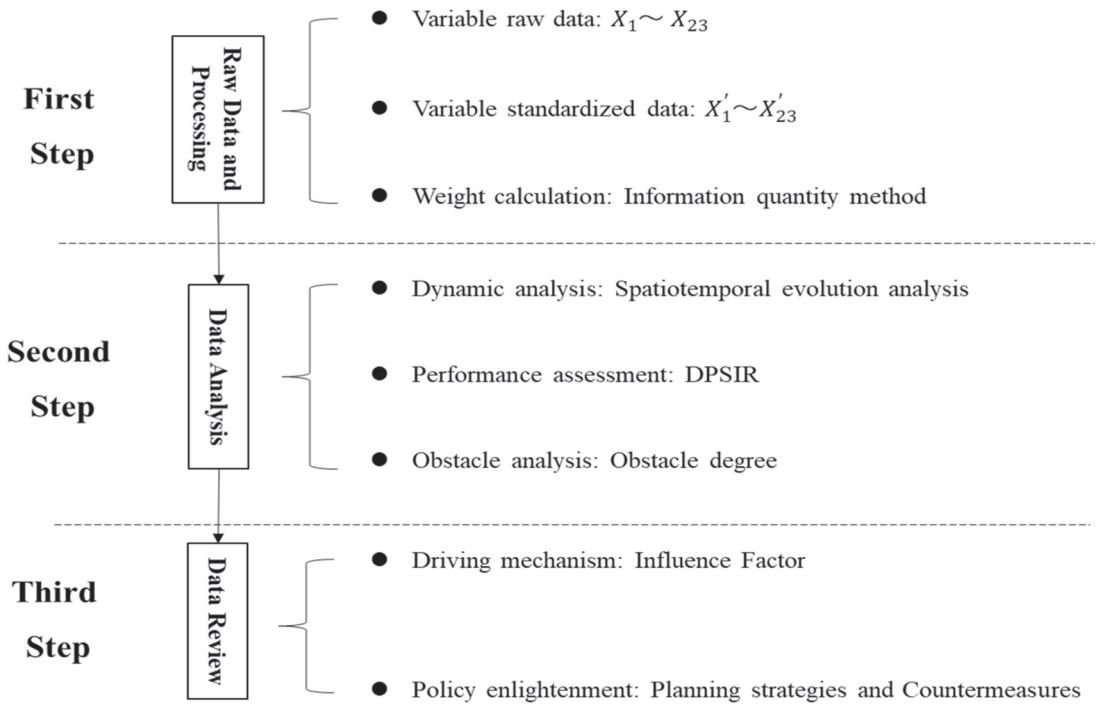

Figure 5. Research steps.

The second step is data analysis, including Dynamic Analysis, Performance Assessment, and Obstacle Analysis. Dynamic Analysis includes both time series analysis and spatial analysis. The former studies the development trend based on data changes from 2010 to 2019, while the latter studies the spatial characteristics based on the coefficient of variation and spatial clustering. We should note that the coefficient of variation is an important index to measure spatial heterogeneity, and its trend can also better reflect the characteristics of convergence. According to the research by Guan [110], Zhang [111], Ruan [112], Liu [113], Miyamoto [114], and She [115], dispersion is classified into weak, medium, and strong levels based on the CV values. That is, a CV value of 0–0.15 shows weak dispersion, reflecting a low degree of spatial inequality of urbanization; a value of 0.16–0.35 shows medium dispersion, reflecting a high degree of spatial inequality of urbanization; a value of 0.36 or more shows strong dispersion, reflecting a very high degree of spatial inequality of urbanization. Performance Assessment includes real estate inventory management performance rating analysis and spatial clustering analysis, while Obstacle Analysis includes analysis of the critical obstacle factors to real estate destocking management and comparative analysis of the differences between different regions.

The third step is data review. This section discusses the real estate inventory management performance and influence factors in China, and proposes optimization strategies or policy insights for real estate inventory management. This is a summary of the analysis of the results in Section 3, drawing a conclusion that is broadly applicable, replicable, and worthy for popularization. We also present some policy suggestions here based on our

analysis to lay the foundation for the government and enterprises to apply the findings of this paper for real estate inventory management.

The indexes in this paper mainly come from the China Real Estate Statistics Yearbook, China Statistical Yearbook, China City Statistical Yearbook, and China Urban Construction Statistical Yearbook. Some missing data were collected from provincial and city statistical yearbooks, statistical bulletins, and government work reports. There are two main reasons for setting the study period from 2010 to 2019. One is to ensure the consistency of the statistical caliber of the data. For example, in 2009, the National Bureau of Statistics adjusted the "vacant area of commercial buildings" to "area for sale", and a prolonged research time would affect the accuracy of the conclusion due to poor comparison between the two indexes. The other is to maintain the relative consistency of the policy background. China's housing market as a whole was under severe control from 2010 to 2019, when anti-overheating, financial retrenchment, destocking, and housing without speculation constituted the keynote policy; especially, a series of special policies on real estate destocking were implemented after 2015.

3. Results

3.1. Spatial and Temporal Dynamic Analysis

From the perspective of Area of Real Estate for Sale, Jiangsu, Guangdong, and Liaoning have the largest inventory of real estate, followed by Zhejiang, Shandong, and Henan, which also have a large one. From 2010 to 2019, all provinces and cities in China, except Beijing and Shanghai, showed an "inverted U-shaped" trend under the intervention of real estate destocking policy (Figure 6). The coefficient of variation remained around 0.8 from 2010 to 2019, much larger than 0.36, indicating a very high degree of spatial inequality in the amount of real estate inventory [116] (Figure 7). According to the relative share of the real estate inventory scale ($\frac{X_j}{X_{max}} \times 100\%$), the 31 provinces and cities were divided into five levels with significant spatial differentiation and agglomeration [117] (Figure 8). In 2010, Guangdong and Liaoning were at the Higher level; Jiangsu and Beijing were at the High level; Sichuan, Heilongjiang, Shanghai, Henan, Hubei, Zhejiang, Shandong, and Chongqing were at the Mean level; Hunan, Inner Mongolia, Fujian, Jilin, Shanxi, Anhui, Hebei, and Ningxia were a the Low level; and Jiangxi, Xinjiang, Guangxi, Guizhou, Yunnan, Tianjin, Gansu, Shaanxi, Qinghai, Hainan, and Tibet were at the Lower level. In 2019, the regions of Lower level underwent a significant expansion; there were no High-level regions; the regions of Higher level were Guangdong and Jiangsu; the regions of Mean level were Shanghai, Shandong, Beijing, Henan, and Liaoning; and the regions of Low level were Zhejiang, Sichuan, Chongqing, Fujian, Anhui, Heilongjiang, Hubei, Hunan, Guangxi, and Xinjiang. The real estate in this paper includes houses for residential, office, commercial, industrial, and other purposes, which are used for market operation and sales, excluding public welfare buildings such as government, schools, hospitals, science and technology museums, and museums.

From the perspective of Inventory Digestion Cycle of Real Estate, Beijing and Tibet have the longest period of real estate destocking, much longer than 1.5 years, followed by Shanxi, Liaoning, Jilin, Heilongjiang, Shanghai, Hainan, Ningxia, and Xinjiang, which have a longer period, remaining at around 1 year for a long time. From 2010 to 2019, the destocking period of most provinces and cities showed an "inverted U-shaped" trend under the intervention of the real estate destocking policy. It is worth noting that Beijing and Shanghai showed a rapid upward trend in the fluctuation (Figure 6). The coefficient of variation fluctuated from 2010 to 2019, but always above 0.36, indicating a high degree of spatial inequality and a very unstable development of the real estate destocking period (Figure 7). In 2010, Beijing was at the Higher level; Tibet and Shanghai were at the High level; Heilongjiang, Shanxi, and Ningxia were at the Mean level; Jilin, Liaoning, Zhejiang, Fujian, Guangdong, Henan, Hubei, Qinghai, and Xinjiang were a the Low level; and most regions, such as Hainan, Guizhou, Jiangsu, and Tianjin, were at the Lower level. In 2019, Beijing was still the only region at the Higher level; no province or city was

a the High level; Shanghai was the only region at the Mean level; regions at the Low level shrank greatly (only Heilongjiang, Liaoning, Hainan, Ningxia, and Xinjiang); and regions at the Lower level expanded significantly, showing a significant decrease in spatial complexity (Figure 8).

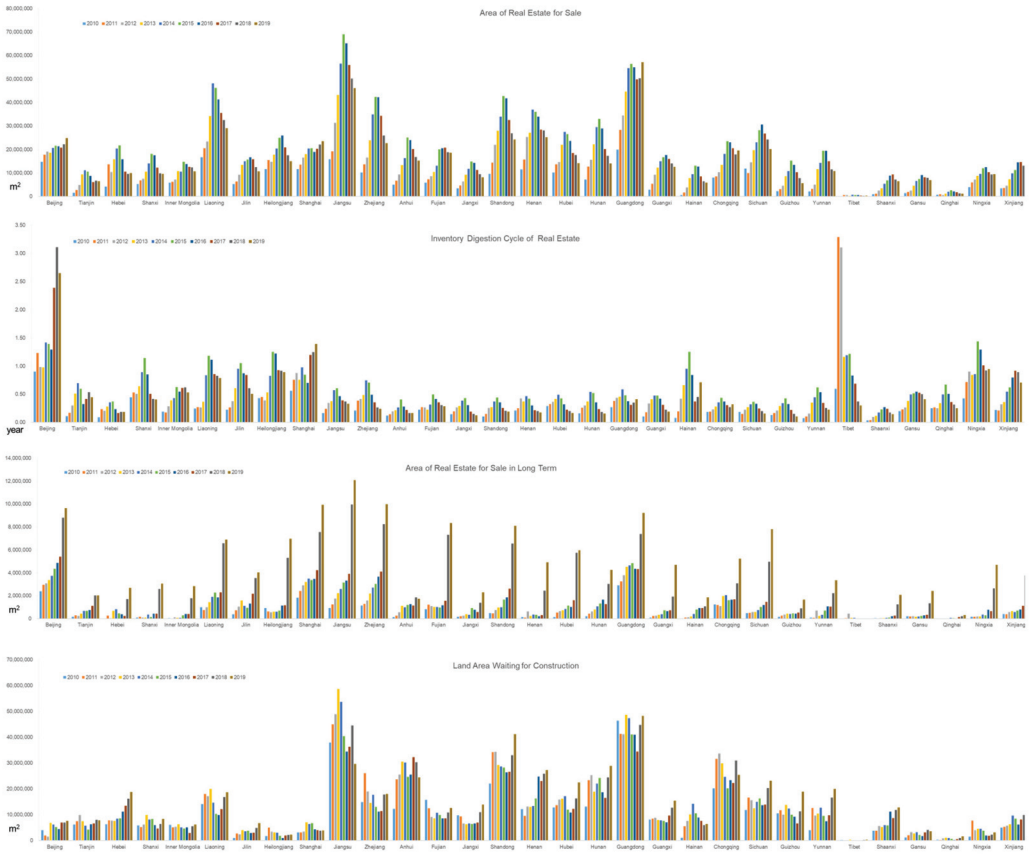

Figure 6. Analysis of the real estate inventory change from 2010 to 2019 in China.

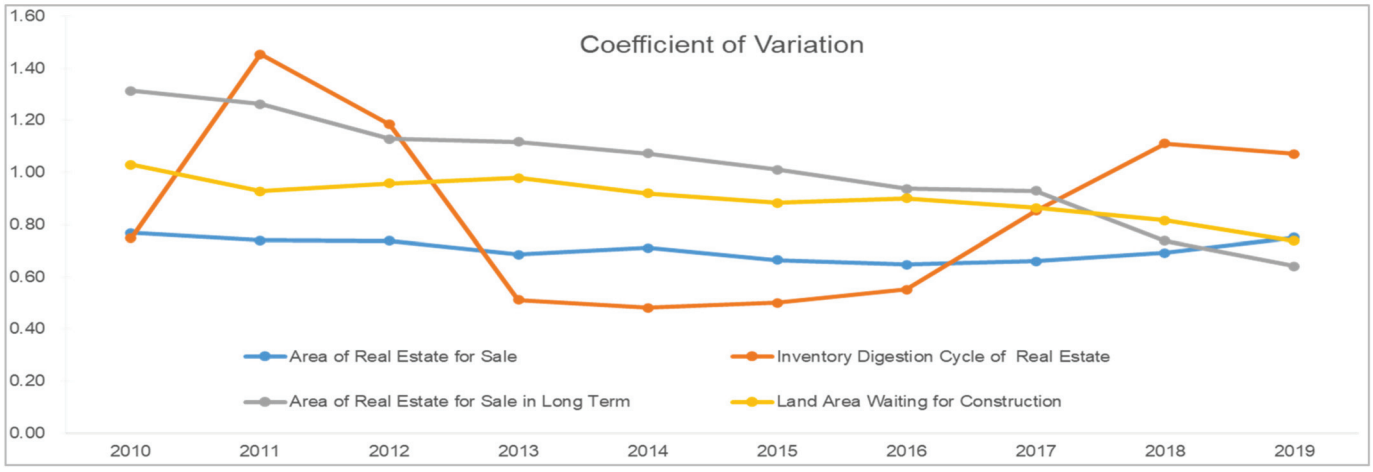

Figure 7. Analysis of the heterogeneity and convergence of the real estate inventory in China.

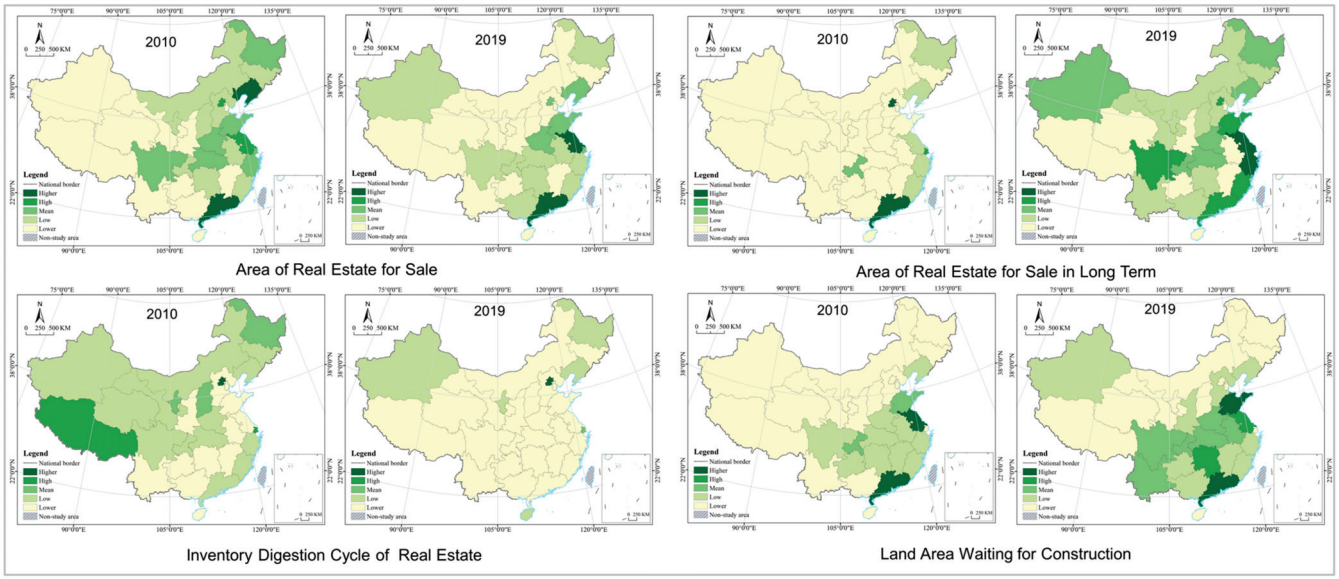

Figure 8. Analysis of the spatial difference in the real estate inventory in China.

From the perspective of Area of Real Estate for Sale in Long Term, Jiangsu, Shanghai, Zhejiang, Fujian, Shandong, Guangdong, Sichuan, Beijing, Liaoning, and Heilongjiang have the largest inventory, followed by Ningxia, Xinjiang, Chongqing, and Hubei, which have a larger one. Different from the Area of Real Estate for Sale, the Area of Real Estate for Sale in Long Term in provinces and cities across China except Tibet generally has enjoyed a rapid growth, especially in the last two years (Figure 6). The coefficient of variation was in a continuous decline from 2010 to 2019, but always over 0.36, indicating that the spatial inequality of long-term real estate inventory was very high with spatial convergence (Figure 7). In 2010, Beijing and Guangdong were at the Higher level; Shanghai was the only region at the High level; Chongqing was the only region at the Mean level; Heilongjiang, Liaoning, Jiangsu, Zhejiang, and Fujian were at the Low level; and most regions, such as Shandong, Hebei, Hainan, and Shanghai, were at the Lower level. In 2019, regions at the Higher level were Jiangsu, Shanghai, and Zhejiang; Beijing, Tianjin, Shandong, Sichuan, Fujian, and Guangdong were at the High level; regions at the Mean level expanded to Heilongjiang, Liaoning, Henan, Hubei, and Xinjiang; regions at the Low level expanded significantly with the coverage of Yunnan, Guangxi, Hunan, Gansu, Ningxia, Inner Mongolia, Shanxi, and Hebei; and regions at the Lower level shrank significantly to only Hainan, Jiangxi, Anhui, Beijing, Tianjin, Shaanxi, Qinghai, and Tibet (Figure 8).

From the perspective of Land Area Waiting for Construction, real estate enterprises in Jiangsu, Guangdong, Shandong, Anhui, and Chongqing have the largest area, followed by those in Henan, Hunan, Sichuan, Liaoning, Hubei, and Yunnan, which also have a large one. From 2010 to 2019, the undeveloped land area of real estate enterprises in provinces and cities of China showed a variety of changing forms, including a J-shaped change in Hebei, Jilin, Shaanxi, and Xinjiang, U-shaped change in Liaoning, Jiangxi, and Fujian, inverted U-shaped change in Hainan, Shanghai, and Jiangsu, and wave-shaped change in Tianjin, Shanghai, and Inner Mongolia (Figure 6). The coefficient of variation showed a slow decline from 2010 to 2019, but still remaining above 0.8, much larger than 0.36, indicating a very high spatial inequality of undeveloped land of real estate enterprises with spatial convergence (Figure 7). In 2010, Guangdong and Jiangsu were at the Higher level; no regions were at the High level; Shandong and Chongqing were at the Mean level; Liaoning, Zhejiang, Fujian, and Anhui were at the Low level; and most regions, such as Hainan, Guangxi, Yunnan, and Xinjiang, were at the Lower level. In 2019, regions of Higher level were Shandong and Guangdong; only Jiangsu and Hunan were

at the High level; regions at the Mean level expanded significantly with the coverage of Sichuan, Yunnan, and Hunan; and regions at the Lower level shrank slightly, but they were still highly concentrated (Figure 8).

In general, the spatio-temporal evolution of China's real estate inventory is characterized by the following features: in terms of the evolution trend, Area of Real Estate for Sale and Inventory Digestion Cycle of Real Estate shows an "inverted U-shaped" change; Area of Real Estate for Sale in Long Term is dominated by "J-shaped" growth; while Land Area Waiting for Construction has diversified trends, such as "J-shaped", "U-shaped" and "inverted U-shaped". In terms of spatial distribution, the spatial heterogeneity and agglomeration of real estate inventories in China are prominent, with provinces having large total inventories clustered mainly in the coastal and riverine (Yangtze) regions, especially Jiangsu, Guangdong, Shanghai, Zhejiang, and Fujian. It is worth noting that China has a long and lengthening real estate destocking period, with long-term real estate inventory growing rapidly over the past two years.

3.2. Performance and Obstacle Analysis

We calculated the real estate inventory management performance indexes of all provinces based on Equation (5) and averaged them to represent the general level of real estate inventory management performance in China (Table 2). The average real estate inventory management performance index in China in 2010 was 0.43, with the maximum being 0.65 (Shanghai) and the minimum being 0.34 (Tibet). According to the classification criteria, there are no geographical areas at the Lower and Higher real estate inventory management performance levels in China. In 2010, Guangdong and Shanghai were at the High level; regions at the Mean and Low levels were concentrated in a contiguous distribution; regions at the Mean level were mainly distributed in the eastern coast and central China, including Beijing, Tianjin, Shandong, Jiangsu, Zhejiang, Fujian, Hunan, Hubei, Jiangxi, Henan, Shaanxi, Shanxi, Inner Mongolia, and Sichuan; and regions at the Low level were mainly distributed northeast, northwest, and southwest China, including Heilongjiang, Liaoning, Jilin, Hebei, Xinjiang, Gansu, Qinghai, Yunnan, Guangxi, Guizhou, Hainan, and Anhui (Figure 9). The average real estate inventory management performance index decreased to 0.42 in 2019, with the maximum being 0.65 (Guangdong) and the minimum being 0.34 (Jilin). According to the classification criteria, there were still no regions at the Lower and Higher levels; only Guangdong and Shanghai were regions at the High level; regions at the Mean level shrank significantly, with a concentrated, contiguous distribution in coastal areas and some parts of central China; and regions at the Low level underwent further expansion, mainly distributed in northwest, northeast, and southwest China. From the perspective of changes in real estate inventory management level from 2010 to 2019, Tibet, Beijing, Hebei, Liaoning, Hubei, Fujian, Guangdong, and Guizhou had a significant increase; Tianjin, Shandong, Jilin, Sichuan, Shanghai, Inner Mongolia, Shanxi, Jiangsu, Zhejiang, Guangxi, Hainan, and Shaanxi showed a significantly decrease; and Anhui, Jiangxi, Chongqing, Yunnan, Gansu, and Xinjiang remained stable (Figure 10).

We calculated the obstacle degree of each index to real estate inventory management based on Equations (1) and (2), with the results listed in Tables A1 and A2. Since there are many factors in the evaluation index system of China's real estate inventory management level, this paper takes the indexes ranked in the top 5 obstacles as the critical factors. According to the different obstacle factors, the 31 provinces for 2010 were divided into three categories. The first category covers the widest geographical area, including Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, and Hunan. Their critical obstacle factors are New Construction Area of House, Building Construction Area of House, Completed Construction Area of House, Land Area Purchased by Real Estate Enterprises, and Area of Real Estate for Sale, reflecting the great impact of supply exceeding demand and historical inventory. The second category covers Hainan, Tibet, Shaanxi,

Qinghai, Ningxia, Xinjiang, Guizhou, Yunnan, and Gansu, mainly underdeveloped areas in western China. Their critical obstacle factors are Financial Revenue (or Per Capital GDP), Profits of Real Estate Enterprises, Total Retail Sales of Social Consumer Goods, Disposable Income of Urban Residents, and Loans Balance of Financial Institutions, which reflect the great impact of lagging economic development. The third category covers Guangdong, Guangxi, Chongqing and Sichuan, and their critical obstacle factors are complex (Table A1).

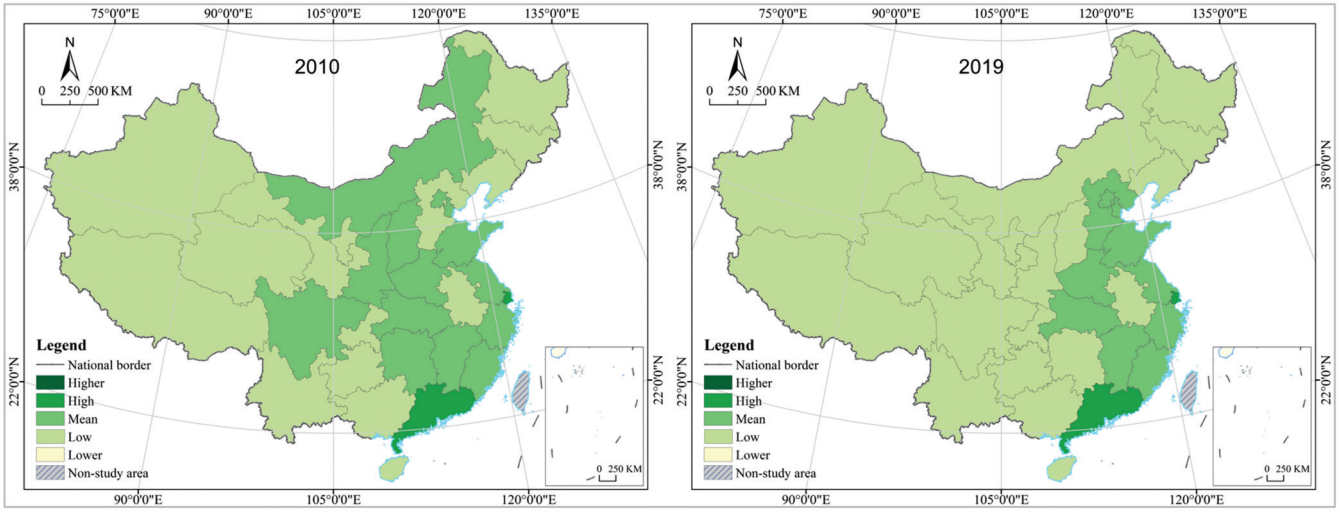

Figure 9. Analysis of the spatial difference in the real estate inventory management index in China.

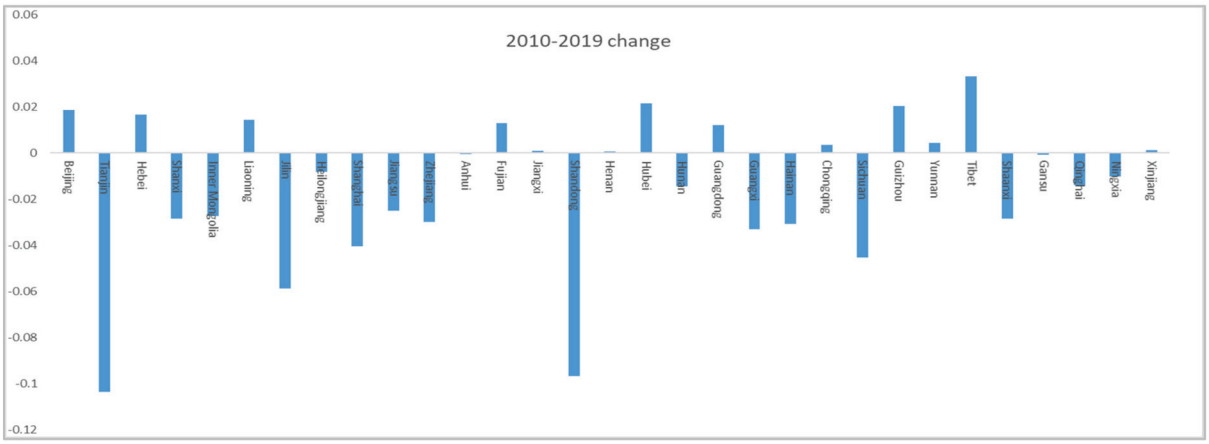

Figure 10. Analysis of the change in the real estate inventory management index in China.

Table 2. Performance evaluation of the real estate inventory management index in China.

		2010			2019		
Code	**Name**	**Index**	**Ranking**	**Light**	**Index**	**Ranking**	**Light**
1	Beijing	0.5456	5	Yellow	0.5641	26	Yellow
2	Tianjin	0.5276	6	Yellow	0.4238	29	Yellow
3	Hebei	0.3957	17	Orange	0.4122	25	Yellow
4	Shanxi	0.4057	14	Yellow	0.3772	27	Orange
5	Inner Mongolia	0.4257	11	Yellow	0.3982	13	Orange
6	Liaoning	0.3822	21	Orange	0.3966	23	Orange

Table 2. *Cont.*

		2010			2019		
Code	**Name**	**Index**	**Ranking**	**Light**	**Index**	**Ranking**	**Light**
7	Jilin	0.3954	18	Orange	0.3367	20	Orange
8	Heilongjiang	0.3806	22	Orange	0.3724	22	Orange
9	Shanghai	0.6519	1	Blue	0.6115	17	Blue
10	Jiangsu	0.5750	3	Yellow	0.5500	18	Yellow
11	Zhejiang	0.5569	4	Yellow	0.5270	28	Yellow
12	Anhui	0.3671	26	Orange	0.3666	30	Orange
13	Fujian	0.4391	8	Yellow	0.4521	1	Yellow
14	Jiangxi	0.4027	15	Yellow	0.4034	14	Yellow
15	Shandong	0.4992	7	Yellow	0.4025	7	Yellow
16	Henan	0.4025	16	Yellow	0.4031	11	Yellow
17	Hubei	0.4224	12	Yellow	0.4438	12	Yellow
18	Hunan	0.4130	13	Yellow	0.3984	10	Orange
19	Guangdong	0.6350	2	Blue	0.6470	6	Blue
20	Guangxi	0.3784	23	Orange	0.3454	24	Orange
21	Hainan	0.3852	19	Orange	0.3544	5	Orange
22	Chongqing	0.3835	20	Orange	0.3871	4	Orange
23	Sichuan	0.4340	9	Yellow	0.3885	2	Orange
24	Guizhou	0.3520	30	Orange	0.3724	21	Orange
25	Yunnan	0.3717	25	Orange	0.3759	31	Orange
26	Tibet	0.3351	31	Orange	0.3683	16	Orange
27	Shaanxi	0.4277	10	Yellow	0.3991	15	Orange
28	Gansu	0.3572	27	Orange	0.3563	19	Orange
29	Qinghai	0.3759	24	Orange	0.3618	9	Orange
30	Ningxia	0.3566	28	Orange	0.3462	8	Orange
31	Xinjiang	0.3563	29	Orange	0.3576	3	Orange

The 31 provinces and cities for 2019 can be divided into five categories, with significant geographical differentiation and increasingly complex obstacle factors. The division is based on the commonness and dissimilarity of the obstacle factors. The first category covers Hebei, Shanxi, Jilin, Jiangxi, Anhui, Henan, Hubei, Hunan, Sichuan, Guizhou, and Yunnan. Their obstacle factors are Financial Revenue, Profits of Real Estate Enterprises, Per Capital GDP, Disposable Income of Urban Residents, and Loans Balance of Financial Institutions. The obstacle factors are reflected in the process of declining economic growth and structural transformation, in which the government's reliance on land finance and companies' pursuit of profits are coupled, resulting in a real estate supply that exceeds demand and does not match the current stage of industrialization, the size of the population, nor its income level. The second category covers Hainan, Tibet, Shaanxi, Qinghai, Ningxia, and Xinjiang, mainly the less developed areas in western China. Their critical obstacle factors include Financial Revenue, Profits of Real Estate Enterprises, Total Retail Sales of Social Consumer Goods, Disposable Income of Urban Residents, and Loans Balance of Financial Institutions. The difference with the first category is that consumption power has replaced the level of industrialization. The third category covers Liaoning, Heilongjiang, Shandong, Guangxi, Gansu, and Inner Mongolia. Their critical obstacle factors are Financial Revenue, Profits of Real Estate Enterprises, and Disposable Income of Urban

Residents, supplemented by Per Capita GDP and Total Retail Sales of Social Consumer Goods. The fourth category covers Fujian, Chongqing, Beijing, Tianjin, and Shanghai. Their critical obstacle factors are Financial Revenue, Profits of Real Estate Enterprises and Gross Domestic Product, supplemented by Total Retail Sales of Social Consumer Goods and Loans Balance of Financial Institutes. The fifth category covers Jiangsu, Zhejiang, and Guangdong, and their critical barrier factors have a complex composition and are significantly different from those of other geographic regions (Table A2).

The evolution of China's real estate inventory management performance generally shows the following characteristics. In terms of index changes, the real estate inventory management performance in China is at a low level with a downward trend. In terms of performance types, regions at the higher and lower levels never appear, regions at the high level remain unchanged, regions at the mean level are spatially clustered but cover a significantly contracted territory, and regions at the low level areas are rapidly expanding. In terms of the obstacle degree, the barrier factors of different regions vary widely and are becoming more complicated, especially the differentiation between coastal and western regions is becoming more significant. The historical inventory is the primary constraint for the eastern region, while the lower level of economic development is the biggest obstacle and challenge of destocking in the western region.

4. Discussion

4.1. Influence Factor

With the average obstacle degree of each province and city representing the overall obstacle degree of China's real estate inventory management, and based on the comprehensive analysis of the calculated results, we can find that Profits of Real Estate Enterprises, Disposable Income of Urban Residents, Financial Revenue, Per Capita GDP, Resident Population, Gross Domestic Product, Total Retail Sales of Social Consumer Goods, Financial Expense, and Loans Balance of Financial Institutions are critical obstacle factors (Figure 11). Changes in the obstacle degree of each factor were significantly differentiated from 2010 to 2019. Specifically, Profits of Real Estate Enterprises, Area of Real Estate for Sale in Long Term, Disposable Income of Urban Residents, Financial Revenue, and Per Capita GDP had a further increase as obstacles, while GDP Growth Rate, GDP Growth Rate, Land Area Purchased by Real Estate Enterprises, Urbanization Rate of Population, Investment of Real Estate Enterprises, and Number of Real Estate Enterprises had a decline, with the rest of the factors remaining stable.

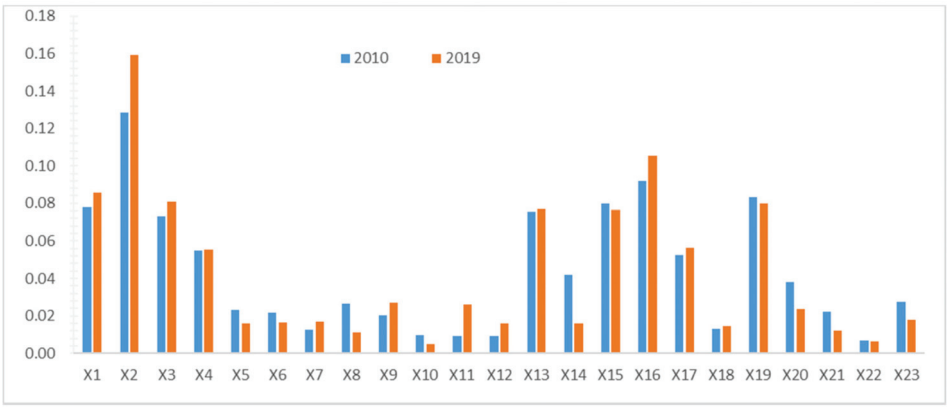

Figure 11. Obstacle factor analysis of China's real estate inventory management from 2010 to 2019.

Some of the findings of the study support certain viewpoints of the existing papers. Zhao [118] conducted an empirical study based on GeoDetector and data from 35 key cities in China, finding that the factors influencing real estate inventories in Chinese cities are becoming increasingly diverse, with real estate market competition intensity, population size, government support, and social consumption vitality level having the strongest influence on inventories, and that different factors show the interaction between bifactor enhancement and non-linear enhancement, and the driving mechanism is becoming increasingly complex. Shen [119] analyzed the panel data of 35 key cities in China of 2004–2014, arguing that land supply has a significant positive impact on real estate destocking. Based on spatial autoregressive models and principal component analysis, Barreca [120] concluded that community services and retail activity have a large and positive impact on real estate inventory levels. Li [121] and Hoekstra [122] argued that population size, especially population structure, has a huge impact on the real estate markets in China and the Netherlands, and that the size of urban real estate inventories will further expand in the future as the population ages and the number of empty nesters increases. Wang [123], Hui [124], and Coskun [125] believed that real estate drags down the social consumption vitality in China and OECD countries (Organization for Economic Co-operation and Development), and significantly squeezes household consumption. Besides, some empirical results in this paper are inconsistent with the findings of existing studies, and they can be considered as an important addition to the theory of real estate inventory management as a new finding. For example, Cai [126] and Hidalgo [127] argued that real estate is closely associated with urbanization development, but this paper finds no significant connection between the population urbanization rate and real estate destocking. The obvious success of China's household registration system reform in recent years may be an important reason for that. Wu [128] argued that the Chinese real estate market is not experiencing oversupply, and it is clear that this paper does not support this view. Such a discrepancy may stem from differences in the timing of the study and the selection of indexes.

Influenced by multiple factors such as government policies, corporate sales strategies, and residents' house purchasing behaviors, the housing price is in a very complex relationship with inventories in China. Lazear [129] believed that there is a reverse correlation between real estate inventory and price, and a high housing price is the key factor affecting destocking, but the empirical results of this paper indicates that the housing price has no significant impact on inventory management. In other words, the housing price is not the critical obstacle to real estate destocking, and it is hard to achieve the destocking target by enforcing a lower housing price. There are two possible reasons to explain it: first, China's housing prices are highly influenced by government and policy interventions, especially in recent years when the central and local governments have executed vigorous regulation and control over the real estate market; and second, there is a long-standing abnormal relationship between housing prices and real estate sales in China, and residents buy houses "when the prices are going up instead of going down", which further leads to the complicated relationship between housing prices and inventory. To get a refined view on the relationship between the two, specialized empirical studies are needed in the future.

There are also some deficiencies in our research, which may affect the accuracy and applicability of some research conclusions in this paper. For example, in recent years, Chinese governments at all levels have intensively issued a series of real estate market development and governance policies, which have exerted a great impact on inventory management [130]. However, due to the difficulties in data acquisition and quantification, they are not included in the index system of this paper.

4.2. Policy Suggestion

Due to the huge scale and significant spatial variation in China's real estate inventory, as well as the increasingly diverse and complex factors influencing inventory management, real estate destocking policies must be tailored to local conditions and a "one-size-fits-all" approach should not be allowed. The first step is to find out the real situation of the real estate market and get acquainted with the inventory quantity, inventory structure, inventory distribution, and companies with high inventory pressure in each province. The second step is that the central government should delegate more autonomy to local governments, so that they can formulate and implement differentiated real estate destocking policies according to local social and economic foundations and different development stages. The third step is to design differentiated policies based on the real conditions of supply and demand in the real estate market, focusing on coordinating the short-term and long-term goals of destocking, direct and indirect forces, and administrative and market means, so as to steadily improve the performance level of inventory management.

From the perspective of destocking goals, it is necessary to take into account and connect the relationship between short-term tactical objectives and long-term strategic objectives. The near-term goal is to achieve sustainable development of the real estate market, so it is required to control the investment scale and improve corporate profits, encourage mergers and acquisitions of real estate enterprises, improve industry concentration, and enhance the destocking capacity and financial risk tolerance of real estate enterprises. For example, tighten the financial support policies in the investment field of real estate enterprises, and moderately relax the conditions of residents' house purchase loans. The long-term goal is to reduce the risks posed to the financial and economic system by high real estate inventories, so the government must take reasonable measures to accelerate economic development, increase GDP per capita, and promote high-quality industrialization and urbanization [131]. For example, reduce the proportion of real estate investment in urban investment, promote the decoupling between urban financial (or GDP) growth and real estate, and gradually resolve the dependence of urban economy on real estate.

We should note that the high inventory of real estate in China is not only a market economy phenomenon but also an issue involving politics and economics. The government plays a vital role in generating and clearing up the inventory of real estate. With its monopoly on urban land supply and over-reliance on "land finance", the Chinese government has long adopted a land grant model similar to that of Hong Kong; i.e., restricting land supply to drive up land prices, resulting in structural imbalances in the real estate market. The coexistence of a high inventory and high housing price has become a popular phenomenon in China's urban real estate market. From the results of obstacle degree analysis in the section above, government financial input and bank credit policy are significant and even critical obstacle factors in Shaanxi, Inner Mongolia, Qinghai, Ningxia, Tibet, Hainan, and Guizhou; the structure and scale of land supply also play a remarkable constraining role in Jiangsu, Zhejiang, Shandong, Guangdong, and Sichuan. Therefore, local and city governments must develop and implement destocking policies according to their local conditions. The first is to accelerate the reform of the government's land supply system, for first- and second-tier cities and developed regions, to moderately expand the scale of land supply, while tightening the real estate supply in third- and fourth-tier cities and western regions. The second is to update the real estate purchase restriction policy; specifically, to standardize the purchase restriction policy in the first- and second-tier cities and keep it stable to prevent speculation caused by policy fluctuations. The third is to remove the house purchase quota policy in the third- and fourth-tier cities and less developed regions that are under great pressure to reduce inventory, and encourage purchasing houses and settling. The fourth is to reform financially, especially real estate credit-related policies, specifically for third- and fourth-tier cities and less developed regions with high real estate inventory pressure, to

raise the share of housing provident fund loans, promote off-site loans, increase the loan amount, extend the loan term, relax the withdrawal conditions, reduce taxes, provide deed subsidies, reduce the down payment and interest rates, and make a rational use of financial leverage to meet and activate potential demand, to rebalance the market supply and demand; on the contrary, for the first- and second-tier cities and developed regions to strictly control speculative demand. The fifth is to change the government's financial investment mode, increase investment in urban construction in third- and fourth-tier cities and less developed regions, and prioritize the strengthening of urban hardware facilities and the software environment, such as transportation, education, medical care, leisure, entertainment, culture, and security, to enhance the attractiveness to the population, and in turn to stimulate the demand for home ownership and achieve sustainable development of the real estate market.

From the perspective of destocking forces, the roles of direct and indirect driving forces should be integrated. It has been indicated in the previous section that population size, residents' income level, and corporate profits are the critical obstacles affecting inventory management. Therefore, taking reasonable measures to improve the agglomeration, attractiveness, and carrying capacity of cities for the population should become a priority for the government in real estate destocking [132]. In addition, to improve the income and consumption ability of urban residents, to increase the supervision and regulation of the real estate market, to control the profitability of the industry and real estate prices, and to reduce the impulse of the society and the market to blindly invest in real estate are all relevant tasks that should not be ignored in real estate inventory management.

From the perspective of destocking measures, the government and market forces should be integrated, starting from both the supply side and demand side. Bao [133], Wang [134], Deng [135], Han [136], Jin [137], and Agunbiade [138] et al. analyzed the connection between supply-side land reserves, land finance, and real estate development, indirectly suggesting that land finance and land supply reform are the keys to destocking. This paper also finds that fiscal revenue and land supply are the critical obstacles to inventory management, showing that promoting the reform of land supply and financial system should be the core work of the government in the process of destocking [139], such as scientific preparation of annual plans for land supply, mastering the timing of land supply, controlling the scale of land supply, reducing "raw land" sales, and preventing excessive land allocation to reduce real estate inventory from the beginning [140,141]. Moreover, on the demand side, the influence of per capita GDP and GDP on real estate inventory management is increasing, which enlightens the government to take reasonable measures to improve the driving force of economic development, especially to promote industrialization, guide population agglomeration with industrial development, and create real estate consumption demand, thereby indirectly driving real estate destocking, and realizing the rebalancing of real estate market development.

5. Conclusions

Inventories of varying degrees can be found in real estate markets at present around the world, so it is of great theoretical and practical importance to reasonably evaluate inventory management performance and reveal its critical obstacle factors. With the help of the DPSIR framework, we constructed a real estate inventory management performance evaluation and obstacle diagnosis model based on multidimensional influence factors such as economic, social, and environmental elements, and conducted an empirical study on 31 provinces and cities in China, finding that the scale of real estate inventory in China is huge with significant spatial heterogeneity and agglomeration, the inventory management performance is unsatisfactory for a long time, the inter-provincial differences are large, and the inventory management barrier factors are becoming increasingly diversified and complex. Therefore, we propose the development of differentiated and precise response strategies based on the knowledge of the actual supply and demand in

the real estate market and the integration of near-term and long-term goals, direct and indirect forces, and administrative and market instruments.

From a theoretical perspective, this study provides a new research framework and methodology for researchers in real estate economics, land management, human geography, spatial economics, and spatial planning, which facilitates revealing the patterns of real estate inventory management and its governance mechanisms [142].The current characteristics of an inventory are the core of real estate inventory management, but not all, and must be extended to the front end, focusing on the drive to create inventory and the pressure; and extended to the back end, considering the behavior of enterprises and governments in the face of inventory, as they are the key segments in the inventory management that should not be ignored. Past studies have been concerned only with inventory status evaluation, ignoring the front-end and back-end segments. The innovation of this paper is to incorporate the causes of inventory, current status, and response initiatives into a holistic framework, achieving a comprehensive study with full front-end–middle-end–back-end coverage. From a practical perspective, this paper analyzes the development trends and evolution laws of China's real estate inventory, as well as the performance evaluation, obstacle diagnosis, and coping strategies of inventory management, which is helpful for policy makers and decision makers to find a scientific and reasonable real estate inventory governance model and provides the necessary decision basis for government management and policy regulation [143]. The research methods and findings of this paper are not only applicable to China but also can be used as a reference for decision making to solve the real estate inventory management problems in the United States, India, Japan, Mexico, Germany, the United Kingdom, Italy, and other countries.

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

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Data Availability Statement: The data used in this study mainly come from the China Statistical Yearbook and the China Real Estate Statistical Yearbook. Most of the data can be obtained by visiting the following links: http://www.stats.gov.cn/tjsj/ndsj/, https://data.cnki.net/yearbook/Single/N2021010050 (accessed on 11 June 2021).

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

Appendix A

Table A1. Obstacle factor analysis of China's real estate inventory management in 2010.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
Beijing	0.09	0.22	0.00	0.10	0.00	0.01	0.01	0.00	0.01	0.04	0.06	0.01	0.10	0.02	0.10	0.00	0.07	0.01	0.08	0.00	0.01	0.05	0.01
Tianjin	0.10	0.18	0.07	0.08	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.10	0.03	0.10	0.09	0.07	0.01	0.09	0.00	0.01	0.01	0.01
Hebei	0.08	0.18	0.10	0.03	0.02	0.02	0.01	0.01	0.02	0.00	0.01	0.02	0.07	0.01	0.08	0.12	0.05	0.01	0.08	0.03	0.01	0.00	0.02
Shanxi	0.09	0.17	0.10	0.06	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.09	0.02	0.09	0.12	0.06	0.00	0.09	0.02	0.00	0.00	0.01
Inner Mongolia	0.10	0.18	0.08	0.07	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.09	0.03	0.10	0.10	0.06	0.01	0.10	0.02	0.00	0.00	0.01
Liaoning	0.09	0.17	0.09	0.06	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.02	0.08	0.02	0.08	0.11	0.06	0.00	0.08	0.02	0.01	0.00	0.01
Jilin	0.09	0.16	0.09	0.06	0.00	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.09	0.04	0.09	0.12	0.06	0.01	0.09	0.02	0.00	0.00	0.01
Heilongjiang	0.10	0.17	0.10	0.06	0.00	0.01	0.01	0.00	0.01	0.01	0.03	0.00	0.09	0.03	0.09	0.13	0.06	0.01	0.06	0.02	0.00	0.00	0.01
Shanghai	0.08	0.18	0.01	0.11	0.01	0.01	0.02	0.00	0.01	0.02	0.07	0.01	0.11	0.03	0.11	0.00	0.07	0.01	0.07	0.00	0.02	0.04	0.02
Jiangsu	0.05	0.12	0.05	0.04	0.04	0.05	0.06	0.03	0.08	0.00	0.07	0.04	0.01	0.02	0.02	0.10	0.03	0.06	0.03	0.02	0.04	0.01	0.04
Zhejiang	0.06	0.15	0.06	0.06	0.03	0.03	0.03	0.03	0.05	0.00	0.06	0.02	0.06	0.02	0.05	0.05	0.05	0.03	0.04	0.02	0.03	0.01	0.04
Anhui	0.08	0.14	0.09	0.04	0.02	0.02	0.03	0.04	0.04	0.00	0.01	0.02	0.07	0.01	0.06	0.11	0.05	0.04	0.08	0.03	0.02	0.00	0.02
Fujian	0.10	0.16	0.05	0.06	0.01	0.02	0.02	0.01	0.03	0.00	0.04	0.01	0.07	0.01	0.07	0.10	0.07	0.01	0.09	0.02	0.02	0.01	0.02
Jiangxi	0.09	0.16	0.10	0.05	0.01	0.01	0.01	0.01	0.03	0.00	0.01	0.01	0.08	0.00	0.08	0.12	0.06	0.02	0.09	0.03	0.01	0.00	0.01
Shandong	0.06	0.15	0.08	0.01	0.05	0.04	0.05	0.04	0.06	0.00	0.04	0.04	0.04	0.02	0.03	0.10	0.03	0.03	0.06	0.02	0.02	0.00	0.04
Henan	0.08	0.14	0.09	0.01	0.03	0.03	0.03	0.01	0.06	0.00	0.02	0.03	0.05	0.01	0.05	0.13	0.04	0.01	0.08	0.03	0.02	0.00	0.04
Hubei	0.09	0.15	0.08	0.05	0.02	0.02	0.01	0.01	0.04	0.00	0.03	0.02	0.07	0.01	0.06	0.12	0.05	0.02	0.09	0.03	0.01	0.00	0.02
Hunan	0.09	0.16	0.09	0.04	0.02	0.02	0.02	0.02	0.04	0.00	0.02	0.03	0.07	0.01	0.07	0.11	0.05	0.01	0.08	0.03	0.01	0.00	0.02
Guangdong	0.00	0.00	0.10	0.00	0.06	0.08	0.08	0.03	0.11	0.01	0.07	0.08	0.00	0.03	0.00	0.14	0.00	0.04	0.00	0.02	0.07	0.02	0.08
Guangxi	0.09	0.16	0.09	0.05	0.01	0.01	0.01	0.01	0.03	0.00	0.02	0.01	0.08	0.02	0.08	0.11	0.05	0.02	0.08	0.03	0.01	0.00	0.01
Hainan	0.10	0.16	0.09	0.08	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.10	0.02	0.10	0.11	0.07	0.00	0.10	0.02	0.00	0.01	0.01
Chongqing	0.09	0.14	0.07	0.06	0.01	0.01	0.02	0.01	0.03	0.00	0.02	0.02	0.08	0.02	0.08	0.11	0.06	0.02	0.09	0.02	0.01	0.00	0.01
Sichuan	0.08	0.15	0.09	0.02	0.03	0.03	0.02	0.01	0.06	0.00	0.04	0.02	0.06	0.01	0.05	0.12	0.04	0.04	0.07	0.03	0.02	0.00	0.02
Guizhou	0.09	0.17	0.10	0.06	0.01	0.01	0.00	0.01	0.02	0.00	0.01	0.02	0.09	0.00	0.09	0.12	0.06	0.00	0.09	0.03	0.01	0.00	0.01
Yunnan	0.09	0.17	0.10	0.05	0.02	0.01	0.01	0.01	0.02	0.00	0.01	0.02	0.08	0.00	0.08	0.11	0.05	0.01	0.09	0.03	0.01	0.00	0.01
Tibet	0.11	0.17	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.11	0.07	0.00	0.10	0.05	0.00	0.00	0.00
Shaanxi	0.09	0.17	0.08	0.06	0.01	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.08	0.02	0.08	0.12	0.06	0.01	0.09	0.02	0.01	0.00	0.01
Gansu	0.10	0.17	0.10	0.06	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.09	0.02	0.09	0.12	0.06	0.01	0.09	0.03	0.00	0.00	0.01
Qinghai	0.11	0.17	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.10	0.12	0.08	0.00	0.10	0.03	0.00	0.00	0.00
Ningxia	0.10	0.17	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.10	0.01	0.10	0.11	0.08	0.00	0.10	0.02	0.00	0.00	0.00
Xinjiang	0.09	0.17	0.09	0.06	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.09	0.02	0.09	0.12	0.06	0.01	0.10	0.03	0.00	0.00	0.01

Table A2. Obstacle factor analysis of China's real estate inventory management in 2019.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
Beijing	0.07	0.09	0.00	0.10	0.02	0.02	0.01	0.02	0.01	0.05	0.04	0.00	0.10	0.09	0.09	0.02	0.06	0.01	0.07	0.00	0.05	0.04	0.04
Tianjin	0.10	0.17	0.01	0.10	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.01	0.11	0.00	0.12	0.06	0.09	0.01	0.11	0.01	0.01	0.02	0.01
Hebei	0.08	0.14	0.08	0.03	0.04	0.03	0.02	0.06	0.02	0.00	0.00	0.00	0.06	0.05	0.07	0.10	0.04	0.01	0.08	0.04	0.03	0.00	0.03
Shanxi	0.09	0.16	0.08	0.06	0.01	0.01	0.01	0.02	0.01	0.02	0.00	0.00	0.09	0.03	0.09	0.11	0.06	0.00	0.10	0.04	0.01	0.00	0.02
Inner Mongolia	0.09	0.14	0.05	0.07	0.03	0.02	0.01	0.04	0.02	0.01	0.00	0.00	0.08	0.02	0.09	0.10	0.06	0.00	0.10	0.03	0.01	0.00	0.02
Liaoning	0.06	0.12	0.06	0.05	0.05	0.04	0.02	0.06	0.04	0.01	0.01	0.01	0.06	0.03	0.06	0.09	0.04	0.03	0.07	0.03	0.04	0.00	0.04
Jilin	0.09	0.15	0.07	0.06	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.09	0.03	0.09	0.11	0.06	0.01	0.10	0.03	0.01	0.00	0.01
Heilongjiang	0.09	0.14	0.08	0.05	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.00	0.08	0.04	0.08	0.11	0.05	0.01	0.10	0.03	0.01	0.00	0.02
Shanghai	0.07	0.00	0.00	0.12	0.02	0.03	0.01	0.01	0.02	0.04	0.04	0.00	0.11	0.12	0.12	0.00	0.06	0.02	0.06	0.00	0.04	0.05	0.05
Jiangsu	0.01	0.05	0.06	0.03	0.08	0.07	0.05	0.05	0.07	0.01	0.02	0.04	0.01	0.06	0.03	0.08	0.01	0.06	0.00	0.04	0.07	0.01	0.07
Zhejiang	0.06	0.09	0.06	0.06	0.04	0.05	0.02	0.05	0.03	0.01	0.02	0.02	0.06	0.07	0.06	0.04	0.05	0.03	0.01	0.04	0.05	0.02	0.07
Anhui	0.08	0.13	0.09	0.04	0.03	0.02	0.01	0.04	0.02	0.00	0.00	0.01	0.07	0.03	0.08	0.10	0.05	0.02	0.09	0.04	0.03	0.00	0.03
Fujian	0.09	0.14	0.07	0.06	0.02	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.08	0.04	0.08	0.07	0.07	0.01	0.09	0.03	0.02	0.01	0.03
Jiangxi	0.09	0.15	0.09	0.05	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.08	0.03	0.09	0.11	0.06	0.00	0.10	0.04	0.01	0.00	0.02
Shandong	0.05	0.13	0.07	0.01	0.06	0.05	0.03	0.06	0.06	0.00	0.01	0.02	0.02	0.06	0.02	0.09	0.03	0.02	0.05	0.05	0.05	0.00	0.06
Henan	0.07	0.14	0.09	0.01	0.03	0.03	0.02	0.05	0.03	0.01	0.00	0.01	0.05	0.05	0.06	0.10	0.03	0.01	0.08	0.05	0.03	0.00	0.04
Hubei	0.09	0.14	0.08	0.04	0.02	0.02	0.01	0.03	0.02	0.01	0.00	0.01	0.07	0.03	0.07	0.11	0.05	0.02	0.09	0.04	0.02	0.00	0.03
Hunan	0.08	0.15	0.09	0.03	0.03	0.02	0.01	0.02	0.02	0.01	0.00	0.01	0.07	0.03	0.07	0.10	0.05	0.01	0.09	0.05	0.02	0.00	0.03
Guangdong	0.00	0.06	0.09	0.00	0.06	0.07	0.04	0.05	0.06	0.02	0.06	0.06	0.00	0.08	0.00	0.09	0.00	0.03	0.01	0.04	0.07	0.02	0.09
Guangxi	0.09	0.14	0.09	0.05	0.02	0.02	0.01	0.02	0.01	0.00	0.00	0.01	0.08	0.03	0.09	0.09	0.06	0.02	0.09	0.05	0.01	0.00	0.03
Hainan	0.10	0.14	0.09	0.08	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.10	0.01	0.10	0.10	0.08	0.00	0.11	0.04	0.01	0.01	0.00
Chongqing	0.08	0.13	0.08	0.06	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.09	0.00	0.09	0.09	0.06	0.01	0.09	0.03	0.02	0.00	0.02
Sichuan	0.07	0.13	0.10	0.02	0.03	0.03	0.02	0.02	0.04	0.01	0.01	0.01	0.07	0.02	0.07	0.11	0.02	0.02	0.08	0.05	0.03	0.00	0.04
Guizhou	0.09	0.13	0.10	0.05	0.01	0.01	0.00	0.02	0.01	0.00	0.00	0.01	0.09	0.04	0.09	0.11	0.06	0.00	0.10	0.05	0.01	0.00	0.01
Yunnan	0.08	0.14	0.10	0.05	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.09	0.05	0.09	0.10	0.05	0.02	0.09	0.05	0.01	0.00	0.02
Tibet	0.10	0.14	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.09	0.04	0.10	0.10	0.07	0.00	0.11	0.06	0.00	0.00	0.00
Shaanxi	0.09	0.15	0.09	0.06	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.09	0.03	0.09	0.11	0.06	0.01	0.10	0.04	0.01	0.00	0.01
Gansu	0.09	0.15	0.09	0.06	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.09	0.05	0.09	0.11	0.06	0.00	0.10	0.05	0.00	0.00	0.01
Qinghai	0.10	0.15	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.10	0.02	0.10	0.11	0.08	0.00	0.11	0.04	0.00	0.00	0.00
Ningxia	0.10	0.15	0.08	0.08	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.09	0.04	0.10	0.10	0.08	0.00	0.10	0.04	0.00	0.00	0.00
Xinjiang	0.09	0.14	0.08	0.07	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.09	0.06	0.09	0.11	0.06	0.00	0.10	0.04	0.00	0.00	0.01

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