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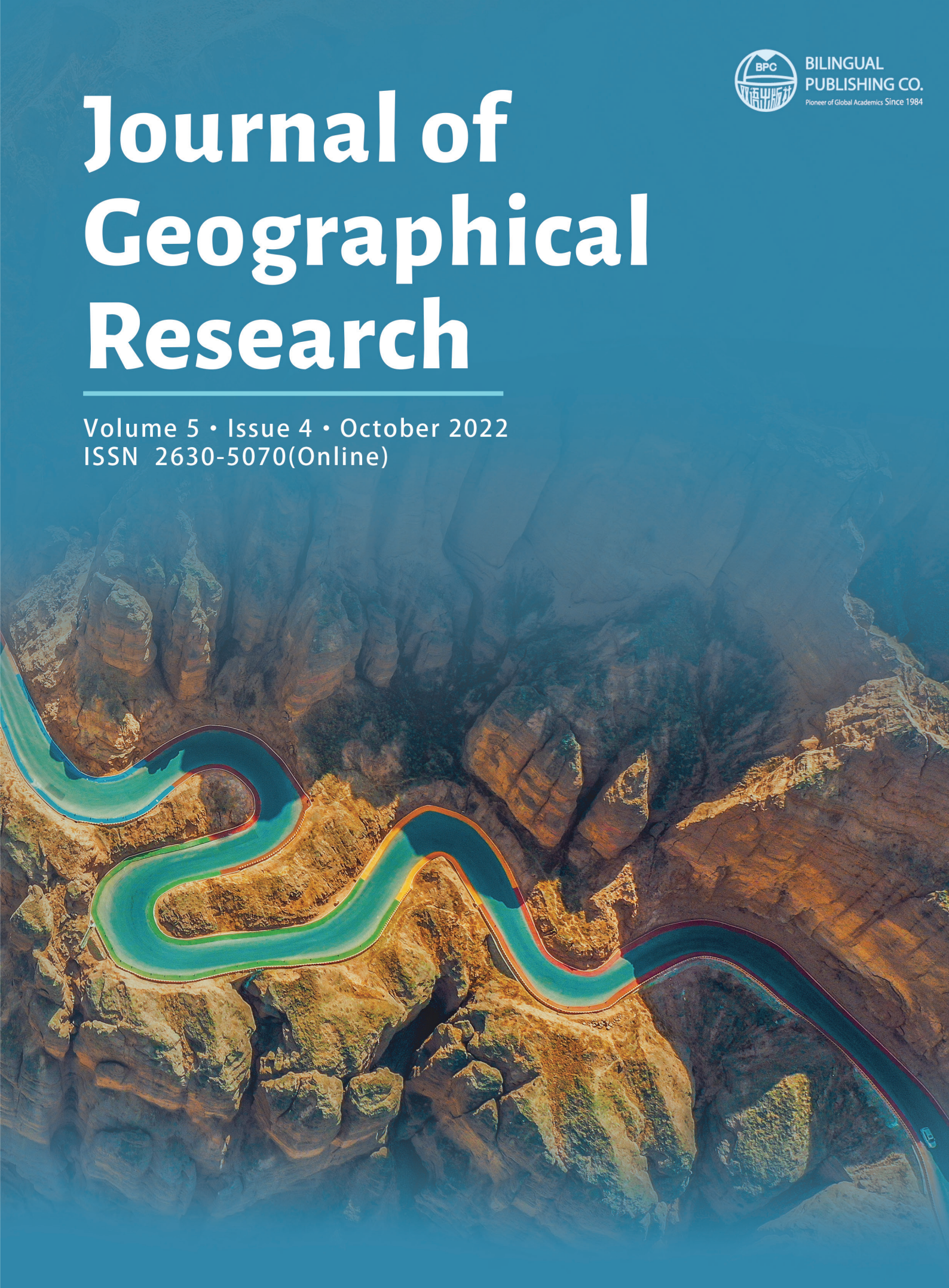

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ARTICLE

What Influences The Family Migration Decision of China's New Generation Rural-urban Migrants? A Multilevel Logistic Regression Analysis

Meiling Hou[1,2] Xiaoyan Zhou[1*] Ronghao Jiang[3]

1. School of Resource and Environmental Sciences, Wuhan University, Wuhan, Hubei, 430079, China
2. Power China Urban Planning & Design Institute Company Limited, Guangzhou, Guangdong, 511458, China
3. Department of Geography, The University of Hong Kong, Hong Kong, 999077, China

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ABSTRACT

The massive scale of new-generation rural-urban migrants in China has attracted extensive scholarly attention in recent years. While previous studies on China's rural migrant workers focus on migrants' settlement intentions, migrants' family migration decision-making and the intergenerational differences between the old-generation migrants and new-generation migrants are underexplored. Based on the data of the 2017 China Migrants Dynamic Survey, this paper adopts a multilevel logistic regression approach to explore family and destination factors influencing the family migration decisions of China's new generation of rural migrant workers. The empirical results reveal that both the migrants' family and destination attributes significantly influence their family migration decision. The demographic and socioeconomic characteristics of the family have been pivotal factors underlying the family migration decision of China's new generation rural-urban migrants, while 16.9% of the chances are explained by between-destination differences. Self-employed migrants with housing properties in host cities, long migration duration and high-income levels are more likely to migrate with their family members. Yet, the possibility of family migration is found to be significantly and negatively correlated with the age, education level, number of children and inter-provincial mobility of the new generation of migrant workers. In addition, new-generation rural-urban migrants' family migration is more likely to be found in cities with service-oriented industry structures, better environmental quality, and higher *hukou* barriers which is possibly related to more job opportunities. These research findings not only complement the existing literature on China's new generation of rural urban migrants, but also have important policy implications for reforming *the hukou* system and enhancing social integration of the rural-to-urban migrant population.

*Corresponding Author:
Xiaoyan Zhou,
School of Resource and Environmental Sciences, Wuhan University, Wuhan, Hubei, 430079, China;
Email: zhouxiaoyan@whu.edu.cn

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1. Introduction

Migration studies have long focused on individual migration which is often motivated by human capital development and economic considerations [1-3]. Compared with the extensive research on the determinants of individual migration across regions, relatively less scholarly attention seems to be paid to the issues of migrants' family migrations [4-6]. To our best knowledge, until recently, a burgeoning body of literature started to highlight the importance of family and identified how family factors influence migrants' decisions [7-9]. From the existing studies, it can be seen that higher income, a better life for family members and family reunification in the destinations are usually the main incentives of those migrants no matter which country they come from [10,11]. This gave rise to a worldwide heated discussion on social integration, identities and migration. Family migration has been a significant issue on the political agendas of many countries [12,13].

Rural-to-urban migration in a developing country has also been one of the central topics investigated in population geography and migrant studies [14-16]. The last three decades have witnessed an unprecedented wave of rural-to-urban migration in China, which has been the keystone of China's rapid economic development and urbanization. This ever-expanding wave of internal migration in China has attracted much attention from both academic researchers and policymakers. Meanwhile, in the past ten years, the new generation of migrant workers has become the major force of rural-to-urban migration in China. New-generation migrant① workers are rural-to-urban migrants who were born after 1980, including but not limited to the offspring of former migrants. The 'post-80s' migrants are found to be more skilled and educated, and prefer to work in the service and manufacturing sectors instead of the construction industry [17]. As China's urbanization further advances and regional differences increase, the new-generation rural migrants (NGRMs) have a strong desire to settle in urban destinations. Remarkably, an increasing number of married NGRMs migrated with their family members to seek better social welfare for their whole households [18,19]. This indicates that family migration has become a prominent mode of new-generation rural-to-urban migration in China.

In the past few years, realizing social discontent caused by the development model of land-based urbanization, the Chinese central government has gradually put forward the "people-oriented urbanization" strategy that highlights and enhances inclusiveness, social equality and life quality among urban residents. One of the critical parts of this "people-oriented urbanization" policy has been to progressively release the household registration (*hukou*) restriction in cities and designated towns.② NGRMs are given priority to acquire local *hukou* in their urban destinations, which enables them to migrate to the cities they prefer with comparative freedom and based on the needs of their families. In this case, cities may need to transform how they operate to manage the pressures of people coming in. Therefore, it is critical for academic scholars and policymakers to understand the determinants of the family migration decision of NGRMs, known as the major migrant labor force in urbanizing China, so that appropriate migration measures can be carried out.

Much of the literature concerns the intergenerational difference between the old generation and the new generation of rural migrants, investigating NGRMs' career development, social integration and self-identity in their urban life [20-22]. Compared to the old generation, NGRMs are eager to be recognized as urban residents and to find a the sense of belonging in their adopted cities [20]. A steady job with satisfaction and fulfillment is an important way to realize this desire [21]. A small but increasing number of scholars have also attempted to reveal the determinants of NGRM's settlement intention [23-25]. However, attention has been so overwhelmingly paid to the individual permanent settlement intention of NGRM that it obscures the role played by the demographic and socioeconomic characteristics of family and the behaviours of the family settlement.

Meanwhile, a growing number of studies have paid efforts to explore the underlying factors that influence the family migration decision of China's rural-to-urban migrants [26-28]. Most of these studies have treated China's rural-to-urban migrants as a homogeneous and uniform group, while little is known about migrants' internal heterogeneity. While the NGRMs have emerged to constitute a large proportion of the current rural-to-urban migrant population in Chinese cities, studies focusing on the nature

① In the Western literature on migrant studies, 'new generation migrants' refer to migrants who were born in host countries or migrated to host countries at a young age [61,62].

② Since the 2020 China's New Urbanization Document was released, Chinese government has lifted up the *hukou* restriction of cities where urban residence population is less than 3 million, with permission for the access of stable and legal home and employment to *hukou* acquirement for migrants. For cities with population above 3 million, the government has released the *hukou* restriction on the new-generation rural migrants and other migrants who have lived in the city for above 5 years and migrated with their family. Most cities like Dalian, Jinan and Changsha have deregulated. But some better-developed cities located in the central or coastal region like Wuhan, Xiamen and Dongguan, still request for long duration of stay and home ownership. Those cities who have been implementing the credit system for *hukou* acquisition assessment also lower the credit threshold.

and dynamics of the family migration decision of China's NGRMs have been very limited until recent years. As there are remarkable differences between the first-generation migrants and new-generation migrants in their socio-economic characteristics, the dynamics of NGRMs' family migration decision cannot be gleaned from the existing migrant studies which are largely generalized from the experience of the old-generation rural-to-urban migrants.

Based on the sample data of the China Migrants Dynamic Survey in 2017, which involved 43,165 samples and 253 prefecture-level cities, we develop a multilevel logistic model to examine the factors influencing NGRMs' family migration decisions through the family and destination perspectives. We hope to contribute to the existing literature on China's rural-to-urban migrants by empirically exploring the determinants of NGRMs' family migration decisions and associating family and destination factors with NGRMs' intention of urban settlement. We attempt to address a series of questions that remain significant both theoretically and empirically. Can any particular characteristics of NGRMs be identified? What are the family factors that are responsible for NGRMs' family migration decision-making? What are the destination factors underlying NGRMs' family migration decision-making? What are the differences between the old generation and the new generation in terms of family migration decisions? Answering these questions provides a useful complement for empirical research in the literature on NGRMs and new insights into NGRMs' permanent urban settlement as well as China's high-quality urbanization.

The article is organized as follows. The next section reviews the relevant literature on family migration. Section 3 introduces the data source and methods. Section 4 presents the results of our empirical estimation and the robust checks. The final section concludes the major research findings and discusses the important implications.

2. Literature Review

Family is built up of individuals. Previous studies of family migration have divided family migration into two aspects: One is migrating process in the way of one-step moving or moving in batches [7,18], and the other is the completion of family migration and reunion in the destination [26]. We focus on the latter. Although family migration is not the same as a permanent settlement, it can still impact the migrants' settlement intention positively, increasing the possibility of permanent settlement [19].

To date, a growing number of studies have highlighted the influence of factors that are associated with family migration. A family migration decision is a rational and synthesized decision based on multiple conditions in terms of the whole household [29]. Hence we cannot ignore the impact of family factors. Meanwhile, one major approach in early migration studies emphasized economic incentives behind the migration decision [30]. Based on human capital theory, this approach regarded migrant settlement as a process to maximize the value of human capital and economic benefits [31-33]. in particular, education, including formal school learning and vocational training, is an essential part of human capital. Owing to the requirement for degrees from job openings in cities, well-educated migrants are more likely to get employed and attain high income, which promotes their family members' accompanying migration [34]. It is worth mentioning that rural migrants highly value children's education, but the opportunities and costs of attending school in the destination city are closely related to their local *hukou* acquirement [35]. Moreover, the longer stay that migrants have in the urban destinations, the more human capital they will cultivate, which increases the possibility of their family settlement [36]. Distance is also demonstrated as an important factor [37]. Compared with inter-provincial migration, intra-provincial migration is easier for the migrants to cultivate human capital because of the similarity of local language and socio-cultural context within the same regions [38,39].

In China, early rural migrants suffered from serious institutional discrimination in the host cities and could not get employed in the formal sectors due to their rural *hukou*. Many of them chose to work in the informal sectors or became self-employed [40]. As China's urbanization further advanced, an increasing number of rural migrants started to set up their family-owned businesses, such as small stalls and small- and medium-sized firms [41]. It has been noted that self-employed rural migrants can prolong business hours to obtain higher income, which finances their family settlement [42,43]. In addition, housing is considered a major necessity for family settlement. Research reveals that the ownership of rural housing land can influence the urban settlement intention of migrants because of the existing economic and emotional attachment [24], while urban home ownership can contribute to their family migration [44,45].

The *hukou* restriction and unfair access to local public service make destination factors a study focus in the recent literature on family migration decisions in China [46]. Rural-to-urban migrants fail to acquire the same public service and welfare like health insurance, children's elementary education and public housing as residents. Migrants' family migrations are thus discouraged. Existing research proves that the mechanism of destination factors is complex [47]. Migrants tend to move to cities with a higher proportion of non-agricultural industry and greater expected income levels for better employment and career

development opportunities [23,47,48]. A few studies also show that public service provisions such as an abundant supply of elementary education and high environmental quality also encourage migration [27,49-51].

With the successive retirement of the old generation of rural migrants in the last decade, NGRMs, born after 1980, become the major rural-to-urban group and the main urban workforce [17,52]. They show a series of intergenerational differences in economic and social characteristics, which causes concerns from Chinese scholars and policymakers. It has been argued that, compared to the old generation, NGRMs have higher education, careful attention to employment and career, limited farming experiences, and strong aspirations toward urban lifestyles [17,52]. These characteristics may facilitate their family migration and drive them to settle in the host cities. When it comes to policy, since 2016 the Chinese central government has released a circular to urge the necessity for plans to grant *hukou* to the existing 100 million rural migrants with steady jobs, especially NGRMs. This offers NGRMs relatively more choices for the permanent urban dsetinations. All these imply that the determinants of family migration decisions of NGRMs may differ from those of the old generation. But still, the literature on this aspect suffers from a lack of empirical support. We believe that a comprehensive investigation on the determinants of family migration decision of NGRMs will not only help better understand the adjustment and compromise of family migration decisions of Chinese rural-to-urban migrants in the changing social and political context, but also act as useful guides for both Chinese central and local government to make better people-oriented urbanization policies and to steer NGRMs to reasonable family migration and settlement.

This article contributes to the growing body of literature on China's new generation of rural-to-urban migration on two fronts. First, aimed at complementing the lack of studies on the family migration decisions of NGRMs, we explicitly tested the influence of family and destination factors on the family migration decisions of NGRMs. Second, in methodological terms, many previous studies on the determinants of family migration and settlement have been based on frequently-used logistics models which ignores the estimation bias of multilevel data [46,53]. Therefore, we proposed a multilevel logistic model to carry out the test, which we believe will help tackle the bias issue.

3. Data and Methodology

3.1 Data and Variables

China Migrants Dynamic Survey is yearly conducted by China's National Health Commission, using probability proportionate to size sampling. Migrants are defined as those who have been living in their host city for above a month without local *hukou*. The 2017 survey included nearly 170,000 respondents aged above 15.78% of which hold rural *hukou*. In this research, NGRM refers to a married migrant who was born after 1980, received senior high school education or below and had rural *hukou*. Urban socio-economic data of destination cities in 2016 are collected from the 2017 China City Statistical Yearbook. Considering the availability and integrity of a sample and city-level data, we deleted samples whose city only had less than 10 valid samples. We finally selected 43,165 samples from 253 prefecture-level cities. In this study, family refers to the nuclear family [18]. We define the dependent variable of family migration decision as a dummy variable (*Family migration*), which equals 1 if a migrant lives in the urban destination with his spouse and at least 1 underage child (childless couples are also involved), and 0 otherwise.

Following the previous literature, we selected 9 explanatory variables in the family perspective and 5 variables in the destination perspective to explore what are the influences of all these factors. Table 1 shows the definitions and summary statistics of the variables. Among the family factors, we include *Age*, *Years of schooling*, *Number of children*, *Duration of stay*, *Inter-provincial mobility*, *Self-employment*, *Rural housing land*, *Homeownership* and *Income*. *Age*, *Years of schooling*, *Duration of stay* and *Inter-provincial mobility* can promote and reflect the accumulation of human and social capital in the destination and contribute to the economic integration of the migrant following the migration of their family members. Particularly, *Inter-provincial mobility* is set to study the effect of the migration distance which has an impact on migrants' migration cost and social integration [54]. Previous studies display that intra-provincial migration can help reduce costs. Compared with inter-provincial migration, intra-provincial migration is easier for the migrant to cultivate human capital because of the similarity of local language and socio-cultural context within the same province. The *Number of children* measures the household size of migrants' family and can reflect the migration cost that the family suffers from. Since the group of self-employed rural migrants is sizeable, the dummy variable *Self-employment* is added to test if there are differences between the self-employed and the employed. *Rural housing land* and *Homeownership* are also dummy variables to measure the influences of rural housing land and urban home ownership on family migration decisions.

When it comes to the destination factors, we include *Economy*, *Industry*, *Elementary education*, *Environment*

quality and *Hukou threshold*. We include *Economy* and *Industry* to capture a destination city's economic development level and opportunities in the labor market. *Elementary education* and *Environment quality* are set to measure the supply of elementary education and the provision of public green areas. Married migrants are proven to be concerned with the availability and quality of elementary education for their underage children [53]. Due to China's *hukou* system, access to elementary education is closely related to the local *hukou*. The children of migrant workers thus do not have equal access to elementary education compared with those of the local urban residents. Therefore, children's elementary education is often considered an important factor influencing rural-to-urban migrants' migration decisions in the existing literature. The *Hukou threshold* refers to the extent of household registration restriction and the threshold of *hukou* acquisition in the destination city. As found in Liu and Xi's work [46], cities with greater *hukou* registration restrictions tend to discourage migrants' family migration decisions.

3.2 Descriptive Analysis

Figure 1 shows that the ratio of family migration of the selected respondents has maintained continuously above 70% in recent years. This proves the distinct tendency towards family migration in the NGRM group. Table 2 presents the descriptive analysis of our variables. Most selected respondents have one or two underage children. More than half of the samples have only received middle school education, and owned rural housing land in their rural registered place. According to *2020 China's New Urbanization Plan* published by China's State Council, migrants living in the current destination for 5 years or above are thought to be permanent residents and will be given priority in the urban *hukou* acquisition. Results show that 54.9% of NGRMs have lived in their current destination for below 5 years. Those who migrate inter-provincially and got employed account for more than 50% of the selected respondents. Only 16.2% of respondents possessed home ownership in their host cities. After we divided the respondents into 5 groups by their income listed in order from low to high, we found that nearly a half of the respondents fell into the middle-income and low-income group. To sum up, most of NGRMs have small-size families, attain low education, and migrate inter-provincially. Also, the majority of them still own rural housing land, stay in the host cities for less than 5 years and do not obtain high income or house ownership in their urban destinations. Working for employers is the major way for them to access a job in the host cities.

Table 1. Variables included in the multilevel models

Variable	Definition	Mean	SD
Dependent variable			
Family migration	1 for family migration and 0 otherwise	0.70	0.456
Family (householder) characteristics			
Age	Years	30.60	4.077
Years of schooling	Respondent's educational attainment (0 for uneducated experience, 6 for primary school, 9 for junior middle school, 12 for senior high school or technical secondary school)	9.54	1.987
Number of children	Respondents' number of children whose age < 18	1.36	0.715
Duration of stay	Years (in the host city)	5.14	4.488
Inter-provincial mobility	1 for inter-provincial mobility and 0 otherwise	0.51	0.500
Self-employment	1 for if self-employed	0.31	0.464
Rural housing land	1 for having residential land in the rural village	0.70	0.459
Home ownership	1 for owning estates in the host city	0.16	0.368
Income	Family monthly income (yuan)	7354.19	5071.998
Destination characteristics			
Economy	GDP per capita	68949.33	40847.552
Industry	Ratio of GDP of tertiary industry to GDP of secondary industry	1.22	0.677
Elementary education	Number of teachers for every 100 pupils	5.70	1.221
Environmental quality	Public green areas for every 100 residents	0.10	0.083
Hukou threshold	Ratio of residence population to registered population	1.16	0.681

Source: 2017 data of China Migrants Dynamic Survey and 2016 China City Statistical Yearbook.

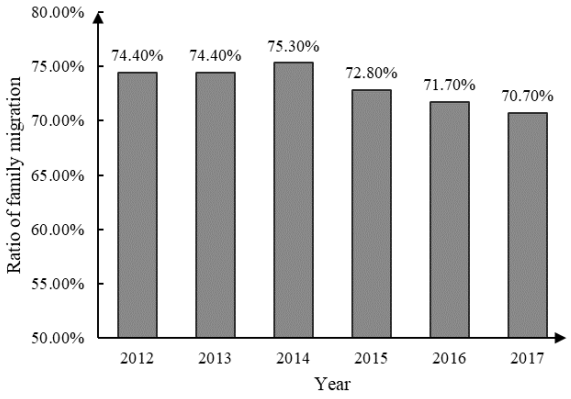

Figure 1. Ratio of family migration of the married new-generation Chinese rural migrant respondents during the period from 2012 to 2017

3.3 Method

A standard logistic regression model cannot be used in a multilevel data structure where participants are nested in clusters (cities) because this violates the fundamental assumption of independence of the residuals in the linear model [55]. In this research, respondents nested in the same city are interdependent and more likely to act in the same way than those nested in various cities. A multilevel logistic model can tackle this bias issue of multilevel data effectively compared to the frequently-used standard logistic model [35,56]. Multilevel logistic models can be divided into 3 model purposes. Here we use a null model to examine whether there are between-destination differences in family migration decisions. The random coefficients regression model is used to select family variables whose $p<0.05$ and examine whether there are between-destination differences in the estimation results of the family variables. We use a full model to estimate the whole influences of family and destination variables. These 3 models are listed as follows.

(1) Null model

$$\text{Level 1: } \text{logistic}\{\text{Prob}(Y_{ij}=1|X)\}=\beta_{0j} \quad (1)$$

$$\text{Level 2: } \beta_{0j}=\gamma_{00}+\mu_{0j} \quad (2)$$

(2) Random coefficients regression model

$$\text{Level 1: } \text{logistic}\{\text{Prob}(Y_{ij}=1|X)\}=\beta_{0j}+\beta_{kj}X_{kij} \quad (3)$$

$$\text{Level 2: } \beta_{0j}=\gamma_{00}+\mu_{0j} \quad (4)$$

$$\beta_{kj}=\gamma_{k0}+\mu_{kj} \quad (5)$$

(3) Full model

$$\text{Level 1: } \text{logistic}\{\text{Prob}(Y_{ij}=1|X)\}=\beta_{0j}+\beta_{kj}X_{kij} \quad (6)$$

Table 2. Profiles of the married second-generation Chinese rural migrant respondents

Householder characteristics	Respondents (%)	Ratio of family migration (%)	Householder characteristics	Respondents (%)	Ratio of family migration (%)
Number of children			Rural housing land		
Childless family	9.4	80.7	1	69.8	68.7
1	49.2	68.4	0	30.2	74.5
2	37.5	70.8	Self-employment		
3 or above	3.9	68.0	1	31.3	75.5
Age			0	68.7	68.2
Born before 1990	75.7	69.9	Home ownership		
Born after 1990	24.3	72.1	1	16.2	76.2
Years of schooling			0	83.8	69.3
0	0.9	76.2	Income		
6	9.2	71.3	Low income	20.1	69.4
9	60.0	70.3	Lower-middle income	20.1	72.8
12	29.9	70.3	Middle income	22.9	70.6
Mobility			Upper-middle income	26.7	67.7
Inter-provincial mobility	51.1	65.1	High income	10.2	74.6
Intra-provincial mobility	48.9	76.1			
Duration of stay					
< 5 years	54.9	66.2			
≥ 5 years	45.1	75.6			

Notes: Householder characteristics are defined in Table 1.

Level 2: $\beta_{0j}=\gamma_{00}+\gamma_{0m}W_{mj}+\mu_{0j}$ (7)

$$\beta_{kj}=\gamma_{k0}+\gamma_{km}W_{mj}+\mu_{kj} \quad (8)$$

The respondents are indexed by the subscript i (Level 1), and the destinations are indexed by the subscript j (Level 2).

Y_{ij}, a binary dependent variable, represents the family migration decision.

In Level 1, X_{Kij} represents variables of respondent i, and k means their numbers.

β_{oj} and β_{kj} respectively represent the intercept and slope of the clusters comprised of respondents from the same destination j.

In Level 2, W_{mj} represents variables of destination j, and m means their numbers.

γ_{00} and γ_{K0} are intercept and slope of Level 2.

γ_{0m} and γ_{k0} are slopes that connect the intercept and slope of Level 1 with W_{mj} of Level 2.

μ_{0j} and μ_{kj} are residuals of Level 2.

4. Empirical Findings

4.1 Null Model

We first run a null model to find out the extent to which the odds that the family migration decisions equalled 1 rather than 0 varied from one destination to another, and calculated the intraclass correlation coefficient (ICC). ICC>0.059 indicates a applicable multilevel logistic model and its ICC can be calculated as the formula $ICC=Var(U_0)/[Var(U_0)+\pi^2/3]$, in which $Var(U_0)$ is the between-cluster variance. In this research, $Var(U_0)=0.669$, $ICC=0.169$, means that 16.9% of the odds of a family migration decision was explained by between-destination differences. Therefore, it is appropriate to use multilevel models to estimate the determinants of family migration decisions, which includes both the family factors and the socioeconomic characteristics of host cities.

4.2 Random Coefficients Regression Model

After the z-score standardization, we employ the random coefficients regression model. Table 3 presents the estimation results. It is found that the self-employed NGRMs are more likely to migrate with their family members. This may be because self-employment is a more financially rewarding option for most rural migrants, and an initiative and rational decision based on the interest of their families [57]. Meanwhile, the possibility of NGRMs' family migration tends to be higher if they own a housing property in the host cities. House purchasing is a way to acquire local *hukou* and accompany public goods [58]. Also, it indicates that the NGRMs' family has a considerable amount of money to afford houses in cities. NGRMs with a longer length of migration and a higher income level at the host locations are found to be more willing to migrate with their family members. These characteristics will help NGRMs cultivate social capital and financial capital and prepare for their families' migration.

However, *Age*, *Years of schooling*, *Number of children* and *Inter-provincial mobility* is significantly and negatively associated with NGRMs' family migration. Small families are proven to be easier to migrate and unite in the destination cities [59]. A long distance away from their hometowns and diverse socio-cultural environments may not help the migrants integrate into the local community, which discourages them from bringing spouses and children to the host cities. The negative impact of *Age* is possibly caused by the intergenerational differences [17]. Younger NGRMs may accept and be used to the urban lifestyle, while some older NGRMs are kind of closer to the old generation in their attachment to their hometowns. For the negative effect of migrants' education, it may be the fact that those who have few school years would immigrate to cities to find a job due to the lack of farming experience, which could help them accumulate human and social capital in an early time and help with the following migration of family members.

The variable of *Rural housing land* does not have a significant impact (p=0.284) on the family migration decision and *Rural housing land* would be deleted in the following full model. In fact, because of the early urban working experience and the lack of farming experience, NGRMs show a weaker connection with their original villages. Although rural residential land becomes an economic insurance for first-generation migrant workers after their retirement, it does not work on NGRMs. On the contrary, home ownership in the host cities can improve the attractiveness of NGRMs in the marriage market and increase their household wealth with housing appreciation [45]. In addition, the result of variance component testing can show whether the outcome of family attributes variables varies from destination to destination. We found that all family attributes variables had passed the significance test ($p<0.01$) except *Years of schooling*, which happened before the migration of NGRMs. This means that the outcome of family variables varied from host city to host city and it is necessary to build Level 2 model for revealing the influence of destination variables.

Table 3. Results of the random coefficients regression model

Variable	Coeff.	Variance component testing	
		Variance Components	Chi-square
Inter-provincial mobility	–0.114** (0.031)	0.131**	288.794
Rural housing land	–0.027 (0.025)	0.048**	277.585
Self-employment	0.362*** (0.033)	0.169***	372.037
Home ownership	0.086* (0.042)	0.314***	403.995
Number of children	–0.030* (0.015)	0.034***	406.491
Age	–0.047** (0.014)	0.022**	293.471
Years of schooling	–0.024* (0.010)	0.007	213.885
Duration of stay	0.168*** (0.017)	0.054***	487.564
Income	0.118*** (0.014)	0.036***	320.298
Intercept	0.758*** (0.053)	0.864***	701.513

Notes: All numbers in parentheses are robust standard errors. ***, ** and * represent statistical significance at the 0.001, 0.01 and 0.05, respectively. Results are based on the calculation of the software HLM 6.08. Variables are defined in Table 1.

4.3 Full Model

Following the results above, we added the family variables (except *Rural housing land*) to Level 1 and destination variables to Level 2 in the full model. The full model of multilevel model not only estimates the outcomes of family variables and destination variables respectively, but also reflects the interaction between them. If the coefficients of these two variables are consistent (both plus or both minus), the interaction results of family migration decisions will be intensified by the consistent effects, otherwise, it will be weakened.

The column whole samples (1) in Table 4 shows the result of the full model. The estimations coincided with the result of Section 4.2. In terms of destination factor variables, *Industry*, *Environmental quality* and *Hukou threshold* had a significantly positive impact on the family migration decision of NGRMs, while *Economy* and *Elementary education* did not influence significantly. The positive influence of *Industry* and *Environmental quality* has been proved in previous studies [27,48,51]. Developed tertiary industries warrant more job opportunities in service sectors for both low-skilled and high-skilled migrants. Meanwhile, environmental quality can significantly influence the health of migrants and their children. The married NGRMs are more concerned with the environmental quality in their destination cities when making family migration decision. But the positive effects of *hukou threshold* found in this research seems to contradict the existing studies [46]. Thereby we will have a further test in the following part.

When the significance level is 0.05 and we look at the interactions of variables, we found that the *Economy* intensified the positive impact of *Duration of stay*. *Industry* and *Environmental quality* respectively intensified the positive impact of *Income*. These indicate that a city with a developed tertiary industry and more green areas tend to retain more NGRMs and their families, especially those who can afford the cost of living. The *Hukou threshold* intensified the negative impact of *Inter-provincial mobility* and the positive impact of *Self-employment*, and weakened the positive impact of *Homeownership* and *Duration of stay*. Although the *Hukou threshold* shows a positive impact in this study, it remains a critical institutional barrier for NGRMs to settle down in cities, whether they can afford the house in the destination city or not. For self-employed migrants, it seems that *hukou* could not limit their work, but still public welfare like medical insurance related to the local urban *hukou* is inaccessible.

Table 4. Results of the full models of multilevel logistic models of family migration decision

Variable	Whole samples (1)	Eastern group	Central group	West group	Whole samples (2)
For *Intercept 1* β_{oj}					
Intercept γ_{00}	0.732*** (0.050)	0.817*** (0.070)	0.684*** (0.090)	0.867*** (0.079)	0.713*** (0.078)
Economy	0.062 (0.060)	0.039 (0.068)	0.149 (0.173)	0.150 (0.126)	0.024 (0.066)
Industry	0.089* (0.042)	0.081 (0.070)	0.069 (0.099)	0.119 (0.084)	0.074 (0.040)
Elementary education	0.035 (0.057)	–0.226** (0.067)	0.195* (0.074)	0.027 (0.081)	0.049 (0.056)
Environmental quality	0.208** (0.066)	0.016 (0.070)	0.174 (0.187)	0.139* (0.070)	0.222** (0.066)
Hukou threshold	0.119*** (0.028)	–0.021 (0.038)	0.179* (0.073)	0.090 (0.159)	0.128*** (0.029)
City size (refer to *Small city*)					
Megacity					–0.231 (0.185)
Large city	No	No	No	No	0.260* (0.120)
Medium-size city					–0.115 (0.130)
For *Inter-provincial mobility*					
Intercept	–0.120** (0.035)	–0.312*** (0.050)	–0.067 (0.049)		–0.204** (0.061)
Economy	–0.017 (0.035)				–0.025 (0.043)
Industry	–0.018 (0.029)				–0.009 (0.028)
Elementary education	0.035 (0.041)				0.052 (0.041)
Environmental quality	–0.068 (0.038)				–0.071 (0.038)
Hukou threshold	–0.077** (0.022)				–0.077** (0.021)
For *Rural housing land*					
Intercept		–0.079 (0.063)			
Economy		–0.111* (0.052)			
Industry		0.042 (0.024)			
Elementary education		0.148* (0.074)			
Environmental quality		0.099 (0.054)			
Hukou threshold		0.142*** (0.031)			
For *Self-employment*					
Intercept	0.381*** (0.034)	0.470*** (0.062)	0.430*** (0.071)	0.185*** (0.043)	0.419*** (0.058)
Economy	–0.151*** (0.036)	–0.111* (0.056)	–0.080 (0.123)		–0.127** (0.042)

Table 4 continued

Variable	Whole samples (1)	Eastern group	Central group	West group	Whole samples (2)
Industry	–0.047* (0.022)	–0.072* (0.033)	–0.056 (0.072)		–0.042 (0.022)
Elementary education	–0.038 (0.039)	0.030 (0.058)	–0.100 (0.079)		–0.047 (0.040)
Environmental quality	–0.022 (0.027)	0.043 (0.069)	–0.318* (0.147)		–0.026 (0.029)
Hukou threshold	0.148*** (0.029)	0.291*** (0.060)	–0.033 (0.063)		0.155*** (0.034)
For *Home ownership*					
Intercept	0.100* (0.044)		0.250** (0.079)		0.201* (0.079)
Economy	0.075 (0.046)		–0.200 (0.136)		0.136* (0.057)
Industry	–0.100** (0.031)		–0.136 (0.088)		–0.084** (0.032)
Elementary education	–0.027 (0.045)		0.001 (0.073)		–0.026 (0.047)
Environmental quality	–0.080* (0.031)		0.328 (0.179)		–0.088* (0.036)
Hukou threshold	–0.060* (0.025)		0.000 (0.071)		–0.046 (0.030)
For *Number of children*					
Intercept	–0.019 (0.015)	–0.038 (0.030)			0.010 (0.031)
Economy	–0.065** (0.019)	–0.101** (0.033)			–0.051* (0.023)
Industry	–0.014 (0.010)	–0.014 (0.020)			–0.012 (0.011)
Elementary education	–0.008 (0.018)	0.059 (0.037)			–0.014 (0.018)
Environmental quality	0.012 (0.022)	0.047 (0.035)			0.011 (0.021)
Hukou threshold	0.006 (0.013)	0.009 (0.022)			0.010 (0.011)
For *Age*					
Intercept	–0.031* (0.015)	–0.057 (0.030)		–0.056* (0.023)	–0.056* (0.026)
Economy	–0.078*** (0.016)	–0.063** (0.023)			–0.093*** (0.021)
Industry	–0.024* (0.011)	–0.032* (0.016)			–0.028* (0.011)
Elementary education	0.011 (0.015)	–0.003 (0.031)			0.017 (0.016)
Environmental quality	0.058*** (0.010)	0.109*** (0.024)			0.061*** (0.010)
Hukou threshold	0.027 (0.015)	0.072*** (0.015)			0.023 (0.017)
For *Years of schooling*					
Intercept	–0.021* (0.010)		–0.034* (0.017)	–0.071** (0.019)	–0.021* (0.010)
Economy					
Industry					
Elementary education					

Table 4 continued

Variable	Whole samples (1)	Eastern group	Central group	West group	Whole samples (2)
Environmental quality					
Hukou threshold					
For *Duration of stay*					
Intercept	0.162*** (0.019)	0.257*** (0.032)	0.184*** (0.036)	0.099** (0.034)	0.207*** (0.033)
Economy	0.066** (0.020)	0.075** (0.025)	–0.079 (0.073)	–0.055* (0.024)	0.102*** (0.025)
Industry	0.007 (0.012)	–0.020 (0.013)	–0.011 (0.035)	0.002 (0.015)	0.018 (0.012)
Elementary education	–0.025 (0.017)	0.032 (0.027)	-0.072* (0.029)	0.052* (0.024)	–0.031 (0.018)
Environmental quality	–0.069*** (0.017)	–0.088** (0.032)	0.132 (0.099)	–0.024 (0.022)	–0.070*** (0.018)
Hukou threshold	–0.036** (0.012)	–0.096*** (0.018)	0.066 (0.038)	–0.004 (0.023)	–0.020 (0.014)
For *Income*					
Intercept	0.111*** (0.017)	0.114** (0.034)	0.137*** (0.025)	0.057* (0.026)	0.120*** (0.028)
Economy	–0.008 (0.015)	0.034 (0.030)		0.011 (0.030)	–0.022 (0.019)
Industry	0.022* (0.010)	0.028* (0.013)		0.008 (0.019)	0.016 (0.010)
Elementary education	–0.030 (0.018)	–0.075** (0.028)		0.005 (0.027)	–0.032 (0.019)
Environmental quality	0.034* (0.014)	0.075* (0.034)		0.040** (0.014)	0.041** (0.013)
Hukou threshold	–0.026 (0.014)	–0.084* (0.035)		–0.032 (0.020)	–0.035* (0.015)
Observations	43165	20000	9795	13370	43165
Cities	253	82	89	82	253
Between-cluster variance	0.669	0.362	0.770	0.773	0.669
ICC	0.169	0.100	0.190	0.190	0.169

Notes: All numbers in parentheses are robust standard errors. ***, ** and * represent statistical significance at the 0.001, 0.01 and 0.05, respectively. Results are based on the calculation of the software HLM 6.08. Variables are defined in Table 1. For each family variable (X_{kij}), there are 1 intercept (γ_{k0}) and 5 destination variables (W_{mj}) in its Level 2 equation (Equations 7-8). The fact that the cells are vacant means the corresponding variables are not added into the full model for their results of the random coefficients regression models. In the column Whole samples (2), City size variables are also added into Level 2, but here we do not present their results of Level 2 due to the limited space.

4.4 Robust Check

Given the regional difference of destinations, the samples were divided into three groups, namely, Eastern, Central and Western groups, to carry out the models. Columns 2 to 4 of Table 4 show that there were no distinct differences between the nationwide samples and regional groups (except *Elementary education*). Although the result of *Elementary education* was not significant, it had a significantly negative impact on the family migration decision of NGRMs in the model for the Eastern group subsample ($p<0.01$) and a significantly positive impact on the family migration decision of NGRMs in the model for the Central group subsample ($p<0.05$).

Another problem we have mentioned before is that the positive impact of the *hukou threshold* ($p<0.000$) seems contradictory to previous studies. To ensure robustness, we added a control variable *City size* based on the work by Qi et al. [60]. Although China's State Council released the new standard of city-size classification in 2014, it did not provide an official list of cities of different sizes. Meanwhile, official statistics concerning the urban resident population which is a key indicator in the new standard are often unavailable in non-census years. Following the new standard of city-size classification released by China's State Council

in 2014, Qi et al. [60] classified the city-size hierarchy of China according to the 6th census data in 2010.

According to their classification, there were 12 megacities, 53 large cities, 70 medium-sized cities and 118 small-sized cities in the list of our destination cities. We found that the significant positive impact of the *hukou threshold* still stayed sound when we looked at the column of Whole samples (2) in Table 4. From the perspective of city size, the chances of family migration were higher if NGRMs immigrated to large cities instead of small cities. Relatively speaking, there are more job opportunities in large cities than in small and medium-sized cities. Moreover, the *hukou* restriction and living cost in large cities is looser and lower than those in megacities. These appeal to NGRMs. In addition, existing studies have already proved the positive externalities of the concentration of a large number of rural migrants, which will encourage more rural migrants to immigrate [48]. By contrast, those who migrated into medium-sized cities and megacities were less likely to settle in urban destinations with their family.

5. Conclusions

Using a multilevel logistic model, this article explored the factors influencing the family migration decisions of the new-generation rural-urban migrants. We found that both family and destination factors influenced NGRMs' family migration decisions. Family factors had a primary influence on the family migration decision, while 16.9% of the chances were explained by between-destination diversities. From a family perspective, this research shows that house purchasing, self-employment, a long and stable settlement with enough income in the destination city strengthen the family migration decision of NGRMs, while migrants' age, education, numbers of children and inter-provincial mobility weaken their intention to reunite families in the host cities. It is also found that whether NGRMs own rural residential land in their original hometowns would not affect their family migration decision, which differs from the important impact of rural housing land on migration decision found in the existing studies focusing on the whole rural-to-urban migrants.

When we look at the destination factors, we found that the development of tertiary industry, environmental quality and *hukou* threshold had a significantly positive impact on the family migration decision of NGRMs, while the economy development level and supply of elementary education did not influence the family migration decision of NGRMs significantly. The NGRMs showed a sensitivity towards work opportunities and environmental quality in the host cities, which is consistent with previous studies on China's rural-to-urban migrants [48,51]. For the unexpected positive impact of the *hukou* threshold, we added the city size variable to the model in the part of the robustness check. Further analysis found that the impacts of the *hukou* threshold remained significantly positive. NGRMs living in large cities are more willing to migrate with family members compared to those residing in small cities. A possible explanation of the positive effect of city size is that cities that impose more barriers on *hukou* entry tend to have larger size of job markets. The concentration of existing rural-to-urban migrants in those cities will also encourage more immigration. However, as shown by the interaction results, when *hukou* restrictions are rigid, it intensifies the impacts of some family factors like inter-provincial mobility and self-employment, and weakens the impact of home ownership and duration of stay, which indicates that the *hukou* threshold is still a critical destination factor underlying NGRMs' family migration decision.

This article enriches the empirical research related to China's new generation of rural-to-urban migrants by focusing on the determinants of their family migration decision through the family and destination perspectives against the backdrop of the *hukou* system reform. The findings deepen our understanding of the obstacles and decisions of NGRMs' family reunions in the urban destinations, which will facilitate better policymaking for migration management and social inclusion. Our analysis shows the new-generation Chinese rural migrants' preference for urban destinations. Compared to small and medium-sized cities where urban *hukou* quotas are comparatively sufficient, NGRMs prefer to settle in large cities and megacities which have abundant job opportunities but with the cost of a high threshold of both *hukou* acquisition and public service bound to *hukou* identity. Therefore, the city government should balance the demand of the labor market and the provision of public service for NGRMs. Meanwhile, the Chinese government at different levels should steer NGRMs' migration among metropolitan areas and various-sizes cities.

Due to the limitations of cross-sectional data, our research on the intergenerational differences between first-generation migrants and the new generation is still exploratory and limited. Therefore, more efforts should concentrate on how the intergenerational differences of family migration connect with their family life experience, demographic characteristics and the socioeconomic characteristics of their host cities. Moreover, compared with NGRMs, family migrants of migrants with urban *hukou* indentities may have different preferences and choices because of their advantages in skills and education. Thus, future research may continue to explore the difference in family migration between NGRMs and urban migrants.

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Conflict of Interest

There is no conflict of interest.

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ARTICLE

Spatial Accessibility of Bakeries and Supermarkets in Belo Horizonte, Brazil

João Guilherme da Costa Braga França[1] Isabela Kopperschmidt de Oliveira[2]
Leise Kelli de Oliveira[1,2*]

1. Department of Transportation and Geotechnical Engineering, Federal University of Minas Gerais, Belo Horizonte, 31270-901, Brazil
2. Pos-graduation in Civil Engineering, Federal University of Pernambuco, Recife, 50670-901, Brazil

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ABSTRACT

The recent events and constant global changes show the importance of rethinking city planning. In this context, the 15-Minute City concept got important as it brings people closer to activities and services, through short trips by active modes, being the key to a sustainable city. Based on this concept, this paper analysed the spatial accessibility of residents of Belo Horizonte (Brazil) to two establishments essential to the quality of life: bakeries and supermarkets. The analyses were made through the influence areas, spatial clusters, and the Local Indicators of Spatial Association. The results showed that bakeries are more accessible than supermarkets, which are not accessible to the entire population, especially in low-density and low-income regions. In addition, areas with potential for new projects were identified by the relationship between existing facilities (supermarkets or bakeries) and population density/income. Finally, the results highlight the challenges for developing sustainable cities considering the 15-Minute City concept throughout the territory of Belo Horizonte.

1. Introduction

The COVID-19 pandemic has changed people's way of living and, consequently, their consumer behaviour [1]. Additionally, the increase in extreme weather events shows the need to rethink city planning towards more sustainable and resilient urban areas [2]. As a result, new concepts rethinking the city have emerged, mainly in Europe and Asia, based on accessibility, walkability, density, mixed land use, and design diversity [2]. One form was translated into the 15-Minute City concept by Carlos Moreno, which advocates that geographic proximity between people, services, and activities is the key to a sustainable city.

The 15-Minute city is the motivation for this work. The

*Corresponding Author:
Leise Kelli de Oliveira,
Department of Transportation and Geotechnical Engineering, Federal University of Minas Gerais, Belo Horizonte, 31270-901, Brazil;
Email: leise@etg.ufmg.br

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concept is composed of four pillars: density, digitalization, diversity, and proximity [3]. These pillars support the development of sustainable communities with spaces for living, working, commerce, healthcare, education, and leisure [3]. Also, within 15 minutes by bicycle or on foot displacements, people should be able to access such services or a public transport station that enables them to reach all services in the city [3].

Moreover, the concept of accessibility is the core of this paper and is understood as the easiness of reaching goods, services, activities, and destinations, hereby called opportunities [4]. Accessibility is directly related to the availability of opportunities for a specific activity when compared to another and varies according to socio-economic characteristics [5]. Accessibility to groceries is important to citizens [6] as it is closely related to people's life quality.

In Brazil, the neighbourhood design was historically oriented towards car use, and people depend on private vehicles for their daily activities, including accessing essential and basic opportunities [7]. As a result, access to essential retailing is designed for automobiles, even if the travel distance is little, makes it possible the usage of active modes. Retailing establishments with no parking areas are frequently not accessed by private car users, and consequently have a reduction in their potential consumer demand. It is worth mentioning the reasons that motivate essential goods purchases are not obvious or are impulsive [8]. In this way, providing a retail network of essential goods is vital for the population's quality of life, and access to these establishments through active modes can contribute to more sustainable urban transport.

Based on these issues, it was hypothesized that the adequate location of retail establishments increases the accessibility of the consumers by reducing the travel distance, contributing to the improvement of the quality of life of communities and making the environment more conducive to implementing the concept of a 15-Minute City. The 15-Minutes City creates accessible mixed communities, reducing inequality and meeting the 11th sustainable development goals. In addition (i) they promote the use of clean and affordable energy (goal 7) by encouraging the use of active modes, electric vehicles, and public transport; (ii) promote decent growth and economic development (goal 8), as the concept is based on of the community economic development; and (iii) combating climate change (goal 13) by reducing travel and the use of fossil fuels.

This paper focuses on the accessibility of supermarkets and bakeries, which offer essential services and kept running during the COVID-19 outbreak in Brazil. The accessibility to these commercial establishments was more critical during the pandemic time, with a restricted movements in the cities. In addition, most Brazilian cities had a reduction in public transport services, demonstrating the importance of having a nearby bakery and/or supermarket to access essential products during the lockdown. the population that depends on public transport for shopping was the most harmed during the pandemic, restricting their access to shop options. Those who did not have commercial establishments close to their home had to purchase the products in other ways, including e-commerce and peer-to-peer application services.

Based on the above, this paper aims to evaluate the accessibility of supermarkets and bakeries by active modes, using spatial analysis. The research question is "Are bakeries and supermarkets accessible for all?". Answer this question was identified the accessibility by buffer analysis. The spatial concentration of these establishments were analysed using the Local Indicator of Spatial Association based on the bivariate Moran Index. Findings showed that bakeries are more accessible than supermarkets by active modes. Moreover, few clusters were identified in Belo Horizonte, indicating potential regions for new supermarket and bakery businesses to contribute to a sustainable city, based on spatial distribution and accessibility (without considering other variables e.g., consumer behaviour, product quality, or others).

The contribution of this paper is twofold. First, the accessibility to supermarkets and bakeries was measured. Second, this research identified neighbourhoods with potential for new shop opportunities, more precisely, supermarkets and bakeries contributing to transforming Belo Horizonte into a 15-Minute city. Findings were based on public data and open-source software, allowing replication to other territories.

2. Importance of the Accessibility for Sustainable Trips in Urban Areas

Accessibility to urban services is a crucial component of quality of life [9] and a primary role of the transportation system [10]. In this matter, accessibility to urban services can be related to their use [11]. Neighbourhoods with a high level of accessibility can stimulate sustainable trips more efficiently [12,13]. Following the new urbanism principles, residential and retail areas need to be closer, enhancing a mix of complementary land uses to support the Transit-Oriented Development [14] and focusing on accessibility. Rethinking accessibility strategies are the basis of the sustainable paradigm [15]. The sustainable accessibility concept is based on the combined analysis of densification, mixed land uses, integration, and non-motorized transportation modes [15]. The combination of accessibility and sustainable concepts has become central to urban

planning [16] and the development of Sustainable Urban Mobility Plans (SUMP).

The accessibility is based on the location perspective [17], i.e., "a location is accessible by people, whereas a person has access to locations" [18]. Therefore, increasing the accessibility to the shopping areas means growth in the diversity of goods offered by retailing in the same area.

Some studies analysed the spatial distribution of urban services as a measure of accessibility [9]. In the United States, the rural population has less accessibility to healthy food stores [19]. In Tehran (Iran), 98.3% of citizens have high access to local stores (less than 800 meters from their residence) [11]. The black race residents have less access to grocery stores, restaurants (not including fast-food stores), banks, liquor stores, and movie theatres in Atlanta (United States) [20]. The vulnerable groups have disadvantaged accessibility to shopping and supermarkets in Detroit (United States) [21]. The long travel distances and the obstacles from land-use influence pedestrian accessibility and the accessibility changes in the territory of Montreal [22]. Since shopping is the main reason the elderly make trips, the physical-spatial characteristics needed can make unsafe the way to food stores [22]. The accessibility of shopping malls in Nanjing (China) varies according to the transportation mode [23].

Moreover, the high accessibility level of retail is associated with high residential property values [14]. The trade-off between store accessibility and store size has a positive correlation between household income and store size in Atlanta (US) [6]. Nevertheless, the car is also the main transportation mode for shop travel motive by Americans [6].

Accessibility is also a social equity measure and a component of social sustainability [24]. Based on buffer analysis and evaluation of the 20-Minute City concept to Tempe (Arizona, US) transportation infrastructure system, [24] showed 88.8% of residential units have access to bicycle roads, and 69.1% of residential units have access to pedestrian sidewalks. The authors emphasise the importance to use spatial methods for the accessibility measure. The socio-spatial equity using a time-distance measure and a Spatial Separation Index was used to measure the accessibility of public services in Valencia (Spain) [25]. The pedestrian accessibility to neighbourhood facilities was evaluated in the Cittadella district in Parma (Italy), where 70% of inhabitants live within a 15-minute distance of kindergartens and 91% of inhabitants have shops within a 15-minute walking [13].

The analysis reported by the literature used the minimum distance method [11], grid analysis [23], accessibility measurement [20-22], and service area analysis [13]. A similar approach proposed in this paper was used [24]. However, the goals and results are different. In general, the spatial tools are restricted to accessibility measurement. In this way, this paper innovates using a usual spatial technique and public data in the analysis. Urban planners can use the findings to improve the accessibility of retail and service functions [14]. Rethinking land use based on residence accessibility to services, activities, and trades [3], becomes essential to reduce travel distances and stimulate trips by active modes.

3. Study Area

The accessibility analysis at neighbourhood levels across the city requires data and geographic information systems [26]. This section describes the study area and the spatial data used in the geographic information systems to perform the accessibility analysis.

Belo Horizonte has 2.38 million inhabitants living in 487 neighbourhoods (Figure 1) [27]. Belo Horizonte is the sixth most populous municipality in Brazil. Despite the high population density (7,167/km^2, on average), there is almost no resident population in some parts of the municipality, where environmental preservation areas or urban facilities (e.g., universities and airports). The east region of the municipality is a residential area, and the most populous neighbourhoods have a population of over 12,768 inhabitants. Barreiro region has two districts with more than 12,768 inhabitants. Venda Nova is the most populous region in Belo Horizonte, and the most populous neighbourhood has more than 19,700 inhabitants. The Centre-South region of Belo Horizonte, which concentrates most of the commercial activities, has a population of over 8,501 inhabitants.

Figure 2 shows the income per neighbourhood in Belo Horizonte. The Centre-South region had the highest income, followed by the Pampulha region. On the other hand, Barreiro and Venda Nova regions have the lowest income, below BRL 2,408. In general, the income is heterogeneous among the neighbourhoods in Belo Horizonte.

The location of bakeries and supermarkets was obtained from Municipal Taxpayer Registry [28], based on the National Classification of Economic Activities (CNAE), with the following numbering: 4711301, 4711301, 1091102, and 4721102. Figure 3 shows the spatial pattern of these establishments. Belo Horizonte has more bakeries than supermarkets. Also, the Centre-South region concentrates more on bakeries, supermarkets, and residents and the average income is high in this region compared with others (Table 1). On the contrary, the North region concentrates fewer bakeries and supermarkets in Belo Horizonte. By region, the range of bakeries varies from 202 (North) to 348 (Centre South), while supermarkets range from 28 to 60 in the same regions.

On average, each neighbourhood has 7.7 bakeries

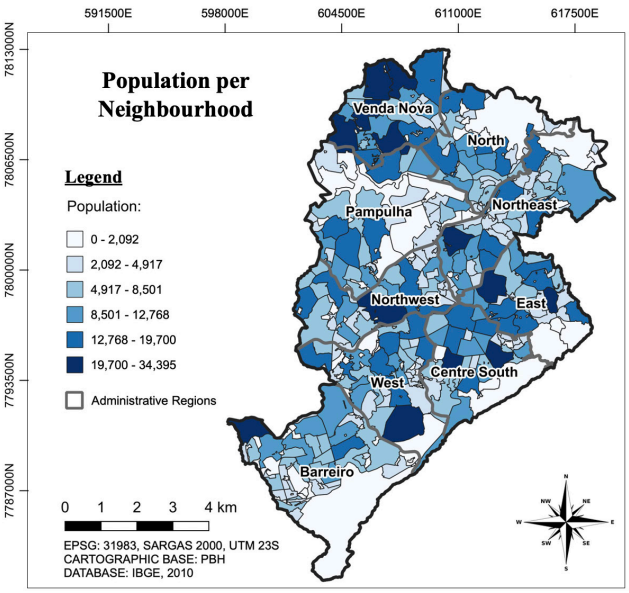


Figure 1. Population per Neighbourhood.

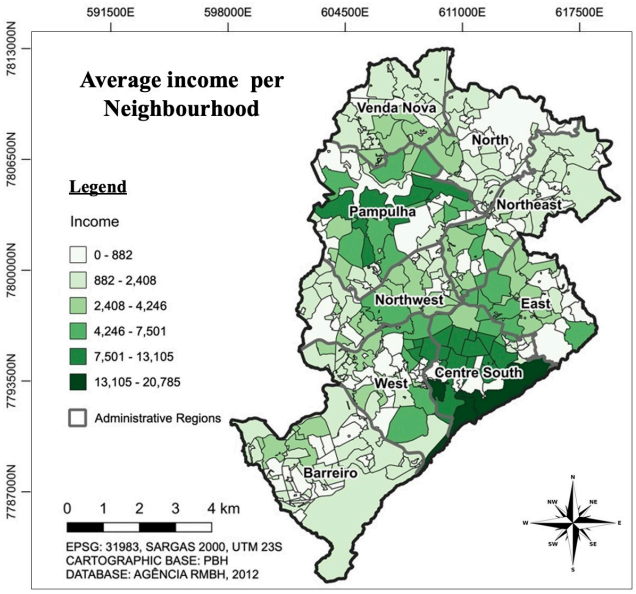
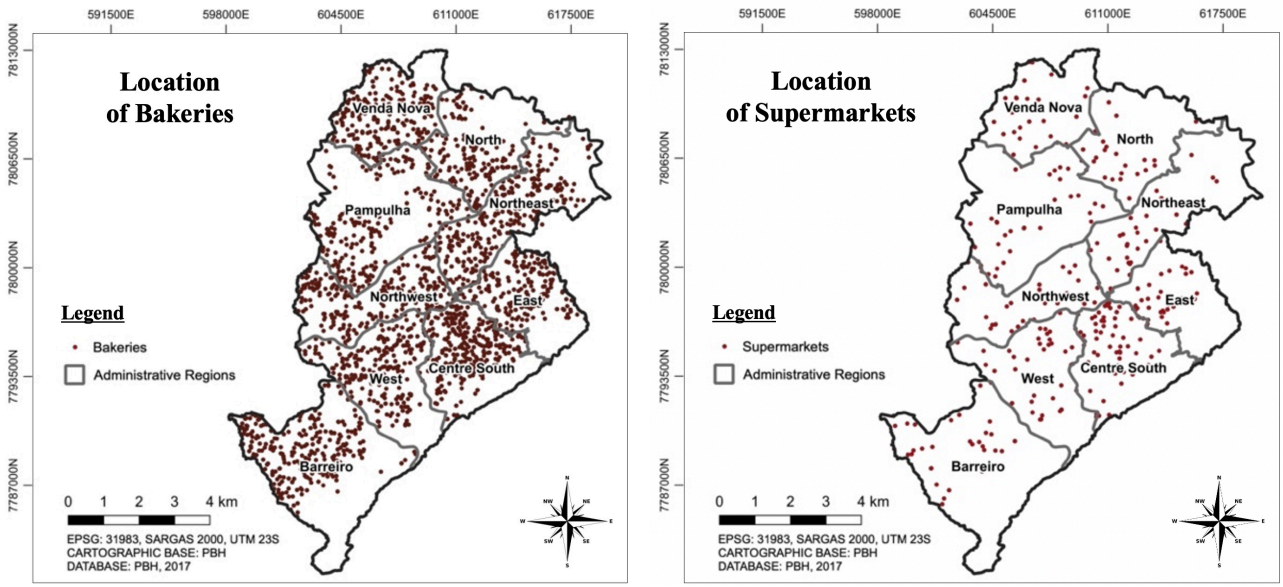


Figure 2. The average income per neighbourhood (in BRL, 1US$ ~ 5.3BRL, in July/2022)



a) b)

Figure 3. a) Location of Bakeries; b) Location of Supermarkets

and 1.9 supermarkets in the Centre South. On the other hand, each neighbourhood of Barreiro and Pampulha has 4.1 bakeries and 0.7 supermarkets (the lowest values by neighbourhood). The centre-South region has the lowest bakery density, 811.93 residents/bakery, while the Northern region has the highest value, 1,398.77 residents/bakery. Supermarkets have a similar pattern in these regions: 4,709.20 residents/supermarkets in the Centre-South region and 10,001.14 residents/supermarkets in the North region. These data give preliminary evidence about the accessibility of residents to these establishments.

Data described in this section were used to assess

Table 1. Belo Horizonte regions characteristic.

Administrative regions	Number of neighbourhoods	Area (km^2)	Bakeries	Supermarkets	Population	Average income (BRL)
Barreiro	74	53.48	303	37	282,552	1,890
Centre South	45	31.74	348	60	272,285	8,097
East	47	27.86	254	36	249,273	3,343
North	44	32.56	202	28	212,953	1,928
Northeast	62	39.32	304	36	291,110	2,663
Northwest	47	30.07	284	41	331,362	2,787
Pampulha	62	51.03	255	37	187,315	3,983
Venda Nova	43	29.17	265	40	262,183	1,915
West	63	35.93	292	44	286,118	3,549

the accessibility of supermarkets and bakeries by active modes in Belo Horizonte. The research approach is described in the hereafter section.

4. Research Approach

The research approach has two steps: accessibility of bakeries and supermarkets, analysis through the influence area, and the spatial pattern of these establishments through Local Indicators of Spatial Association.

4.1 Step 1: Accessibility Analysis

The influence area of the establishments identified the accessibility of the population to the bakeries and supermarkets. A buffer zone was defined around the location of the establishments centred on the distance, based on the distance definition of shopping travel time [29,30], and the 15-Minute City concept. Were analysed three different distance levels: 500 meters (5 minutes walking), 1,000 meters (15 minutes walking or 9 minutes cycling), 2,000 meters (25 minutes walking or 15 minutes cycling). The analysis was performed in QGis software using the spatial join tool.

In each buffer, the number of neighbourhoods, the maximum population served, and the number of bakeries and supermarkets inner were measured. Then, was analysed the accessibility based on the ease of reaching bakeries and supermarkets by walking or cycling.

4.2 Step 2: Spatial Pattern of Bakeries and Supermarkets

The Local Indicators of Spatial Association (LISA) approach, based on the Bivariate Moran Index, was used to identify the spatial pattern of bakeries and supermarkets. Cluster analysis is a technique to classify elements based on their similarity. The local index is a statistic that demonstrates the spatial dependence of each location in a neighbourhood, and they are analysed in terms of clusters [31]. The Moran Index measures the intensity of the spatial correlation by evaluating how much the observed value of an attribute in each region is dependent on the variable values in neighbouring locations, based on deviations from the mean [32].

The Bivariate Moran Index is defined as $I_i^B = cx_i \sum_j w_{ij} y_j$, where w_{ij} is the element of the spatial weights matrix, $\sum_j w_{ij} y_j$ is the lagged variable, x_i is the variable in the standardized form, and c is the constant scaling factor [32]. LISA is based on the relation of Ii = (zi×Wzi)/σ2 where Ii is the local index for the region i, zi is the deviate value in the same area i, Wzi is the average value of neighbourhood region of I, and σ2 is the variance of the deviate distribution.

Based on the Bivariate Moran Index, LISA identifies five types of clusters: High-high, high-low, low-high, low-low, and not significant. The first part of the denomination indicates the intensity of the index value observed in the analysed neighbourhood. The second part of the denomination indicates the intensity of the index value in the surroundings of the analysed neighbourhood. Typically, clusters identify hot and cold spots with high-high and low-low clusters, and high-low and low-high clusters are outliers. The outliers' clusters are considered opportunities for installing bakeries and supermarkets in this paper.

Finally, the spatial dependence of bakeries and supermarkets were verified, and grouped by neighbourhoods, measuring Moran's global autocorrelation index. The analysis of the Moran's Index was made based on the p-value (lower than 0.05), the comparison of the z-value in the module (if the z-value is in greater modulus and not very close in value to the expected value, it is considered

that there is spatial dependence), and signal of z-value (negative signal indicates the spatial dependence due to dissimilarities in space, and positive signal indicates spatial dependence due to similarities in space) [32]. This procedure identified places for the location of new bakeries and supermarkets based on accessibility, i.e., ease of reaching bakeries and supermarkets by foot or bicycle.

The bakeries' and supermarkets' location was geolocated using the ggmap package [33]. LISA was performed using the spdep package [34] in the R environment, with the queen contiguous spatial units, 95% significance level, and a p-value less than 0.05. The LISA analysis was based on the neighbourhood's unit spatial.

5. Results

5.1 Accessibility Analysis of Bakeries and Supermarkets

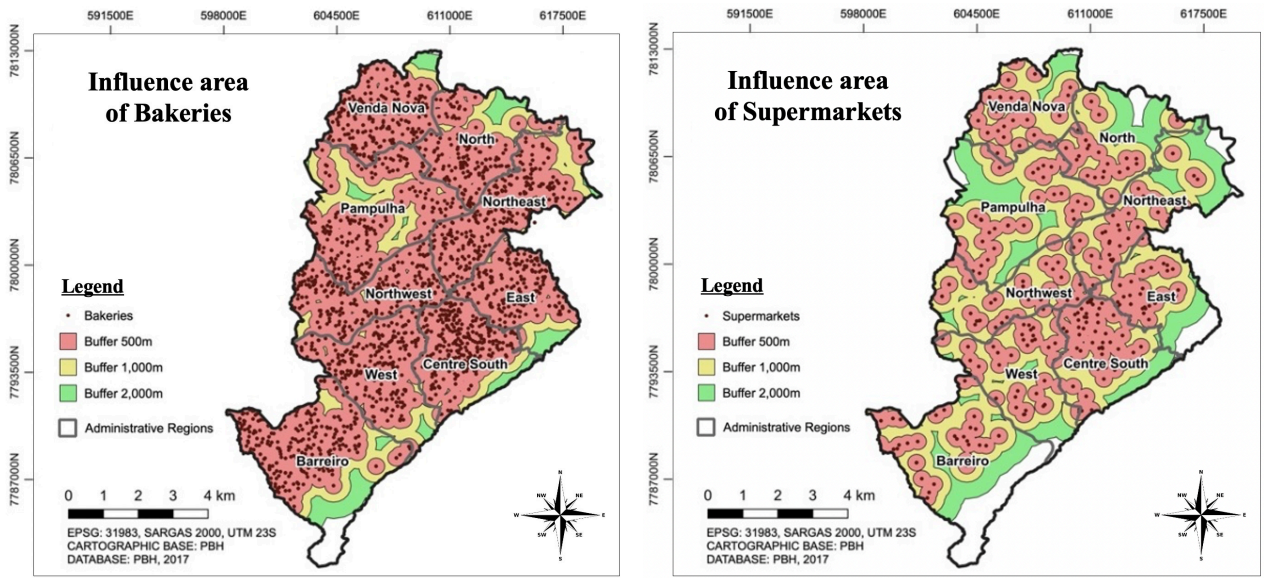
Figure 4 shows the influence area of bakeries and supermarkets. The influence area of bakeries covers 99.9% of the territory of Belo Horizonte with 500 meters buffer. On the other hand, the 500-meter buffer for supermarkets covers 93.8% of neighbourhoods. This result shows that Belo Horizonte is well-served by bakeries for a short walk, but some areas remain unserved by supermarkets. These areas are in the neighbourhood with lower income and lousy infrastructure conditions.

For the 1,000 meters buffer, 97.6% of the population of Belo Horizonte can reach a supermarket within a 15-minute walk. Increasing the walking time, we have an increase in the population covered by the supermarkets. However, this is not the ideal scenario for a sustainable perspective. Usually, people go to supermarkets to buy groceries, which sometimes are heavy or voluminous. Therefore, if the walking distance is close to 15 minutes, the use of an active mode of transportation starts to be unappealing. Additionally, the topographic conditions were not evaluated in this paper, which could further influence the preference for travel in less active modes, depending on the distance.

For a radius of 2,000 meters, 99.3% of the population can reach a supermarket which means they can reach a supermarket with a 15-minute bike ride. This scenario also is not the ideal situation, especially in low-income neighbourhoods. Moreover, this scenario did not stimulate the use of bicycles depending on the purchase volume. Besides that, this situation could be acceptable if the supermarket had a free delivery service for the local community.

The data regarding the coverage area of bakeries and supermarkets are summarized in Table 2. Although the distribution of supermarkets is not ideal, especially in some neighbours with lower income, 93.8% of the municipality area is covered by a supermarket within a 5-minute walk and 99.9% by a bakery, so we consider this a potential scenario for a 15-Minute City, based on these establishments' location. It is worth mentioning that bakeries sell more than typical bakery products in Brazil, working as convenience stores. They also supply essential goods for the population and bakery products. On the other hand, supermarkets are usually bigger and sell various products. Thus, the supermarket location is more restricted because they demand more ground area.

Although apparently, the territory of Belo Horizonte



a) b)

Figure 4. a) Influence Area of Bakeries; b) Influence Area of Supermarkets

Table 2. Summary of Influence Area.

Radius	Supermarkets			Bakeries		
	Neighbourhoods Served	Maximum Population Served		Neighbourhoods Served	Maximum Population Served	
500 meters	370	2,228,210	93.8%	478	2,372,217	99.9%
1,000 meters	431	2,317,671	97.6%	484	2,373,029	99.9%
2,000 meters	456	2,357,632	99.3%	487	2,375,151	100.0%

is all served by bakeries and almost all served by supermarkets, many neighbourhoods have low options for the residents. The comparison of 500 meters service area buffers with the population (Figure 5) and income (Figure 6) shows a concentration of bakeries in the Centre-South region, the same region with population and high-income concentration. Figure 6 shows the same comparison with the population (a) and income (b) for the supermarkets, concentrated in the neighbourhoods with population concentration, such as the Centre-South region, the west of the East region and the west of the Venda Nova region. The Centre-South and the west of East regions also have high-income concentration. These findings show that almost every citizen of Belo Horizonte would have a nearby establishment to go by an active transportation mode for essential needs. However, there are not many options in low-income neighbourhoods. Thus, the products may be overpriced with the low supply of establishments and high demand, or the residents may not find the desired products.

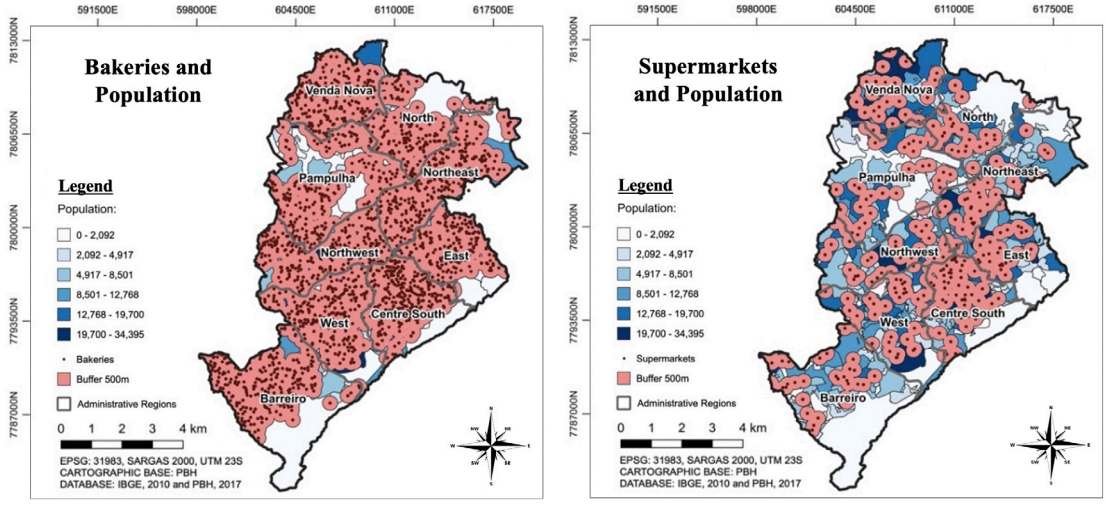
5.2 Spatial Pattern of Bakeries and Supermarkets

Figure 7 shows the LISA map with the spatial pattern concerning the lagged population. The high-high clusters indicate the places well served by bakeries or supermarkets and with a high concentration of population. These establishments are in the same neighbourhoods, with 19 clusters of bakeries (a) and 18 supermarkets (b). The lack of high-high clusters indicates the overall need for bakeries and supermarkets related to the mean population in each neighbourhood. Concerning income, Figure 8 shows the high-high clusters are like the population, with 26 clusters to bakeries (a) and 24 to supermarkets (b). These results mean that supermarkets or bakeries and their surroundings serve the high-high neighbourhood well.

Furthermore, the high-income or high population attracts these facilities and influences the geographic environment. On the contrary, the low-low cluster indicates that bakeries or supermarkets poorly assist places with lower income or population. Supermarkets have more low-low clusters scattered by the Belo Horizonte territory. The neighbourhoods with the low-low relation indicate how the capacity to attract businesses, either because of lack of population or because of low resident income. Independent of the reason, this should not be a motive for these neighbourhoods to be unattended, and they should be a focus of public policies to increase the density population, mix uses and business attraction.

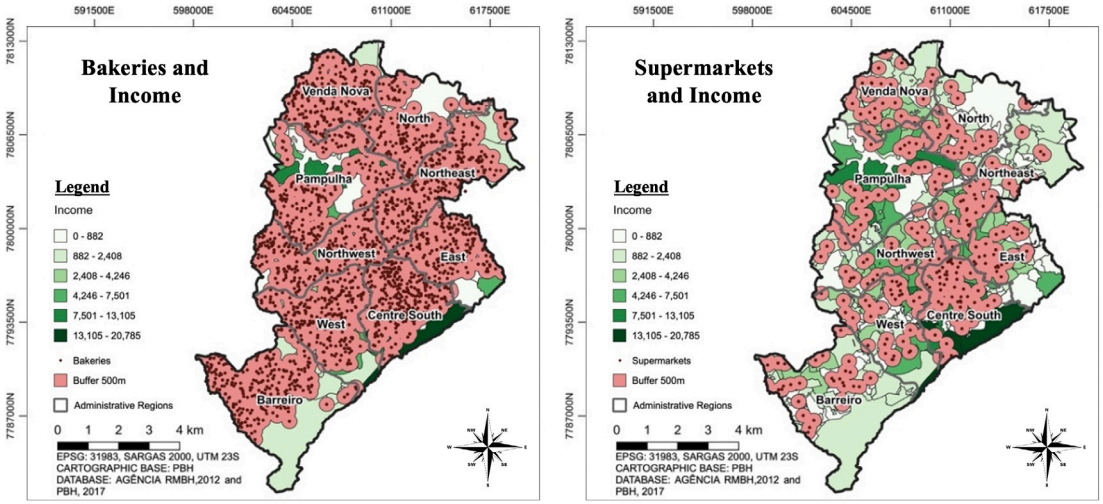
The outliers' clusters (high-low and low-high) indicate the potential to install new bakeries and/or supermarkets in the neighbourhoods. The low-high cluster displays potential neighbourhoods for bakery or supermarket investments, while the high-low clusters indicate areas whose surroundings are poorly assisted by bakeries or supermarkets. Moreover, findings show that the clusters of bakeries and supermarkets are similar and concentrated in neighbourhoods with high income and populations.

Finally, the Global Moran Index was calculated to confirm the spatial pattern of bakeries and supermarkets. For supermarkets, Moran's I was 0.067 (p-value=0.012). Compared with the expected value of –0.002, there is positive spatial dependence for supermarkets, indicating supermarkets are distributed throughout the territory due to their similarities. On the other hand, the p-value is not statistically valid (0.378) for bakeries, making it impossible to analyse the z-value. Thus, there is no spatial pattern in the spatial distribution of bakeries in Belo Horizonte. It is worth mentioning that the overall number of bakeries is considerably higher than the supermarkets', justifying further spatial econometric models for the bakeries' location distribution. Thus, it was concluded that bakeries are more accessible to the population of Belo Horizonte, regardless of income and population concentration. To improve the accessibility of supermarkets, it is necessary for new establishments in peripheral areas where there is less concentration of income and high population density.



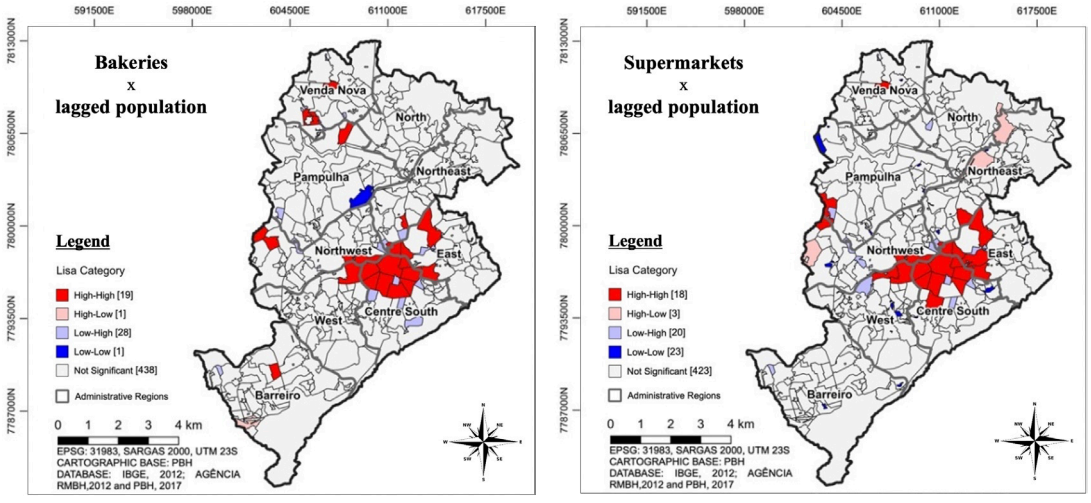
a) **b)**

Figure 5. a) Bakeries and Population; b) Supermarkets and Population



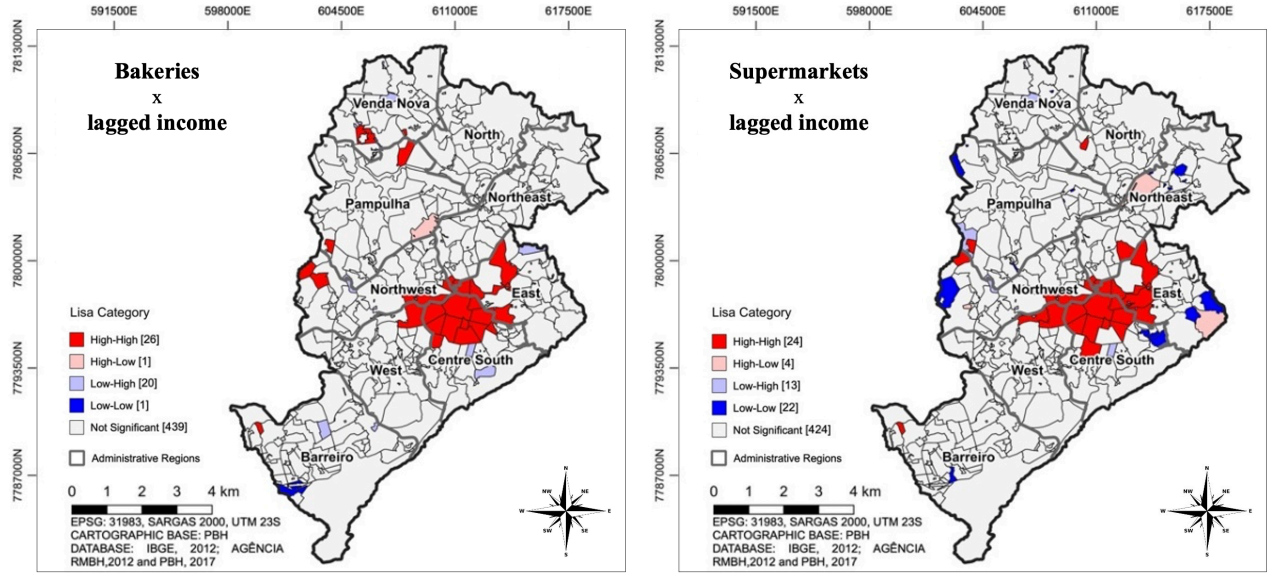
a) **b)**

Figure 6. a) Bakeries and Income; b) Supermarkets and Income



a) b)

Figure 7. a) LISA map: bakeries vs lagged population; b) LISA map: supermarkets vs lagged population LISA map: supermarkets vs lagged population



a) b)

Figure 8. a) LISA map: bakeries vs lagged income; b) LISA map: supermarkets vs lagged income

6. Discussion

Bakeries and supermarkets were vital establishments during the COVID-19 outbreak. For many days they were the only establishments allowed to keep open in Belo Horizonte; it was where people bought essential products. Therefore, during the COVID-19 outbreak, having a bakery or a supermarket close to your residence means having a place to shop. But unfortunately, not all residents of Belo Horizonte can reach these establishments by active modes, which generated some social exclusion and loss of quality of life, especially for those dependent on public transportation, which had its frequency reduced at that period.

The development of a 15-Minute City has the potential to provide accessibility to all residents and reduces socio-spatial inequalities. From the perspective of access to essential services, the 15-Minute displacement by active modes is more critical for such inequalities. However, our findings showed socio-spatial inequalities in Belo Horizonte, based on the location of bakeries and supermarkets. The high-income neighbourhoods have more supermarkets, and the residents can reach within a 2 km radius. On the other hand, low-income communities have fewer options, which may lead to higher product prices for a lower-income population. This uneven spatial distribution of supermarkets reinforces social inequalities.

Another result highlighting social-spatial inequalities was the small number of high-high clusters for both bakeries and supermarkets. The neighbourhoods well-served by these establishments are in the centre-south region, with high-income and high-density populations. Thus, we concluded that less densely populated areas with lower income have less diversity of opportunities. The lack of opportunity diversity represents an increase in prices and a reduction in local job offers, an essential part of a 15-Minute City.

The 15-Minute City concept can effectively promote sustainable transportation since the active modes are at the core of the 15-Minute City network planning. This paper showed that Belo Horizonte has the potential to become a 15-Minute City when analysing the access to essential services, bakeries, and supermarkets. For that, urban planning must focus on locating new establishments in neighbourhoods, and there is no need to find a high number of new ones. New establishments could provide more accessibility to the residents by active modes and reduce socio-spatial inequalities. Also, urban planning should integrate these incentives for establishments' location with adequate transport infrastructures, such as adequate sidewalks and bike lanes. Thus, urban planning must contemplate the reduction of socio-spatial inequalities, not only for the establishments analysed in this article but for the public, health, and education services.

This paper did not consider the quality of the sidewalks and bike paths in Belo Horizonte. The infrastructure attributes are the next stage of analysis, as it has the same importance as the existence of opportunity and influence in the displacement comfort of the citizens. For example, older people were concerned about the sidewalk quality in Belo Horizonte [35]. The quality of sidewalks is also cru-

cial for the owner of commercial establishments [36], as the more people walk, the more people are attracted to such establishments. In this way, sidewalk quality and security safety improvements increase walkability in lower-income neighbourhoods [37], consequently, improving life quality and reducing social inequalities due to the lack of accessibility. In other words, the quality of the sidewalk is a critical factor in developing sustainable cities.

Similarly, benefits associated with sidewalks could be achieved with bike paths. However, Belo Horizonte has only 118 km of the 400 km planned by the municipality since 2017. The planned routes are still far from serving the entire population of Belo Horizonte because they lack connectivity. Moreover, most parts of the city have bike path projects.

We recognise that as far as our effort to identify the location of bakeries and supermarkets as a first step to creating a 15-Minute City, it cannot come isolated. Besides policies incentivising access to groceries and job opportunities with integrated planning with the retail sector, Belo Horizonte Municipality needs to change its urban planning process. Nonetheless, a recent Master Plan was approved in 2019 and is innovative for environmental preservation. Moreover, it has direct guidelines that can contribute to the construction of a SUMP [38]. The new SUMP should follow the master plan guidelines and prioritize active modes and public transport. The most important factor of this new SUMP should be the revitalization of pathways and the adequate planning of connected bike paths. Besides that, the municipality needs to materialize the planning since the last two SUMPs from 1996 [39], and 2013 [40] did not come out of paper. Thus, the municipality must include the concept of a 15-Minute City in the new SUMP. In addition, the SUMP must incentivise land use diversification and increase population density accompanied by a mix of income in each community.

Answering our research question, "Are bakeries and supermarkets accessible for all?", findings showed that bakeries are more accessible than supermarkets. Furthermore, supermarkets are not accessible to the entire population, especially in low-density and low-income regions. The adoption of the 15-Minute City planning concept is a way to increase this accessibility, and the municipality has the crucial role to approve projects aligned with such guidelines and sustainable development. In addition, the municipality may encourage the development of new bakeries and supermarkets in line with the accessibility municipality regulation (Law 8616/03 and Law 9725/09) [41,42], improving sidewalks and creating bike paths as a counterpart to the installation of these projects. The counterpart is already a pioneering initiative in Belo Horizonte in the authorization of projects that are characterized as trips generating hubs. This initiative can be extended to small establishments, encouraging the improvement of sidewalks and/or creating a monetary fund to implement bike paths. Simple measures, in line with the installation of new projects, make it possible to reduce socio-spatial inequalities in the city and develop sustainable cities.

7. Conclusions

The COVID-19 pandemic evidenced the importance to rethink how activities should be distributed in cities. People need alternatives to reach essential services by means other than motorized ones. In this context, the urban planning concept based on the 15-Minute City emerges as an alternative to reduce car or public transport dependence and valuing trips by active modes (foot or bicycle). The mix of the residential area and job opportunities, the variety of trade and services could contribute to this concept.

This paper analysed the spatial accessibility of supermarkets and bakeries in Belo Horizonte (Brazil). These establishments play a central role in people's daily lives and were crucial during the COVID-19 outbreak, providing essential goods for the residents. Giving people accessibility to bakeries and supermarkets increase the equity to access gross products, essential to better life quality.

Findings showed there are many more bakeries than supermarkets in the city, and they are more dispersed in the municipality territory. It was not possible to identify a spatial dependency for the bakeries' spatial distribution: it was found that almost all citizens of Belo Horizonte can reach a bakery within 5 minutes of walking and a supermarket within 15 minutes of es cycling. The two hypotheses were proved: (i) the bakeries are more accessible than the supermarkets, and (ii) the clusters of bakeries and supermarkets regarding the population and income are similar. Therefore, supermarkets are not accessible to the entire population, especially flow-population and income-concentration regions. Also, some neighbourhoods have opportunities for new bakeries or supermarkets, given the relationship between the actual installations and population concentration or income.

Analysing the spatial dispersion of the facilities is extremely important to increase trips by active mode. The accessibility of urban services also contributes to the security and attractiveness of urban areas [43]. Analysing this part of the supply chain, we concluded that Belo Horizonte could become a 15-Minute City. However, the authors recognize that this is just a tiny of the bigger chain that could be further studied.

This paper instigates the analysis of the accessibility to basic services as and education and health services. More-

over, we suggest exploring how the low accessibility of commercial establishments could impact the development of 15-Minute City.

Author Contributions

João Guilherme C. B. França was responsible for the primary data collection. João Guilherme C. B. França and Isabela K. Oliveira were responsible for the analysis. Leise Kelli de Oliveira was responsible for the academic research of this study. All authors read and approved the submitted version of the manuscript

Conflict of Interest

The authors declare no conflict of interest.

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ARTICLE

Mapping Vehicular Noise Pollution in Port Harcourt Metropolis, Rivers State, Nigeria: Implication for a Sustainable Urbanization

Nwaerema P.[1*] Fred-Nwagwu W. F.[2] Jiya Solomon[1] Dangana K.[1]

1. Department of Geography, Ibrahim Badamasi Babangida University, Niger State, Nigeria
2. Department of Surveying and Geo-Informatics, Ken Saro-Wiwa Polytechnique, Bori, Rivers State, Nigeria

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ABSTRACT

This study aims to investigate geo-referenced vehicular noise pollution in the Port Harcourt metropolis of Rivers State, Nigeria. Three types of data were gathered for this study. Data from vehicular traffic noise were measured in decibels (dB) using Noise Dosimeter (ND); data from vehicular traffic counts were carried out by observing and counting traffic flow at junctions and roundabouts as well as vehicular traffic noise location map was established by using Global Positioning System (GPS) instrument processed in the Geographic Information System (GIS) environment. The findings indicated that in the northern segment, Igwurita (99.5 dB) and New road roundabout (96 dB), generated the highest vehicular noise in the spatial distribution. In the eastern road segments, Eleme Flyover (98.1 dB) and Artillery Junction (95.5 dB) contributed the highest vehicular noise levels. In the northern segment, New Road (2311 vehicles) and Igwuruta (1566 vehicles) at the roundabouts, generated the highest vehicular traffic counts in the spatial distribution. Thus, among the eastern roads, Eleme Flyover (6735 vehicles) and Artillery Junction (5539 vehicles) contributed the highest vehicular counts in the area. The results showed that the northern and eastern segments of the Port Harcourt metropolis had the highest level of vehicular traffic noise and traffic flow. Thus, the vehicular noise level values have exceeded the recommended 75 dB national and international health standards. The study recommended the construction of more road networks in the southern and western parts of the Port Harcourt metropolis to decongest traffic flow and noise pollution in the northern and eastern segments of the city.

1. Introduction

Globally, noise pollution has caused serious public health to a great number of people. According to World Health Organization (WHO), an estimated 466 million (5% global population) are troubled by hearing loss and over 1.1 million of the affected people are between the ages of 12 to 35 years with global spending of $750 billion annually [1]. The greatest of hearing-impaired people

*Corresponding Author:
Nwaerema P.,
Department of Geography, Ibrahim Badamasi Babangida University, Niger State, Nigeria;
Email: pnwaerema486@gmail.com

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are in South Asia, Asia Pacific, sub-Saharan Africa. Thus, noise is drawn from a Latin word called "nausea" which means sea sickness or quarreling. Noise is any sound level can create anger or annoyance with physiological and the psychological impact on an individual [2]. Noise pollution has been greatly contributed to by vehicles. Resultantly, there are 1.2 billion vehicles in the world, WHO estimated 16% a rise in vehicles between 2010 to 2013 globally [3,4]. This suggests that there is an expectant increase in noise pollution resulting from vehicular traffic.

In the United States of America (USA), 104 million people suffer serious health problems related to inducing noise levels of over 70 dBA per day resulting from alteration of the natural environment by human activities and vehicular flow [5]. In Asia, the country of Turkey has recorded tremendous effects of noise pollution due to the greater number of vehicles in the urban areas such as Tokat city which recorded over 65 dBA in residential areas [6]. In Europe, deaths of young people involving children of about 12,000 have been recorded, causing 48,000 ischemic heart disease in the continent [7]. It is estimated that road traffic noise has affected 113 million people, 22 million people are affected by railway traffic and 4 million are affected by aircraft, 12,500 school children have poor learning impairment due to noise pollution [8]. An estimated 18% of city dwellers are exposed to dangerous noise and 14.5% of these people affected are caused by road traffic. Also, 7% of European rural dwellers are affected by road traffic noise [8,7]. In African countries such as Egypt, noise pollution has reached 75 dB ~ 85 dB by exceeding the recommended limit of 60 dB (daytime), 55 dB (evening) and 50 dB (nighttime) which was accelerated by vehicle traffic and poor urban planning [9]. In Nairobi, the capital city of Kenya, Public Service Vehicles (PSVs) generated a noise limit of about 95.9 dBA with the minimum noise level in the northern part recording 92.2 dBA, the western part having 88.7 dBA, the southern part having 83.1 dBA and the eastern part having 81.2 dBA respectively thereby causing serious Noise-Induced Hearing Loss (NIHL), physiological as well as psychological restlessness [9]. In the city of Windhoek, Namibia, vehicular and industrial activities contributed to noise pollution ranging between 64 dBA ~ 72 dBA thereby exceeding the WHO standard of 70 dBA in residential areas [10,11].

Serkan, Hasan, Murat and Pervin (2009) studied the evaluation of noise pollution caused by vehicles in the city of Tokat in Turkey using noise level meters at 65 sample points. Statistical relationships showed that vehicular noise pollution on the streets of Tokat varies significantly with some areas exceeding 65 dB above the national recommendation of the Turkish noise control regulation for residential areas. The study recommended proactive reduction of noise pollution sources especially vehicular traffic noise [6]. However, Stansfeld, Haines and Brown (2000), Passchier-Vermeer and Passchier (2000), Quis, (2001), Job (1996), Evans and Hygge (2000) studied the effects of noise in cities using an experimental approach. Findings showed that noise pollution affects sleeping, social behavior, hypertension, cardiovascular disease, psychological symptoms, psychiatric disorders, raised catecholamine secretion, disrupts reading and understanding, long-term memory and high blood pressure as well as causes annoyance [12-16]. Thus, Dancan, Christopher and James (2015) assessed the effects of noise pollution on 60 randomly selected Public Service Vehicles (PSVs) in Nairobi City, Kenya using digital noise level meters. The study analyzed the differences in noise levels and sources across various routes using statistical techniques and student t-tests. Findings showed that noise generated by vehicular traffic was accelerated by the giant speakers and amplifiers of the vehicles especially Public Service Vehicles (PSV) which was a great source of noise pollution in the urban area [9].

Nowadays, more people are dwelling in the cities more than ever before because of the underdeveloped nature and high-level insecurity of most rural dwellings especially the current situation of insecurity in Nigeria. However, over 4.2 billion were already residing in the cities in 2018 [17]. Thus, this population is commuted by vehicles which top-up the already existing noise level in the cities. The increased urbanization is making people and vehicles denser resulting in more noise pollution. Urbanization has caused contemporary global problems that involve greater number of the population buying more vehicles for the movement of people and commodities as well as services. Vehicular noise pollution is a by-product of the Industrial Revolution in Europe. Thus, the population of people and vehicles are rapidly increasing day by day and as such, noise pollution is increasing as vehicle volumes rise [18].

Vehicular traffic noise pollution occurs from the sound of vehicles and commuter passengers. Vehicular noise levels can increase with bad vehicle conditions and congestion of vehicles at bottleneck roads and roundabouts. It can also occur due to over-throttling of the acceleration pedal of the vehicle in motion [7]. Many variables have contributed to the increased noise level pollution in the cities. These factors include bad roads, uncontrolled traffic, high vehicular loudspeakers, shouting of passengers, bad exhaust of vehicles, the bad engines and others [19]. The rapid population of vehicles and people has resulted in serious noise pollution with its attendant health effects that are making the cities very uncomfortable to live [20].

In this vein, this study is aimed at geo-referencing vehicular noise pollution in Port Harcourt Metropolis of Rivers State, Nigeria.

2. Methodology

Port Harcourt area is located within latitudes 04° 30N and 05° 30N as well as longitudes 06° 30E and 07° 30E in the Tropical country of Nigeria (Figures 1 and 2). Port Harcourt is situated in the coastal environment, close to the Atlantic Ocean in the south-south zone of Nigeria. Port Harcourt city experience the harmattan wind that takes place from December to January of every year. The city experiences land-to-sea breezes due to its location close to the Atlantic Ocean. Port Harcourt has an average relative humidity of 80% which is at its peak from April to September but experiences low relative humidity during the dry season from January to March [21,22]. The city has a rainfall range of 2000 mm to 2500 mm [23]. It has an average temperature of 32 °C especially during the dry season from January to March and 26 °C July [24]. The thickness of the cloud is 6 oktas during the wet season with a wind velocity of 0 ~ 3 m/s [21,22]. The calm climatic features of Port Harcourt characterizes the thick vegetation cover and rapid urbanization that has resulted in high traffic volumes in the city area.

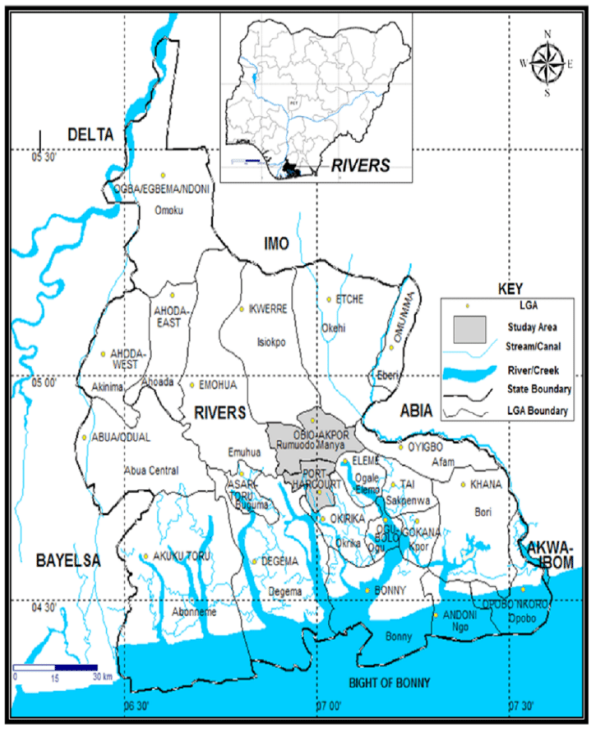

Figure 1. Study Area of Port Harcourt metropolis in Rivers State

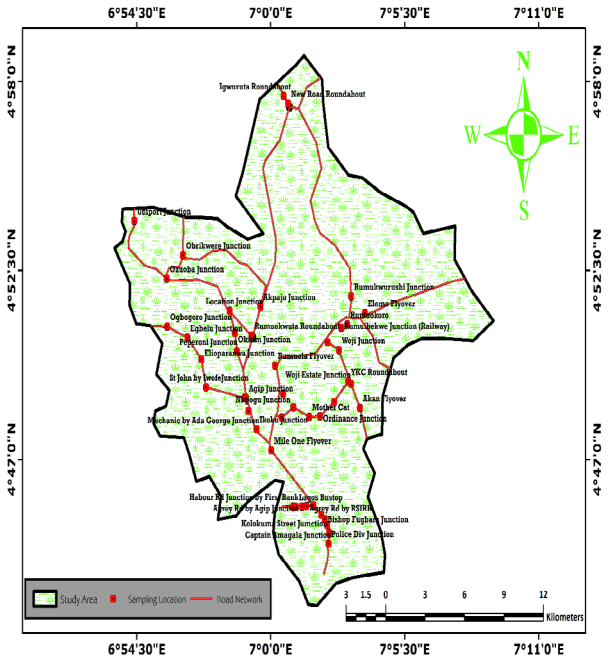

Figure 2. Road Network Locations of Port Harcourt Metropolis

The sampled roads, GPS coordinates, traffic counts and vehicular traffic noise are as in Table 1. Three types of data were gathered for this study: Data from vehicular traffic noise (in decibel dB) using Noise Dosimeter (ND) known as Noise Level Meter (NLM); data from vehicular traffic counts by observation and counting as well as vehicular traffic noise location map data using Global Positioning System (GPS) instruments. The field data collection took place from January 17th to February 27th, 2021 (one month and two weeks). In the first week (January 17th to January 23rd) field assistants were trained for data collection. In the second week (January 24th to January 30th) field reconnaissance survey and sample location mapping were carried out. Thus, from the third to sixth weeks (January 31st to February 27th) one month, data observation and measurements were undertaken. This period is expected to have the highest traffic flow due to the reason that people make many returning trips from their end-of-year travels. Also, the beginning of the year is one peak period with vehicular traffic flow in the cities. The vehicular traffic noise level data were measured using the Noise Level Meters placed at different purposively selected locations of the road such as junctions and roundabouts (a total of 9 roads and 5 sample points per road summing it to 45 sample points) at a height between 1.20 m and at a distance 2 m ~ 3 m from traffic noise sources [27-29]. Another work has used the sound level meter placed on the pavement of the streets at about 1.2 m height and a distance of about 7.5 m

from the existing road level [31].

However, data for vehicular traffic counts and noise levels were randomly collected at different roundabouts and junctions across the various road segments. The reasons for choosing roundabouts and junctions were because of observed high traffic volumes and the resultant noise level due to vehicular speeds, high traffic jams, the hooting of passengers to board vehicles and the bottle-neck nature of their intersections [34].

The Septa Square 15-minute measurement period was used where the number of vehicles was counted and vehicular traffic noise level was recorded every 15 minutes for an hour in the morning (7:00-8:00 a.m.), afternoon (2:00-3:00 p.m.) and evening (5:00-6:00 p.m.). Thus, the mean noise levels of the hourly vehicular traffic noise were calculated and recorded. The nose levels in the morning, afternoon and evening were divided by three to give the average noise level for each day for the period under study. This was done for all the sampled roads across the city. The counted vehicles were identified as Cars, Vans, Lorries and Tricycles [30,27,32]. The GPS instruments were used to establish the locations of all the sample points of the vehicular traffic counts and noise (Table 1). The evaluation and combination of the generated GPS coordinate data and vehicular traffic noise were used to produce the vehicular noise traffic map of the study area.

Table 1. Sampled Roads, GPS Coordinates, Traffic Counts and Vehicular Traffic Noise

Road Trunks (A, B, C)	Name of Roundabout/Junction	GPS Coordinate Easting	GPS Coordinate Northing	Vehicular Traffic Count	Noise
Trunk A (Federal Roads)					
Aba Road	Eleme Flyover	7° 03' 26"	4° 51' 14"	6735	98.1
	Artillery Junction	7° 02' 20"	4° 50' 23"	5539	95.5
	Rumuola Flyover	7° 00' 16"	4° 49' 43"	5200	98.6
	Waterlines Junction	7° 00' 31"	4° 48' 33"	5424	95.8
	Mile One Flyover	7° 00' 00"	4° 47' 15"	6252	97.4
Airport/Ikwerre Road	Igwuruta Roundabout	7° 00' 32"	4° 57' 33"	1566	96
	New Road Roundabout	7° 00' 43"	4° 57' 20"	2311	99.5
	Rumuokwuta Roundabout	6° 59' 22"	4° 50' 18"	1859	92.6
	Agip Roundabout	6° 58' 56"	4° 48' 46"	1616	98
	Ikoku Junction	6° 59' 25"	4° 47' 51"	1654	92.8
East-West Road	Uniport Junction	6° 54' 24"	4° 53' 56"	258	80.6
	ObiriKwerre Junction	6° 57' 14"	4° 52' 28"	268	82.3
	Rumuokoro	7° 03' 02"	4° 50' 54"	180	76.5
	Rumukwurushi Junction	7° 03' 18"	4° 51' 43"	288	82.2
	Akpajo Junction	7° 01' 16"	4° 51' 28"	478	95
Trunk B (State Roads)					
Aggrey Road	Lagos Bustop	7° 01' 02"	4° 45' 36"	5168	90.9
	Habour Rd Junction by First Bank	7° 00' 55"	4° 45' 36"	6108	92.5
	Aggrey Rd by Agip Junction	7° 01' 17"	4° 45' 36"	5388	92.8
	Aggrey Rd by RSIRB	7° 01' 28"	4° 45' 37"	4219	88.1
	Aggrey Rd by Post Office	7° 01' 46"	4° 45' 39"	5558	88.3
Trans-Amadi Road	Garrison Junction	7° 00' 27"	4° 48' 12"	383	77.8
	Nkpogu Junction	7° 00' 55"	4° 48' 30"	333	73.9
	Mother Cat	7° 01' 35"	4° 48' 13"	344	75.2
	Ordinance Junction	7° 02' 01"	4° 48' 14"	354	75.7
	Slaughter Roundabout	7° 02' 36"	4° 48' 39"	388	77.8

Table 1 continued

Road Trunks (A, B, C)	Name of Roundabout/Junction	GPS Coordinate Easting	GPS Coordinate Northing	Vehicular Traffic Count	Noise
Ada-George Road	Location Junction	6° 57' 56"	4° 51' 06"	328	72.5
	Okitim Junction	6° 58' 24"	4° 50' 39"	203	62.1
	Peperoni Junction	6° 58' 36"	4° 50' 07"	317	72.6
	Agip Junction	6° 58' 58"	4° 48' 46"	422	78.0
	Mechanic by Ada George Junction	6° 59' 05"	4° 48' 23"	441	79.7
Trunk C (Neighborhood Roads)					
Borokiri Road	Thumson Numbere Junction	7° 02' 04"	4° 45' 22"	3304	87.0
	Police Div Junction	7° 02' 22"	4° 44' 32"	4835	87.9
	Kolokuma Street Jumction	7° 02' 24"	4° 44' 49"	3250	85.8
	Captain Amagala Junction	7° 02' 19"	4° 45' 03"	4292	87.4
	Bishop Fugbara Junction	7° 02' 13"	4° 45' 14"	5432	82.7
Woji Road	Woji Junction	7° 02' 48"	4° 50' 10"	280	79.7
	RumuibekweJunction (Railway)	7° 02' 54"	4° 50' 49"	401	86.9
	YKC Roundabout	7° 03' 10"	4° 49' 14"	455	90.5
	Woji Estate Junction	7° 03' 18"	4° 49' 10"	170	69.8
	Akan Flyover	7° 03' 40"	4° 48' 28"	325	80.2
Rumuolumeni-Ogbogoro-Ozuoba Road	St John by Rumuolumeni Junction	7° 57' 21"	4° 49' 05"	328	73.2
	Elioparanwa Junction	6° 57' 09"	4° 49' 54"	297	74.4
	Ogbogoro Junction	6° 55' 45"	4° 50' 51"	351	76.1
	Egbelu Junction	6° 56' 34"	4° 50' 31"	350	75.3
	Ozuoba Junction	6° 55' 44"	4° 52' 14"	407	80.2

3. Results and Discussion

The spatial distribution of noise across the space of Port Harcourt indicated that the northern and eastern roads of the metropolis had the highest noise pollution as well as those of the southern roads respectively (Figure 3). In the northern segment, Igwurita (99.5 dB) and New road roundabout (96 dB), generated the highest vehicular noise in the spatial distribution. Thus, among the eastern roads, Eleme Flyover (98.1 dB) and Artillery Junction (95.5 dB) contributed the highest vehicular noise levels in the series. However, Ikoku Junction (92.8 dB) and Habour Road Junction by First Bank (92.5 dB) generated the highest vehicular noise among the roads located in the southern segment of the Port Harcourt metropolis. The part with the least vehicular noise pollution was the western segment with the UNIPORT junction (82.3 dB) and Rumuokwuta Roundabout (92.6 dB) having the highest. The spatial distribution of vehicular noise in the metropolis of Port Harcourt showed that they were not evenly dispersed in space.

Vehicular noise pollution is a product of vehicular counts on the road network. In the northern segment, New Road (2311 vehicles) and Igwuruta (1566 vehicles) Roundabouts generated the highest vehicular counts in the spatial distribution. Thus, among the eastern roads, Eleme Flyover (6735 vehicles) and Artillery Junction (5539 vehicles) contributed the highest vehicular counts in the area. However, Mile One Flyover (6252 vehicles) and Habour Road Junction by First Bank (6108 vehicles) generated the highest vehicular counts among the roads located in the southern segment of the Port Harcourt metropolis. The part with the least vehicular counts was the western segment with Rumuokoro (180 vehicles) and Uniport Junction (258 vehicles). The spatial distribution of vehicular counts in the metropolis of the Port Harcourt showed that they were not evenly distributed in space (Figure 4).

The spatial distribution of vehicular noise pollution across the space of Port Harcourt showed that the northern and eastern roads of the metropolis had the highest noise pollution. The roads with the highest noise in the northern segment were Igwurita (99.5 dB) and New Road roundabout (96 dB). In the eastern section of the metropolis, Eleme Flyover (98.1 dB) and Artillery Junction (95.5 dB) generated the highest vehicular noise level.

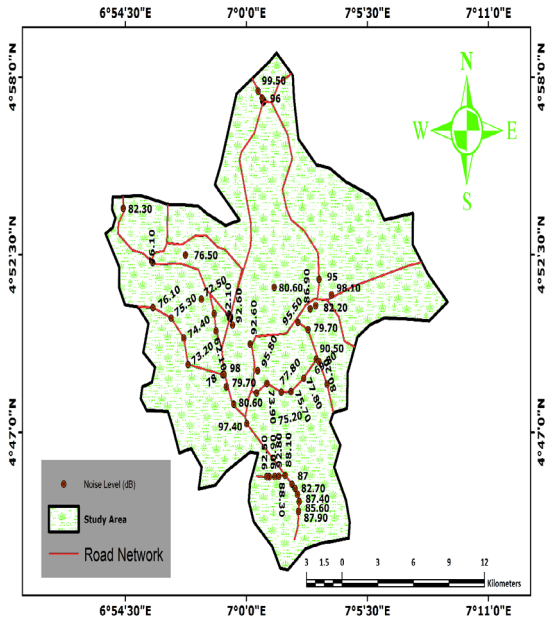

Figure 3. Spatial Distribution of Vehicular Noise Pollution in Port Harcourt Metropolis

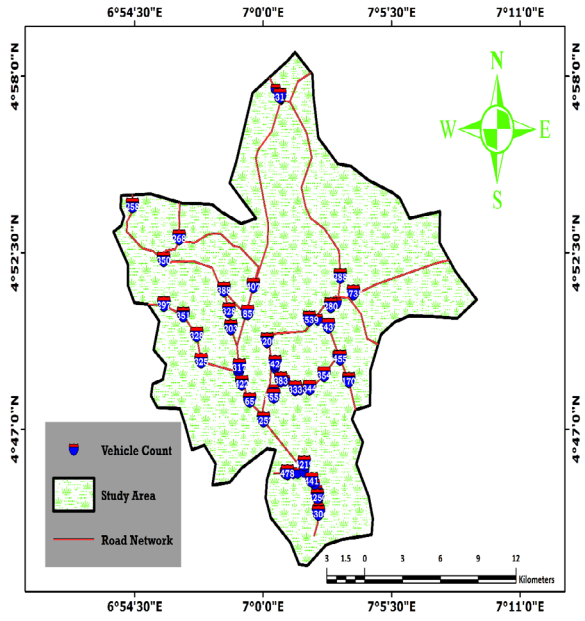

Figure 4. Spatial Distribution of Vehicular Counts in Port Harcourt Metropolis

In this vein, Evans and Hygge (2000) investigated the spatial distribution of traffic-induced noise exposures in a US city: An analytic tool for assessing the health impacts of urban planning decisions using a simple GIS-based noise model. The study discovered that urban noise was found to increase by 6.7 dB resulting from a rise in vehicular traffic on the streets. The spatial distribution of noise indicated that noise along arterial streets increased annoyance by 40%. Also, traffic noise pollution increased in the city's fastest-growing neighborhoods such as the Southern Market Area and those found in Chinatown and Downtown Civic Center. Thus, the study estimated that 17% of the city's population was at risk of high annoyance from vehicular traffic noise in different quarters of the city [16]. Similarly, a study was conducted on the traffic noise pollution assessment of Tehran, the capital city of Iran using the GIS-based spatial distribution map. The result indicated that the maximum equivalent sound level (Leq) was recorded on Basij Highway that is connecting the Central Business District (CBD) of the city at a maximum vehicular noise pollution level of 84.2 dB(A). But the roads around Fajr Hospital had minimum vehicular traffic noise of 59.9 dB(A). These studies, therefore, showed that spatial distribution of vehicular noise pollution can spread differently across the various roadways and in different segments of the city area using the GIS approach [17]. However, noise pollution has been studied in several cities of the world using the Geographic Information System (GIS) with data captured by the Global Positioning System (GPS) and noise level meter. A study was carried out on noise pollution in the city of Nairobi in Kenya. The researchers used the GPS to identify noise spots in CBD and applied the noise level meter to collect noise data. The findings showed that the average noise levels ranged between 61 dB to 78 dB which rose from the western part to the eastern segment of the CBD and was caused mainly by vehicular traffic noise on hot spots found more in the eastern city area [18]. Accordingly, a study has conveniently used the GIS to generate and analyzed data by applying deterministic and statistics models [19]. Furthermore, they spatially examine the dynamics of traffic-induced noise in the city of Tehran by using the Federal Highway Administration Traffic Noise Model (FHWA-TNM) and Iranian Traffic Noise Predictor (ITNP) and presented them in a GIS platform. Measurements were carried out during low and high traffic times within a time frame of six months. The results showed that the commercial areas had the highest noise level which was caused by poor regulation of traffic noise in the study area.

4. Conclusions

This study examined the georeferencing of vehicular noise pollution in the Port Harcourt metropolis. Many cities across the world are faced with noise pollution problems emanating from urbanization, industrialization and overpopulation which have resulted in serious psychological and physiological discomfort to the city dwellers. Thus, the study reviewed that there is a high risk of vehicular noise pollution across the cities of the world. The study used purposive and systematic approaches to

investigate the spatial spread of noise pollution in the city area by employing the GIS techniques in capturing locations of roundabouts and junctions, traffic count and noise level measurement. The vehicular noise level values have exceeded the recommended 75 dB national and international standards thereby exposing people to hearing impairment, sleep disorder, bad social behavior, cardiovascular disease, psychological symptoms, loss of long-term memory, disrupts reading and understanding, raise annoyance, raised catecholamine secretion, high blood pressure and disorders as well as hypertension. The city dwellers who are more affected by vehicular noise pollution are those located in the northern and eastern segments of the Port Harcourt metropolis with noise levels above 75 dB indicating that they are at risk of a psychological and physiological disorders. This study has empirically established that vehicular traffic counts vary across the selected roads; and that there is a strong relationship between vehicular counts and noise pollution. This implies that the higher the vehicular volume at roundabouts and junctions the greater the vehicular noise pollution across the roads in the metropolis. It therefore concludes that some cities have exceeded their vehicular noise pollution and environmental comfort threshold. This study recommends the expansion of more roads to the southern and western segments of the city to reduce traffic flow in the norther and eastern sections. Furthermore, there is a need to develop and implement a road-safety management framework targeting improving the attitude of road users and the environment for a sustainable city free from annoying noise levels.

Conflict of Interest

There is no conflict of interest.

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ARTICLE

Types, Distribution Characteristics, and Development Strategies of Rural Characteristic Industry in Xi'an Metropolitan Area

Xiaomeng Fu* **Pei Zhang** **Zhonghua Zhang**

School of Architecture, Xi'an University of Architecture and Technology, Xi'an, Shaanxi, China

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ABSTRACT

China's urbanization development has entered the "second half", which is at a critical stage of transition from the middle stages to the mature stage. The metropolitan area formed by the mega-city radiating the development of surrounding cities and counties is an important spatial carrier of urbanization. The rural characteristic industry is the main path to promote regional economic development and urban-rural integration in the metropolitan area. Exploring the development characteristics of rural characteristic industries in the metropolitan area has important theoretical and practical significance for promoting the effective connection between urban-rural integration and rural revitalization of the metropolitan area and improving the development quality of the metropolitan area. Take the Xi'an metropolitan area as an example and adopt kernel density analysis and other methods to reveal the spatial differentiation rules of rural characteristic industries. On this basis, the three-dimensional development strategy of "industry-spatial-institutional" for the development of the rural characteristic industry is proposed, to provide theoretical reference for the development of rural characteristic industry in metropolitan areas.

1. Introduction

Metropolitan area is the inevitable result of urbanization development. At present, China is in the stage of improving the development quality of new urbanization, and the metropolitan area is the core carrier for urban-rural integration in the new development stage. However, the long-established urban-rural relationship has put the countryside in a disadvantageous position for a long time, and the development gap between urban and rural areas has seriously restricted the improvement of the development quality of the metropolitan area. Therefore, to solve the urban-rural problems in the metropolitan area, the focus should be on the revitalization and development of the countryside. In 2021, China proposed to form a modern rural industrial system by 2025 [1]. Rural industries have typical characteristics of diversification and differentiation, in particular, the development of industry in the metropolitan area has gradually shown the trend of

*Corresponding Author:
Xiaomeng Fu,
School of Architecture, Xi'an University of Architecture and Technology, Xi'an, Shaanxi, China;
Email: 707561728@qq.com

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multi-function and multi-typology of "differences in different circles", "non-agricultural" and "complexity". The development of rural industry in Xi'an Metropolitan Area has the problems of single development type, low development efficiency, and extensive use of resources, which does not match the market demands for rural products of the Metropolitan Area with a high degree of integration of green countryside and local culture in the development. It is urgent to explore the key path of rural industry development in the Xi'an metropolitan area, which has important theoretical and practical significance for the revitalization of rural industry in the Xi'an metropolitan area.

In China's No. 1 central document in 2019 [2], it was first proposed to develop diverse characteristic agriculture according to local conditions and support the construction of several advantageous development areas for characteristic agricultural products [3]. In 2020, China's Ministry of Agriculture and Rural Affairs issued the National Rural Industry Development Plan (2020-2025) [4], which pointed out the development of rural characteristic industry and the promotion of industrial form from "small specialty" to "large industry" [5]. However, the current academic community has not yet formed a unified view on the concept of rural characteristic industry. Some scholars, by interpreting the relevant policies of national rural industry, propose that rural characteristic industries are based on the local natural environment, history, and culture, and inherit local breeding traditions and handicraft industries to form local economic activities. In addition, rural elements are also used as conditions for integrated development to innovate new industries and new business models such as leisure tourism and modern recreation industries. Scholars generally believe that rural characteristic industries should have the following characteristics: First, market-oriented development; second, integration of regional resources and characteristic advantages; third, strong competitive advantages and significant economic benefits; the development of rural characteristic industries aims to highlight the uniqueness and differences of industrial development [6], drive capital, technology, and talents, etc. to gather in the countryside and provide the impetus for rural industrial development [7]; on this basis, give play to the comparative advantages of characteristic resources in rural areas, provide re-employment opportunities for villagers, and promote the structural optimization and upgrading of rural industry [8,9].

With the successful completion of the task of poverty eradication, improving the quality of rural industrial development and consolidating the results of poverty eradication have become the focus of China's "agriculture - rural - farmers" work. The Academic Circle of Urban and Rural Planning in China has begun to pay attention to the development of rural characteristic industries, mainly focusing on foreign characteristic industrial development patterns [10], the types of rural characteristic industries in China [11], industry chain integration, and extension [12], capital operation mode [13], mutual relationship between industrial development subjects [14], policy [15] and system design [16], etc., and fruitful research results have been achieved. However, previous studies have focused on villages in relatively poor areas, and relatively few studies have been conducted on villages in rural areas around big cities. The current research on the rural characteristic industry in metropolitan areas mainly focuses on urban agriculture and modern agriculture, including the analysis of the evolution of their multiple functions and development patterns. In terms of industrial functions, the development of rural industry in metropolitan areas not only assumes the production function of providing agricultural products for urban residents [17] but also the dual function of providing production and living space for cities [18]. Secondly, in terms of development mode, Zhang Yongqiang and others analyzed the main models of the development of rural characteristic industries around foreign big cities, including the Japanese model of "one village and one product" [19] and the agricultural park model, the American model of citizen farm and commercial farm, and the German model of leisure farm [20], and put forward the experience beneficial to the development of rural characteristic industries in China [21]. Wang Xiaojun combed and compared the typical modes of urban agricultural development in China, and studied the driving mechanism of different modes [22].

In summary, the academic community mainly discusses the connotation, characteristics, and development mode of rural characteristic industry, which provides a useful reference for this paper to study the type, characteristics, and path of rural characteristic industry in metropolitan areas. At the same time, the existing studies on rural characteristic industries in metropolitan areas mainly focus on the expansion of their functions and theoretical discussion of development modes, but lack of research on type level and space level. Therefore, under the background of urban-rural integration at the regional level, based on the combination of field investigation and spatial data, this paper analyzes the types and spatial characteristics of rural characteristic industries in the Xi'an metropolitan area to explore the key path of its development, and to provide theoretical reference for the prosperity of rural industry in the metropolitan area and the promotion of high-quality development in the metropolitan area.

2. Research Methodology and Data Sources

2.1 Research Methodology

This paper adopts the kernel density method to analyze the spatial distribution characteristics and types of rural characteristic industries in the Xi'an metropolitan area (Figure 1). The specific research route is as follows: Firstly, the villages with rural characteristic industries in Xi'an metropolitan area are identified through relevant basic research; secondly, these villages are spatially abstracted into a POI point and their spatial distribution characteristics are identified by the kernel density analysis; and then, the kernel density method is used to determine the agglomeration characteristics of different types of rural characteristic industries.

2.2 Data Sources

In 2021, China issued the National Key Industries Guidance Cataloged for Rural Areas (2021 Version) and the National Rural Characteristic Product Cataloged (Table 1), aiming to make clearer classification development guidelines for the rural characteristic industries. The villages involved in this paper are from the list of "rural characteristic industries", "one village and one product", "rural revitalization demonstration villages", "urban-rural integration pilot" and other names issued by the government departments such as the agricultural and rural departments, rural revitalization departments, natural resources departments of China, Shaanxi Province and cities in Xi'an Metropolitan Area. The relevant data are obtained from public information on government websites, relevant plans, and field research.

Table 1. List of Rural Characteristic Products Cataloged in China[①]

Serial number	Classification	Contents
1	planting products	It mainly includes characteristic vegetables, fruits, edible fungi, authentic Chinese herbal medicines, tea, coffee, cotton and hemp, flower seedlings, etc.
2	aquaculture products	It mainly includes characteristic livestock and poultry products and characteristic aquatic products. Among them, the characteristic livestock and poultry products include the characteristic herbivores, pigs, poultry, bees, etc., as well as the characteristic livestock and poultry products listed in the national livestock genetic resources catalog. The characteristic aquatic products include the products except for the four types of traditional cultured fish green carp, grass carp, bighead carp, and silver carp, and do not include the species listed on the list of national key protected aquatic wild animals.
3	food processing products	It mainly includes characteristic foods with regional characteristics, cultural connotations, and unique flavors after characteristic processing, including local halogen products, sauce products, bean products, preserved meat, national characteristic dairy products, etc.
4	handicrafts products	It mainly includes handicraft products with regional, ethnic, historical, and cultural characteristics produced by traditional characteristic handicrafts, including hand weaving, embroidery, paper cutting, batik, pottery, sculpture, etc.

Source: Ministry of Agriculture and Rural Affairs of China

Figure 1. Schematic diagram of development planning scope of Xi'an metropolitan area

Source: Xi'an metropolitan area development plan

① Ministry of Agriculture and Rural Affairs of China. Notice on Carrying out the Promotion of National Rural Characteristic Products and Rural Craftsmen in 2021. [EB/OL].2021.12.31[2022.9.1]. http://www.moa.gov.cn/nybgb/2021/202112/202112/t20211231_6386160.htm

3. Analysis of the Feature of the Rural Characteristic Industries in the Xi'an Metropolitan Area

3.1 Basic Features of Rural Industry in the Metropolitan Area

A metropolitan area is an urban hierarchy centered on one or several large cities or mega-cities, including the surrounding small cities, towns, and rural areas. Therefore, the rural industry of a metropolitan area includes both urban agriculture in the core circle and rural agriculture in the rural areas around the city [23]. The rural industry in this region often has the advantage of attracting urban production factors and large-scale markets as well as the integration of urban and rural industries due to the strong radiation and diffusion effect of the metropolitan area itself [24]. Therefore, rural industries in metropolitan areas tend to have the following features.

(1) Rural industries in urban areas often have the phenomenon of "big market, small agriculture". As the villages in the metropolitan area are close to the cities, in the process of urbanization, the villages are strongly influenced by the cities, which has a certain impact on the rural agricultural production space. In addition, in this process, a large number of agricultural laborers have been attracted to work in cities. Meanwhile, based on Agricultural location theory, the villages in the metropolitan area mainly provide agricultural products for the cities, and due to the shortened transportation distance, their agricultural products are mainly fruits and vegetables, flowers, and other types that are not resistant to storage and transportation.

(2) With the urbanization of the metropolitan area and the continuous improvement of the level and quality of agricultural modernization, the rural industry in the metropolitan area is developing towards branding, specialization, and scale. At the same time, the quality of products, the technical conditions of production, and the competitiveness of the market are also constantly improving. Under the requirements of expanding the market and improving demand quality, the rural industry in the metropolitan area has entered large-scale, scientific, and industrialized development. At the same time, it gradually began to develop green agriculture, agricultural products with geographical indications, and characteristic agricultural products.

(3) Diversified and compound functions of rural industries in metropolitan areas. In the process of urban-rural integration, the countryside in the metropolitan area has the dual function of providing production space and ecological space for the city. Therefore, the countryside industry in the metropolitan area also extends the industrial chain based on traditional agriculture, combines its ecological and cultural resources, develops leisure agriculture, ecological agriculture, agricultural science, and other industries [25], brings into play its ecological and cultural and other functions [26], and in this process, realize the multi-functional combination of production, ecology, life, and culture.

3.2 Type Features of the Rural Characteristic Industry in the Xi'an Metropolitan Area

Based on the above analysis, the rural industry in the metropolitan area should not develop labor-intensive large-scale agriculture but develop refined and specialized rural characteristic industries. Based on the national classification standards of rural characteristic industries and various agricultural products classification standards such as the Statistical Classification of Agriculture and Related Industries (2020)②, rural characteristic industries in the Xi'an metropolitan area are divided into four categories: characteristic planting industry, characteristic aquaculture industry, characteristic food processing industry and characteristic handicraft industry, and further subdivide each category by comprehensively considering the characteristics of rural characteristic industries in Xi'an metropolitan area. (Table 2).

In terms of the primary classification, among the rural characteristic industries in the Xi'an metropolitan area, the characteristic planting industry accounted for the largest proportion, accounting for 72.8% of the total, followed by the characteristic aquaculture industry, accounting for 15.3% of the total, while the characteristic food processing industry and the characteristic handicraft industry accounted for a very small proportion. From the secondary classification, among the characteristic planting industry, the fruit planting industry accounts for the largest proportion, accounting for 50.7% of the total, followed by edible fungus planting, accounting for 10.2% of the total. In the characteristic aquaculture industry, the proportion of each subcategory is relatively average; in the characteristic food processing industry, the refined tea processing industry accounts for 3.4% of the total, and Jing Yang Fu tea is the main category. On the whole, the trend of diversifying the types of rural characteristic industries in the Xi'an metropolitan area is not obvious.

② National Bureau of Statistics. Statistical classification of agriculture and related industries (2020) (Order No. 32 of the National Bureau of Statistics). [EB/OL].2020.12.14. [2022.9.1]. http://www.stats.gov.cn/tjgz/tzgb/202012/t20201214_1809096.html

Table 2. Classification of rural characteristic industries in the Xi'an metropolitan area

Primary classification	Secondary classification	Three level classification	Proportion
characteristic planting industry (72.8%)	fruits	kiwifruit, grape, winter jujube, and fresh peach	50.7%
	vegetables	-	5.1%
	edible fungi	-	10.2%
	spice	Sichuan pepper	1.7%
	Chinese medicinal materials	honeysuckle and baikal skullcap	5.1%
characteristic aquaculture industry (15.3%)	livestock breeding	sheep and pigs	5.1%
	egg and milk feeding	milk goat	5.1%
	other	rabbit, etc	5.1%
characteristic food processing industry (8.5%)	fruit processing	dried persimmon	1.7%
	sugar processing	qiongguo sugar	1.7%
	refined tea processing	fu tea	3.4%
characteristic handicraft industry (5.1%)	no subdivision subclass	handwoven cloth, straw weaving, shadow play	5.1%

Source: compiled by the author

3.3 Spatial Distribution Characteristics of Rural Characteristic Industries in the Xi'an Metropolitan Area

To further characterize the spatial distribution of rural characteristic industries in the Xi'an metropolitan area, a kernel density analysis was conducted for rural characteristic industries in the Xi'an metropolitan area. On this basis, a kernel density analysis was carried out for the two types of industries that account for a large proportion, namely, the characteristic planting industry and the characteristic aquaculture industry (Figures 2-3). In terms of spatial distribution, there are mainly the following high-density areas of rural characteristic industries within the Xi'an metropolitan area: Baqiao District and Zhouzhi County of Xi'an, Yangling Demonstration Zone, Jingyang County of Xianyang City, Fuping County of Weinan City, and Yaozhou District of Tongchuan City.

The characteristic planting industry is most widely distributed in the Xi'an metropolitan area, among them, the density of the Baqiao area within the core circle is relatively high; the outer circles form high-density areas in Yangling District, Qian County, Zhouzhi County; the characteristic aquaculture industry is mainly in Yaozhou District of Tongchuan City with relatively high-density values; the characteristic food processing and characteristic handicraft industries are very scattered in the metropolitan area, and the number is relatively small, so they cannot form a high-density cluster in the real sense.

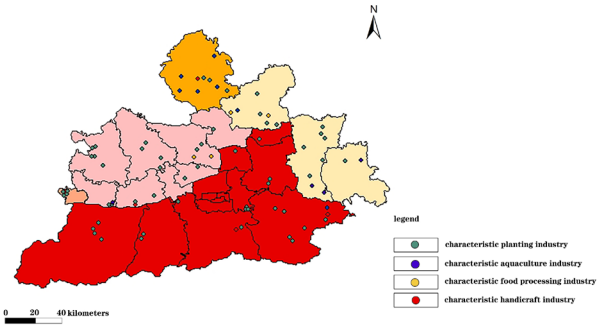

Figure 2. Spatial distribution of rural characteristic industry in Xi'an metropolitan area (Self-drawn by the author)

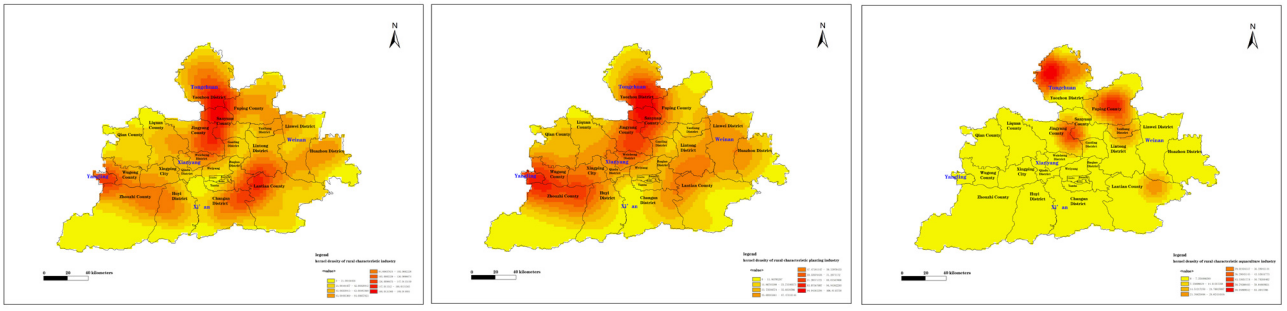

Figure 3. Analysis of kernel density of rural characteristic industries in the Xi'an metropolitan area (Self-drawn by the author)

From the spatial distribution characteristics and type characteristics, the development of rural characteristic industries in the Xi'an metropolitan area relies heavily on its resource background. From the kernel density analysis map, the high-density areas of rural characteristic industries mainly exist in the Guanzhong Plain, which has a good agricultural foundation, while the Qinling Mountain area in the south has very little distribution. At the same time, the influence of market factors on the rural characteristic industry is also more prominent, especially in the metropolitan area, the frequent flow of urban and rural factors also brings a huge demand for fresh agricultural products in the urban market, which makes the characteristic planting industry account for more than 70% of the total rural characteristic industries, and is widely distributed within the metropolitan area, forming several agglomerations. In addition, social factors such as talents and technology also play a large role in the development of rural characteristic industries. For example, the development of rural characteristic industries in Yangling District, where Northwest Agriculture and Forestry University of Science and Technology is located, is supported by scientific and technological talents from universities, and thus a cluster of rural characteristic industries has been formed in this area. Therefore, the natural background, social economy, and policy system are the important driving forces affecting the development of rural characteristic industries in the metropolitan area.

4. Strategies for the Development of Rural Characteristic Industry in the Xi'an Metropolitan Area

Based on the above characteristics, the development of rural characteristic industry in the Xi'an metropolitan area should build a three-dimensional synergy of "industry-space-institution" [27] (Figure 4).

4.1 Spatial Reconfiguration: Transformation of Traditional Farming Areas to Industrial Clusters

4.1.1 Transformation of Traditional Farming Areas into Rural Characteristic Industrial Parks

The rural characteristic industries in Xi'an metropolitan area have shown certain spatial agglomeration, therefore, to realize the spatial reconfiguration of rural characteristic industries in the Xi'an metropolitan area, firstly, various rural characteristic industrial parks and rural characteristic industrial science and technology parks should be built on this basis, taking this as a grip to extend the rural characteristic industrial chain, tap the characteristics of rural industries in Xi'an metropolitan area to increase the value chain and form a competitive and diversified industrial agglomeration pattern [28]. Secondly, all kinds of rural characteristic industrial parks should establish industrial park alliances based on geographical location and economic location, and optimize the layout of rural characteristic industries through integrated planning in space; in

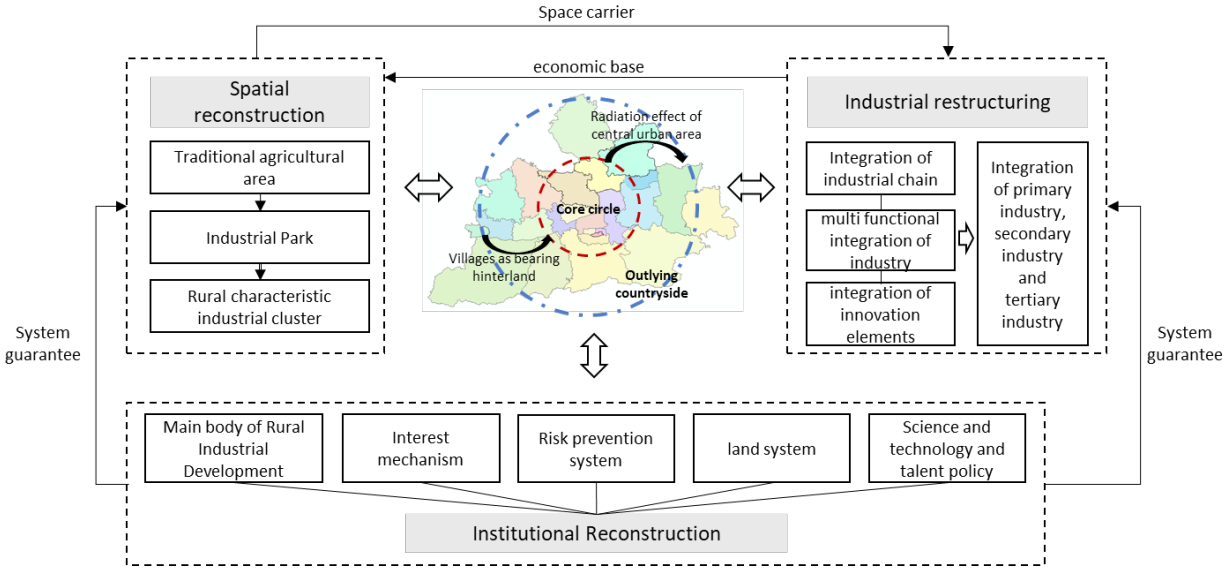

Figure 4. Strategy framework for the development of rural characteristic industries in the metropolitan area

Source: Refer to Article 27 and redraw

the construction of parks, taking into account "scale and characteristics" to avoid homogeneous competition among parks; In terms of industrial development, it is necessary to extend the industrial chain through the level-by-level contact of industrial parks at all levels, namely "industrial parks - Science and Technology Parks - Entrepreneurship parks", to realize "products - commodities - brands", and to promote the extension of rural characteristic industries to pre- and post-production [29].

4.1.2 Transformation from the Rural Characteristic Industrial Park to Rural Characteristic Industrial Cluster

Upgrading the rural characteristic industrial park to an industrial cluster will enable the development of the rural characteristic industry to restructure the rural production, life, ecology, and cultural space in space and help the revitalization of the rural industry. Rural characteristic industrial clusters have four characteristics of spatial concentration, specialization, networking, and rottenness, among which networking is its essence [30]. Therefore, the development of rural characteristic industry clusters must create a rural characteristic industry development network including organizers, actors, and linkage mechanisms of industrial development. Firstly, under the guidance of the government, various non-governmental organizations, including financial organizations and consulting organizations, will be united to establish a dialogue and cooperation platform for the development of rural characteristic industrial clusters, to improve the cooperation efficiency of the main body of rural characteristic industry development, namely, enterprises, agricultural cooperatives, and governments; secondly, accelerate the "government-production-academia-research-use" network. Secondly, we should speed up the combination of "official, industry, learning, research and application" to jointly create an industrialized consortium and form an organic whole for the sustainable development of rural characteristic industries, to meet the main requirements of rural revitalization, such as talent revitalization, organizational revitalization, scientific and technological progress, cooperation and symbiosis, and further promote the high-quality development of rural characteristic industries [31].

4.2 Industrial Reshaping: Strengthen the Cohesion of Rural Characteristic Industries through Industrial Integration

4.2.1 Integration of the Whole Process of Rural Characteristic Industry Chain

First of all, we should promote the cross-fertilization of rural characteristic industries within the industry chain. Taking the combination of the characteristic planting industry and characteristic aquaculture industry, the combination of the characteristic planting industry and characteristic food processing industry, the combination of the characteristic planting industry and characteristic handicraft industry, etc. as the guide, we should accelerate the cross-fusion of various types of rural characteristic industries. Secondly, based on the cross-fertilization of various types of industries, the extension of the industrial chain should be promoted in depth. We should make full use of the foundation and development capacity of secondary and tertiary industries in the Xi'an metropolitan area, and create leisure tourism such as agricultural experience and sightseeing through deep processing of characteristic products and excavation of unique natural ecological and cultural resources in rural areas, to enhance the aggregation power of rural characteristic industries in Xi'an metropolitan area. Again, strengthen the management of logistics and information chains. In each link of the production-processing-marketing of rural characteristic industries, we should coordinate the relationship of various interest subjects, improve the overall efficiency of the rural characteristic industry chain, build a modernized agricultural industry system with a sound system, complete elements, advanced technology, close connection, and benign development, and improve the modern agricultural industry system in all aspects [32].

4.2.2 Integration of Multiple Functions in Rural Characteristic Industries

The multifunctional play of rural characteristic industries is of great significance to the integrated development of rural industries. First, in terms of industrial development, it should combine the unique ecological environment, historical culture and local characteristics of the Xi'an metropolitan area, fully combine the agricultural culture and historical cultural heritage of Guanzhong region, and promote the extension of the rural characteristic industry chain through the industrial integration of tourism, education, culture and recreation, so that it can change from a traditional single industry to a refined, quality and diversified industry; second, in terms of industrial carrier, the development of rural characteristic industries should meet the market demand of metropolitan areas, focusing on cultivating the field complex and characteristic town that integrate leisure agriculture and tourism [29]; again, starting from the industrial form, breaking the conventional industrial form of agriculture focusing on production, industry focusing on processing and commerce focusing on sales, and realizing the rural character-

istic industrial system that integrates the development of agriculture, industry and commerce [33].

4.3 System Reconstruction: Innovation of Supporting System for Rural Characteristic Industry Development

4.3.1 Cultivating Diversified Business Subjects

The development of rural characteristic industry in the metropolitan area needs to cultivate diversified business subjects and promote the integration of interests between cities and villages at different levels and various interest subjects in the metropolitan area. Compared with traditional agricultural areas, rural development in the metropolitan area is highly dynamic, complex, and weakly protected, but in the process of urban-rural integration, rural areas in the metropolitan area attract production factors such as capital and technology from cities. Therefore, the development of rural characteristic industries in metropolitan areas needs to combine leading enterprises, rural cooperative organizations and competent people, etc., to give full play to their efficient management, market gathering, and talent-gathering abilities, build new agricultural production and management relationships and explore a multi-body integrated agricultural development model [34].

4.3.2 Improve the Interest Linkage Mechanism

The fundamental purpose of the development of rural characteristic industries in the metropolitan area is to improve the level of rural industrial development and promote the development of urban-rural integration in the metropolitan area. Therefore, the development of rural industry in the metropolitan area should adhere to the principle of "base in agriculture, benefit in rural areas, and benefit in farmers", and support various business entities to sign long-term contracts with electric business platforms such as Jingdong, Tmall, and Hema, guide enterprises, cooperatives, and other rural characteristic industry development entities to cooperate closely with each other [29], and develop a new type of win-win cooperation relationship, so that farmers can participate more deeply in the rural characteristic industry, thus sharing more value-added industrial income and obtaining higher actual income [35].

4.3.3 Sound Risk Prevention Mechanism

In terms of farmers' rights and interests, the rapid changes in urban-rural relations in the metropolitan area bring about the dynamic and instability of rural characteristic industries will affect farmers' enthusiasm for industrial development, therefore, the development of rural characteristic industries in the metropolitan area should employ farmers who have lost their land and provide them with jobs and new social security. In terms of land use systems, rural characteristic industrial clusters need to integrate rural land resources. The government should actively explore the risk guarantee system of rural land circulation, collective commercial construction land entering the market and agricultural land leasing to ensure the use efficiency of rural land; in terms of industrial development risks, in the face of the current force majeure factors such as the COVID-19, the development of rural characteristic industries should explore the establishment of an insurance system and improve the catastrophe risk transfer and sharing mechanism for rural characteristic industries [29].

4.3.4 Reforming Rural Land System

For the rural areas in the metropolitan area, land resources are particularly tight. Reforming the rural land system is the key to promoting the formation of rural characteristic industry clusters. First, the land rights of rural in the metropolitan area should be confirmed to provide spatial support for the development of rural characteristic industries at the institutional level. Secondly, we should explore the system of rural land transfer, the system of market entry of collective management construction land, and the system of "the ownership, contracting right and management right of rural land shall be managed separately" [36], so that the scattered agricultural land in the countryside can be concentrated into large planters and leading enterprises in the above ways to facilitate the formation of industrial clusters and provide effective land supply for the development of rural characteristic industries. At the same time, we should continue to explore the professional platform and market for rural land transfer, reasonably, and legally transferring rural land, effectively safeguarding the legitimate land rights and interests of farmers [37].

4.3.5 Strengthen Science and Technology and Talent Support Policies

One of the major advantages of the rural characteristic industry in the metropolitan area that is different from the traditional rural industry is that the urban-rural integration in the metropolitan area helps to provide more technical and talent support for the development of the rural characteristic industry. Encourage and guide the new agricultural operation entities represented by leading enterprises to cooperate with universities, scientific research institutes and other research institutions [38], improve the conversion efficiency of agricultural science and innovation results

and increase the added value of products [39]; absorb agricultural science and technology innovation results, relying on research institutions such as Northwest University of agriculture and forestry science and technology, a number of agricultural science and technology alliances integrating agricultural science, education, production, study and research have been established, and rely on the driving force of science and technology innovation to continuously promote the development of "integration of primary industry, secondary industry and tertiary industry" of rural characteristic industries; attract rural migrant population to return home and participate in the construction of rural characteristic industries, promote the training program for modern young farmers and high-quality farmers, and focus on improving the level of rural human capital [40].

5. Summary and Prospect

The metropolitan area is a product of urbanization development and an important spatial carrier for the integrated development of urban and rural areas. How to maintain the rural identity and realize rural revitalization in the rapid urbanization process is one of the key points and difficulties in the development of metropolitan areas. Unlike the highly developed metropolitan areas, the Xi'an metropolitan area is still in the nurturing stage, and its level of urban-rural integration is relatively low, and a large number of rural areas are preserved. For this reason, the research on the rural areas of the Xi'an metropolitan area will also provide a reference for the urban-rural integration of China's metropolitan area. The rural areas in the metropolitan area are highly dynamic, complex, and weakly protected due to their unique location conditions, and in this context, the development of rural industries in the metropolitan area should emphasize characteristics. The types of rural characteristic industries in the Xi'an metropolitan area include characteristic planting industry, characteristic aquaculture industry characteristic food processing industry, and characteristic handicraft industry, however, the types and spatial layout are uneven, which leads to a large development gap between villages and serious homogeneous competition among products. Therefore, it is necessary to build a three-dimensional coordinated "industry-spatial-institutional" strategy system for the development of rural characteristic industries and to promote the development of rural industries in metropolitan areas through spatial reconstruction, industrial reshaping, and institutional reconstruction.

Author Contributions

Author Xiaomeng Fu is responsible for related information, data collection and computing, research methods and results analysis, and article writing.

Author Pei Zhang is responsible for theoretical guidance and logical architecture analysis.

Author Zhang Zhonghua is responsible for the drawing and subsequent proofreading of the pictures in the text.

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Conflict of Interest

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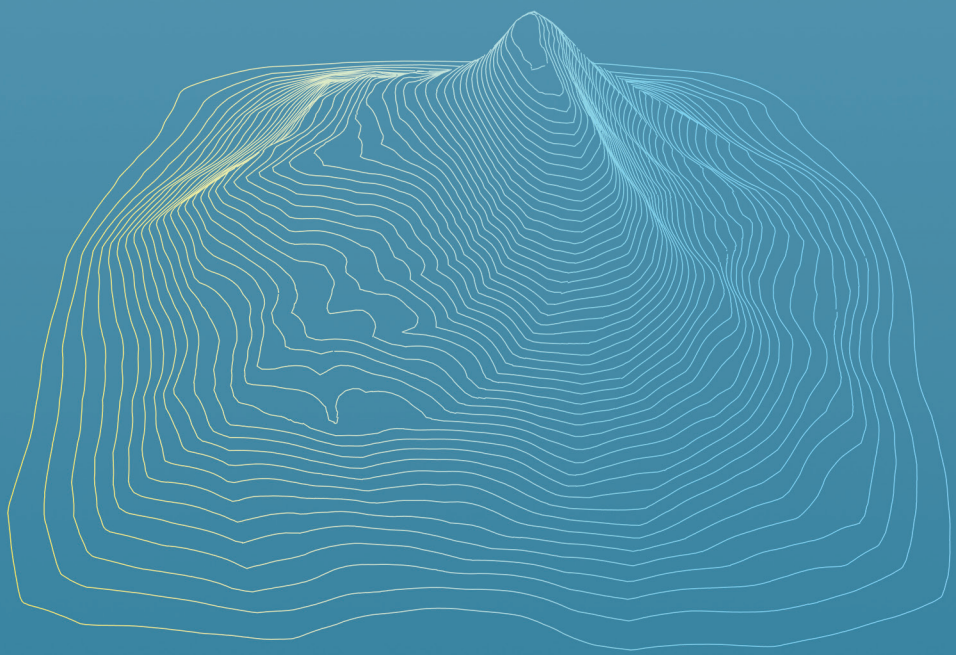

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