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Spatial Distribution and Influencing Factors of Single-Person Households with Social Isolation in Seoul, South Korea

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Abstract: Previous studies on social isolation and quality of life in single-person households (SPHs) faced limitations in identifying socially isolated groups in a citywide and detailed spatial range. The emergence of big data from various sources offers new possibilities for studying the relationship between SPHs and social isolation. This study examined the spatial distribution of SPHs at high risk of social isolation by age group and the influencing factors for Seoul, South Korea, using Seoul Citizen Life Data. Local indicators of spatial association clustering and spatial econometric models were used for the analyses. The results show, first, that SPHs are concentrated in areas with a high proportion of small- and medium-sized houses and non-apartment-type housing. Second, clear spatial distribution patterns based on life-cycle characteristics exist, with young people clustering near universities and employment centers and older people clustering in residential areas. Third, these life-cycle patterns are not as evident for SPHs with a higher risk of social isolation. Our findings show that not all SPHs can be considered a group with a high risk of social isolation, and the residential patterns of socially isolated SPHs differ from those of typical SPHs throughout their life cycle.

Keywords: single-person households; social isolation; living alone; Seoul Citizen Life Data; big data

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1. Introduction

Research on single-person households (SPHs) in Korea has gained attention since the mid-2000s, when their proportion exceeded 20% of all households. The rapid increase in SPHs is considered the main factor in promoting social change [1], as they determine the nature of the housing market, urban spatial structure, and direction of urban development. This is because the lifestyle of single-person households determines not only the nature of the housing market but also the urban spatial structure and the direction of urban development [2]. The proportion of SPHs in Korea was only 15.5% in 2000, but it increased to 34.5% by 2022.

The prevalence of SPHs is on a notable rise, especially among young people and the elderly. According to K-indicators [3], this proportion has surged from 6.5% in 2000 to 12.3% in 2022 for young adults and 4.4 to 9.5% among older people. This trend is the most pronounced in Seoul. The number of SPHs in Seoul increased by 27.69%, from 1.21 million in 2018 to 1.55 million in 2022. In Seoul, SPHs of those aged 20–39 years were approximately 100,000 units higher than those of other age groups between 2018 and 2022 [4]. Therefore, understanding the spatial behavior of SPHs provides useful insights for urban planning and policy formulation [5–8].

Many studies have provided considerable insights into the spatial distribution and factors influencing SPHs by gender and age [9–12]. However, these studies have not sufficiently addressed the issue of social isolation, which is the most important problem caused by the increase in SPHs [13], because they relied on information from small sample data, such as surveys and in-depth interviews [14,15]. Small data can only identify the socially isolated SPHs within limited areas. Such data are unsuitable for studying the spatial distribution of SPHs across a broad geographic area with detailed spatial granularity.

The emergence of big data from various sources offers new possibilities for studying the relationship between SPHs and social isolation. Big data possess spatial details, enabling them to address the limitations of small data. In particular, the Seoul Citizen Life Data, a database recently released by the Seoul Metropolitan Government, combines mobile phone data with public data from Statistics Korea to offer comprehensive details on the locations of SPHs, along with their frequency of going out, texting and calling, and social media usage. This allows for the identification of socially isolated SPHs and an understanding of their location patterns across the city.

Therefore, this study utilized Seoul Citizen Life Data to analyze the spatial distribution of SPHs at high risk of social isolation, categorize them by age group, and explore their influencing factors. First, we utilized local indicator of spatial association (LISA) clustering to determine whether and where SPHs are concentrated. Second, we used a spatial econometric model to explore the factors that affect the distribution of SPHs while addressing the spatial autocorrelation. This study provides practical guidance for establishing of urban policies for SPHs that are at a high risk of social isolation, thereby promoting their social integration in cities and facilitating a more inclusive and vibrant urban environment.

The remainder of this paper is organized as follows. The next section reviews existing research on the social isolation of SPHs and their spatial distribution and presents the distinctions of this study. Section 3 describes the study area, data, and methods. In the Section 4, we describe the spatial distribution of socially isolated SPHs by age group and their influencing factors using a spatial econometric model. In Sections 5 and 6, we summarize the findings and discuss their implications.

2. Literature Review

2.1. SPHs and Social Isolation

In this section, we review the relationship between SPHs and social isolation, and the determinants of the spatial distribution of SPHs, to explore the spatial distribution of SPHs at high risk of social isolation.

The increase in SPHs in Western societies has been acknowledged as a natural phenomenon in late-stage industrial societies. In the past four decades, SPHs have been reorganized as a key household type for urban planning and urban policy [1,2,6]. Japan, Korea and other East Asian countries have experienced a rapid increase in SPHs over the last two decades [16,17]. Therefore, recent studies have analyzed the causes and characteristics of SPHs in Korea and East Asian countries [17–20]. These studies point to the spread of individualism, decline of marriage, rise of divorce and separation, aging population and decline of familism as the main reasons for the rapid increase in SPHs [1,21,22].

The increasing number of SPHs has led to changes in various housing types and living cultures. The loneliness and social isolation experienced by individuals in SPHs have emerged as new social problems. The relationship between SPHs and social isolation has been analyzed in depth in countries such as Germany, France, and the United Kingdom, where the proportion of SPHs reached 30 to 40% of all households in the 1980s and 1990s. Previous studies have shown that SPHs are more likely to experience social isolation and loneliness at relatively high rates, leading to poorer physical and mental health and lower life satisfaction [19,23–28]. However, these studies tend to assume that certain groups are socially isolated. For example, many studies use census data to categorize groups based on marital status and the presence of children and assume that divorced, widowed, or SPHs with children but not living together are socially isolated [14]. However, it is a generalization error to assume that SPHs *per se* are directly related to social isolation or are socially vulnerable [22].

Living alone is not necessarily associated with social isolation. Cultural differences across countries are more important in the relationship between SPHs and social isolation [29]. In Western societies, it has been argued that being an SPH does not necessarily equate to social isolation. Hill, Banks and Haynes [29] analyzed the United Kingdom and found that, while older and childless SPHs are more likely to be socially isolated, the extent to which SPHs experience social isolation is not statistically different from that of non-SPHs, because many SPHs in the UK regularly meet and interact with their children and friends. However, they argue that childless Japanese SPHs in the UK are more likely to be socially isolated than SPHs in other countries, which is similar to other studies on Japanese society [23].

Much of the literature focuses on older adults living in SPHs [15,23,24]. Older people are more likely than other groups to experience social isolation because of declining incomes and diminishing physical abilities, which make it difficult for them to participate in various social activities [23]. However, given that SPHs can be categorized into various groups based on age and socioeconomic characteristics, it is not necessarily only elderly SPHs that are subject to social isolation. In Korea, social isolation and related problems in young and middle-aged SPHs are becoming more serious [30]. Therefore, it is necessary to identify SPHs that experience social isolation from various groups and their characteristics.

Recent studies have largely overcome this problem by collecting the experiences and perceptions of individuals through sample-based surveys [12,15,30]. However, because of the nature of sample surveys, their ability to capture the comprehensiveness of socially isolated SPHs is confined to a limited area [15,30]. Studies using census data have used socioeconomic characteristics (e.g., low income, elderly status, etc.) as predictors of social isolation because a census cannot account for the frequency or regularity of an individual's social contacts. The use of big data, which can identify individual behavioral patterns, socioeconomic levels, and demographic characteristics, provides a new alternative to overcome the above limitations.

This literature review suggests the need for a systematic and in-depth study tailored to the Korean context. In fact, studies focusing on the social isolation of SPHs in Korea are relatively recent and need to be accumulated [31–33]. In Korea, the relationship between SPHs and social isolation has mainly been addressed in sociology and social work; however, there is a lack of research on this topic from a spatial perspective. Understanding the spatial distribution of SPHs is essential for the establishment of place-specific policies by local governments. In the context of various social problems (e.g., crime, suicide, and depression) becoming more serious owing to social isolation in Korean society, exploring the spatial distribution of socially isolated SPHs is important to clearly reveal the spatial behavior of the most vulnerable groups.

2.2. Spatial Distribution and Influencing Factors of SPHs

In the last decade, with the explosive growth of SPHs, geographers and urban planners have conducted studies on the spatial distribution of SPHs and their controlling factors. SPHs are characterized differently from other household groups in terms of their preferences for housing types and prices by region because of the small number of household members and relatively low household income [9,34,35]. Studies have shown that SPHs tend to favor neighborhoods with relatively small house sizes, low-density multifamily housing, and relatively low land and rental prices [9,35].

However, this depends on the life cycle. In general, life-cycle preferences for proximity to work have a significant impact on the spatial distribution of households. Previous studies have argued that SPHs are more mobile than other household types, with housing choices based on individual decisions and preferences [2,36]. Several studies have found that SPHs tend to live near universities or employment centers [9–11,35,37–39]. Young adults have been shown to have a higher preference for proximity to work and access to public transportation than other groups.

Young and middle-aged SPHs tend to value public transportation access and distance to school or work more than housing conditions and neighborhood quality [40]. Moon and Song [41] found that the higher the density of SPHs, the lower the satisfaction with the living infrastructure, indicating that the quality of the leisure facilities and the natural environment in these areas is not high. Several studies have found that young adult SPHs are willing to pay higher rents to stay in smaller living spaces in urban centers at the expense of community, neighborhood, and proximity to leisure facilities [9,12,42].

Studies have shown the influence of two important factors on the spatial distribution of SPHs. First, the spatial distribution of SPHs varies based on their life cycles. Young people tend to live in areas with good access to universities and city centers, whereas older people tend to live in relatively residential areas as they continue to live in their existing neighborhoods. Second, because of the socioeconomic characteristics of SPHs, they tend to live in small- and medium-sized houses or places with low rent, but their strong preference for accessibility leads them to choose areas with higher rent at the expense of a good environment. This is particularly true for young adults.

2.3. Research Gaps

Although previous studies have identified the spatial distribution patterns of SPHs by age and derived the influencing factors, major research gaps still exist. First, owing to data limitations, existing studies have not addressed the issue of social isolation, which is the most fundamental problem caused by an increase in SPHs in a broad geographic area with fine-grained spatial units [15,30,43]. Census data do not provide information on the frequency of face-to-face contact or social interactions, and sampling surveys cannot examine the social isolation of all people. However, recent advances in mobile big data have made it possible to identify groups with fewer face-to-face and non-face-to-face interactions on smaller spatial scales, offering the possibility of addressing the social isolation of SPHs on a citywide scale. Because few related studies have been reported in the literature, this study can serve as a trigger for discussions in the field of urban planning.

Second, the social isolation of SPHs in the literature implicitly tends to focus on elderly SPHs, the so-called elderly living alone [15,23,24,44]. However, it is not only older people who experience social isolation but also young and middle-aged people, who are often assumed to be more physically able and socially engaged. In fact, the lack of social participation and low interaction among young adults, who are supposed to be actively engaged in society, is even more problematic. Therefore, to eliminate policy blind spots, social isolation should be extended to all age groups.

This study differs from previous studies in that it analyzes the distribution of SPHs at high risk of social isolation on a fine spatial scale across the city and systematically identifies its influencing factors. Based on the existing literature, we hypothesized that life-cycle characteristics would have a significant impact on the distribution of SPHs. However, we expected that this characteristic would not be prominent in SPHs with a high risk of social isolation because their behavioral and socioeconomic characteristics are different from typical SPHs.

3. Materials and Methods

3.1. Study Area and Data

This study focused on Seoul, the capital city of South Korea, shown in Figure 1. Seoul is a highly urbanized city with a population of approximately 10 million. The study period was 2023, the latest year for which data were available. The spatial unit of analysis was the dong in Korean, which is the smallest administrative unit in South Korea and the finest scale at which data are available for this study.

This study used Seoul Citizen Life Data, which was developed to identify the lifestyle and behavioral characteristics of SPHs through a pseudonymized combination of private mobile communication data and public census data [45]. These data are calibrated by considering the market share and age-specific penetration of the mobile company that provided the individual's mobile communication history. These data present information based on the spatial unit (i.e., dong), which categorizes SPHs into several groups of interest based on the frequency of going out by gender and age, number of calls, and frequency of interaction with others using alternative means such as text messages and social media (KakaoTalk, Instagram, etc.).

Figure 1. Study area.

In this study, the definition of socially isolated SPHs is vital. In line with existing research, which defines social isolation based on the frequency and regularity of social contact with family, friends, and the community [15,25,29,30], this study classifies socially isolated SPHs as those exhibiting "both low outings and communication". This refers to a group of people who fall within the bottom 25% of their age group in terms of travel frequency and distance on weekdays and weekends, the number of calls and texts exchanged with others, and their use of social media. Therefore, they are low in both face-to-face and non-face-to-face interactions, indicating a high risk of social isolation.

The age groups were divided into young adults (20–39 years old), middle-aged adults (40–64 years old), and elderly adults (65 years or older) based on an existing study [37]. Previously, elderly SPHs were considered the main group with isolation problems. Younger SPHs are generally considered more active and to have fewer isolation problems because they can participate in various social activities despite living alone. However, although they are the most active group, if they have less contact with the outside world and are more isolated, it may lead to more serious social problems than those of elderly SPHs. To this end, this study derives the spatial distribution of young and middle-aged isolated SPHs, as well as older adults, and compares it to the spatial distribution of the total SPH population in each age group to draw implications.

The number of typical SPHs and those with a high risk of social isolation by spatial unit was divided by the total population and converted into the "number of SPHs per population". Many studies have utilized the number of SPHs as a percentage of the total households [34]. However, the number of total households is only counted every five years based on the census; therefore, 2020 is the most recent data available. In the case of the Seoul Citizen Life Data, the number of SPHs is estimated by combining mobile and Statistics Korea data; therefore, the sum of all the age groups does not match the number of census households. As the reason for expressing the number of SPHs as a percentage of all households was to account for differences in population size across spatial units, we decided that dividing by the number of people rather than the number of households was not unreasonable. SPHs were categorized into eight groups based on age and social isolation. Seoul Citizen Life Data has been released monthly since 2022, and this study utilized the most recent data for June 2023, the middle of the year.

The factors affecting the spatial distribution of SPHs by age group were derived from previous studies [9,12,15,35,39,46]. We included a proportion of small houses (SMALL_RATIO) of ≤40 m^2 based on previous studies that show that SPHs are more likely to live in houses with relatively small areas. The proportion of apartments in the housing stock by space unit (APT_RATIO) was included to account for differences in housing types across age groups. The average rental transaction price per m^2 of apartments between January and December 2022 (RENT_PRICE) was included as an explanatory variable to reflect the preference for affordable housing owing to the relatively low household income of SPHs. The apartment ratio was collected using the API of the Statistical Geographic Information Service (SGIS) (sgis.kostat.go.kr) as of 2022 (accessed on 6 July 2023), and the actual transaction price was obtained from the Ministry of Land, Infrastructure, and Transport's real estate transaction database (rt.molit.go.kr) (accessed on 1 July 2023).

SPHs are more likely to live near work and school because they prefer proximity to work and are sensitive to transportation accessibility. In this study, we incorporate employment density (EMP) and four-year university density (UNIV) as indicators of job proximity. Additionally, subway (SUBWAY) and bus stop (BUSSTOP) densities serve as measures of transportation accessibility, as employed in existing studies [46,47]. The subway and bus stop density measures used in our analysis have a similar distribution to the transportation accessibility indexes provided by the Seoul Institute [48], which considers the number of subway lines, the number of subway trips, transit time by mode, and frequency. Therefore, we concluded that there is no bias due to the way transportation accessibility is measured. Employment data were sourced from the Korean Statistical Information Service (KOSIS) (https://kosis.kr/) (accessed on 23 November 2023), while information on the number and locations of universities was obtained from Higher Education in Korea (https://www.academyinfo.go.kr) (accessed on 7 July 2023). Data on subway stations and bus stop locations were retrieved from Seoul Transport Big Data (https://t-data.seoul.go.kr) (accessed on 5 July 2023).

Previous studies have shown that SPHs tend to sacrifice access to various amenities due to their preference for proximity to work and schools [42]. To understand the extent to which this is true, we included the density of hospitals (HOST), restaurants (REST), and urban parks (PARK) as additional variables in the model. The distribution of hospitals and restaurants was collected using Local Administrator License Data (http://www.localdata.go.kr/) (accessed on 23 November 2023), and the distribution of urban parks was obtained from the National Urban Park Standard Data. The variable descriptions and data sources are listed in Table 1.

Table 1. Description of variables and data sources.

Variables		Unit	Description	Sources
Total	All	Households /Person	SPHs to population	Seoul Citizen Life Data (2023)
	Isolated		Socially isolated SPHs to population	
Young	All		SPHs aged 20–39 to population	
	Isolated		Socially isolated SPHs aged 20–39 to population	
Middle-aged	All		SPHs aged 40–64 to population	
	Isolated		Socially isolated SPHs aged 40–64 to population	
Older	All		SPHs aged 65 over to population	
	Isolated		Socially isolated SPHs aged 65 over to population	
RENT_PRICE		KRW (mil.)/m^2	The average apartment rent price per m^2	MOLIT (2022)
APT_RATIO		Ratio (0–1)	The ratio of apartments to all housing stocks	SGIS (2023)
SMALL_RATIO		Ratio (0–1)	The ratio of small- and medium-sized (≤40 m^2) houses to all housing stocks	
EMP		1000 person/m^2	The number of employments divided by spatial unit area	KOSIS (2023)
UNIV		No./m^2	The number of universities divided by spatial unit area	Higher Education in Korea (2023)
SUBWAY		No./m^2	The number of subway stations divided by spatial unit area	Seoul Transport Big Data (2023)
BUSSTOP		No./m^2	The number of bus stops divided by spatial unit area	
HOST		No./m^2	The number of hospitals and clinics divided by spatial unit area	Local Administrator License Data (2023)
REST		No./m^2	The number of restaurants divided by spatial unit area	
PARK		No./m^2	The number of urban parks divided by spatial unit area	

3.2. Methods

3.2.1. Global and Local Spatial Autocorrelation Index

To measure the spatial autocorrelation of the distribution of SPHs, we used the global Moran's I, a statistical indicator that measures the overall spatial autocorrelation of spatial data. The global Moran's I measure how similar the values in a given region are to those in neighboring regions. This was calculated using the following equation:

$$I = \frac{n\sum_i \sum_j w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\left(\sum_i \sum_j w_{ij}\right)\sum_i (x_i - \overline{x})^2} \quad (1)$$

where $x_{i(j)}$ is the variable of interest, $\overline{x}$ is the means of x, w_{ij} is the elements of spatial weights matrix and n is the number of observations. The global Moran's I has a value between -1 and 1. A value closer to 1 indicates that units with similar values are spatially adjacent.

We also used LISA based on the local Moran's I to identify clusters in the distribution of SPHs [49]. The equation used is as follows:

$$I_i = \frac{(x_i - \overline{x})}{S_i^2}\sum_{j=1, j\neq i}^{n} w_{ij}(x_j - \overline{x}) \quad (2)$$

$$S_i^2 = \frac{\sum_{j=1, j\neq i}^{n}(x_i - \overline{x})^2}{n-1} \quad (3)$$

The local Moran's I allow us to determine the occurrence of clusters of neighborhoods with higher-than-average values (high-high), lower-than-average values (low-low), or spatial outliers (high-low, low-high), where high and low values are mixed together. We constructed a spatial weights matrix based on the queen adjacency and row-standardized it for the analysis. The analysis was performed using the *spdep* package in R.

3.2.2. Spatial Econometric Models

Ordinary least squares (OLS) estimation is inefficient when spatial autocorrelation exists in the dependent variable. Spatial econometric models were utilized to explore the factors affecting the distribution of SPHs.

$$y = \rho Wy + X\beta + u \quad (4)$$

$$u = \lambda Wu + \varepsilon \quad (5)$$

where y is the dependent variable, X represents the independent variables, W is the spatial weights matrix, β is the vector of coefficients, ρ is the spatial autoregressive coefficient, λ is the spatial autocorrelation coefficient that controls the variance of the spatially autocorrelated error term u and ε is errors that are independent and identically distributed errors. If there was spatial interaction between spatial units, a spatial lag model (SLM) with $\lambda = 0$ was used, and if there was spatial dependence as a nuisance, a spatial error model (SEM) with $\rho = 0$ was used. If both ρ and λ are zero, the result was the same as the OLS estimation.

If the global Moran's index of the residuals from the OLS estimation suggested the presence of spatial autocorrelation, the choice of the spatial lag and error model was determined using the Lagrange multiplier (LM) test. If both the models were significant, the robust LM test was used. If the robust LM test showed that both models were significant, the model with the larger statistical value was selected as the estimated model. All the model estimations and tests were performed using the *spatialreg* package in R. The overall flow of the research methodology is presented in Figure 2.

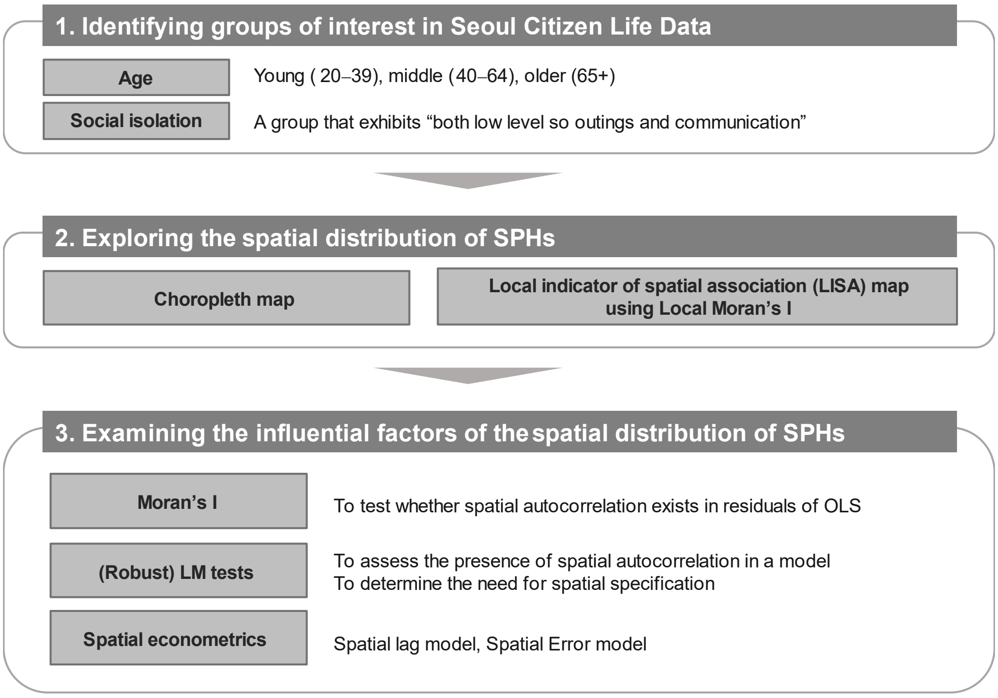

Figure 2. Flow chart of the research methodology.

4. Results

4.1. Spatial Distribution of Socially Isolated SPHs in Seoul

Figure 3 shows the spatial distribution of SPHs to the population according to social isolation and age group. The natural break is used as the classification method for this map. In general, SPHs in Seoul tend to live in neighborhoods near universities, namely Gwangjin and Gwanak, as well as in employment centers, namely Jongno (the central business district, CBD), Gangnam, and Seoul Digital Complex. However, these characteristics differed according to the age group. Younger and middle-aged people tended to be more concentrated in these areas, whereas older people tended to be concentrated in Jongno and residential areas on the periphery of the city, such as Eunpyeong, Gangbuk, Dobong, Nowon, and Guro.

SPHs with a high risk of social isolation seem to have a similar distribution pattern to that of SPHs of the same age; however, differences in the concentration by age group exist. For young adults, isolated SPHs were relatively dispersed compared to SPHs of the same age, whereas middle-aged people were only concentrated in Jongno compared to their counterparts. However, older adults were more concentrated in Jongno and Gwanak.

To better understand the spatial concentration of each group, we present the LISA clusters in Figure 4. Hot spots, representing high-high, are colored in red, and cold spots, representing low-low, are colored in blue. As shown in Figure 1, hot spots are distributed in urban centers, and cold spots are distributed in residential areas on the outskirts of cities. For all the SPHs, hot spots were located in Jongno, Gwanak, and Gwangjin, which are areas near universities. On the other hand, socially isolated SPHs were concentrated in Jongno and a part of Gwanak. Cold spots were particularly prevalent in Seocho, Gangnam, and Songpa, which have high-priced apartments. The high-low areas were predominantly situated in a section of Songpa characterized by low-cost residential housing. In contrast, low-high areas were mainly found in a part of Jongno known for its abundance of single-family homes that are larger than those in the city center.

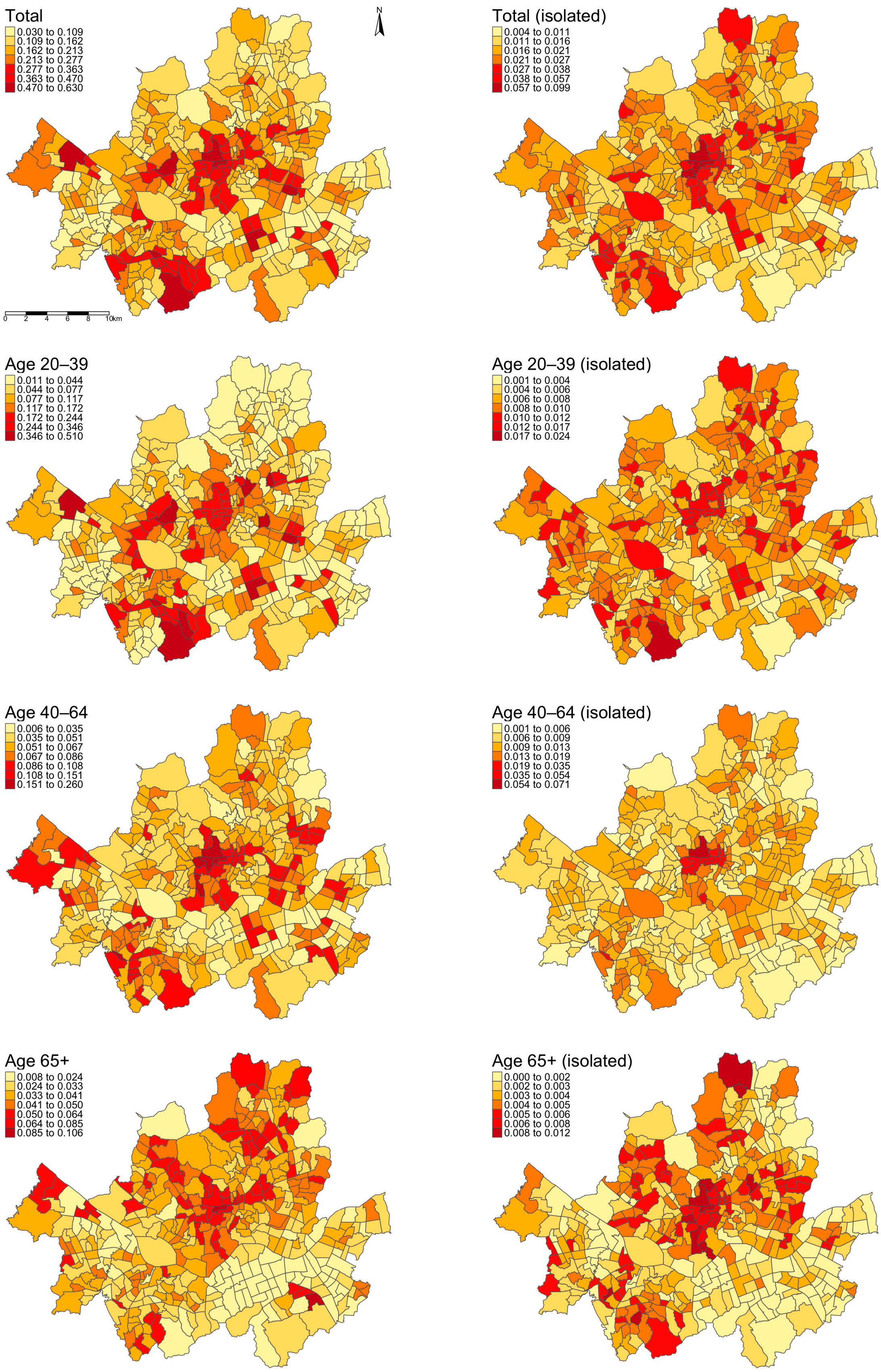

Figure 3. The spatial distribution of SPHs to the population according to social isolation and age group.

In terms of age groups, all the young adult SPHs had hot spots near universities and employment centers, and cold spots in apartment clusters in Dobong and Nowon. However, socially isolated SPHs in the same age group had hot spots in Jongno and Gwanak, where low-rise housing is concentrated, and cold spots in Gangnam. For middle-aged adults, both cohorts were clustered in Jongno; however, while all the SPHs were clustered in the neighborhoods of Gasan and Seoul Digital Complex, where IT companies are concentrated, socially isolated SPHs were not. For older adults, Jongno, Gangbuk, Dobong, and Seongbuk were hotspots for all the SPHs, whereas Jongno, Gwanak, and Eunpyeong were hotspots for socially isolated SPHs. For both groups of seniors, cold spots were found in Seocho, Gangnam, and Songpa, demonstrating the large regional variation in the share of SPHs in Seoul.

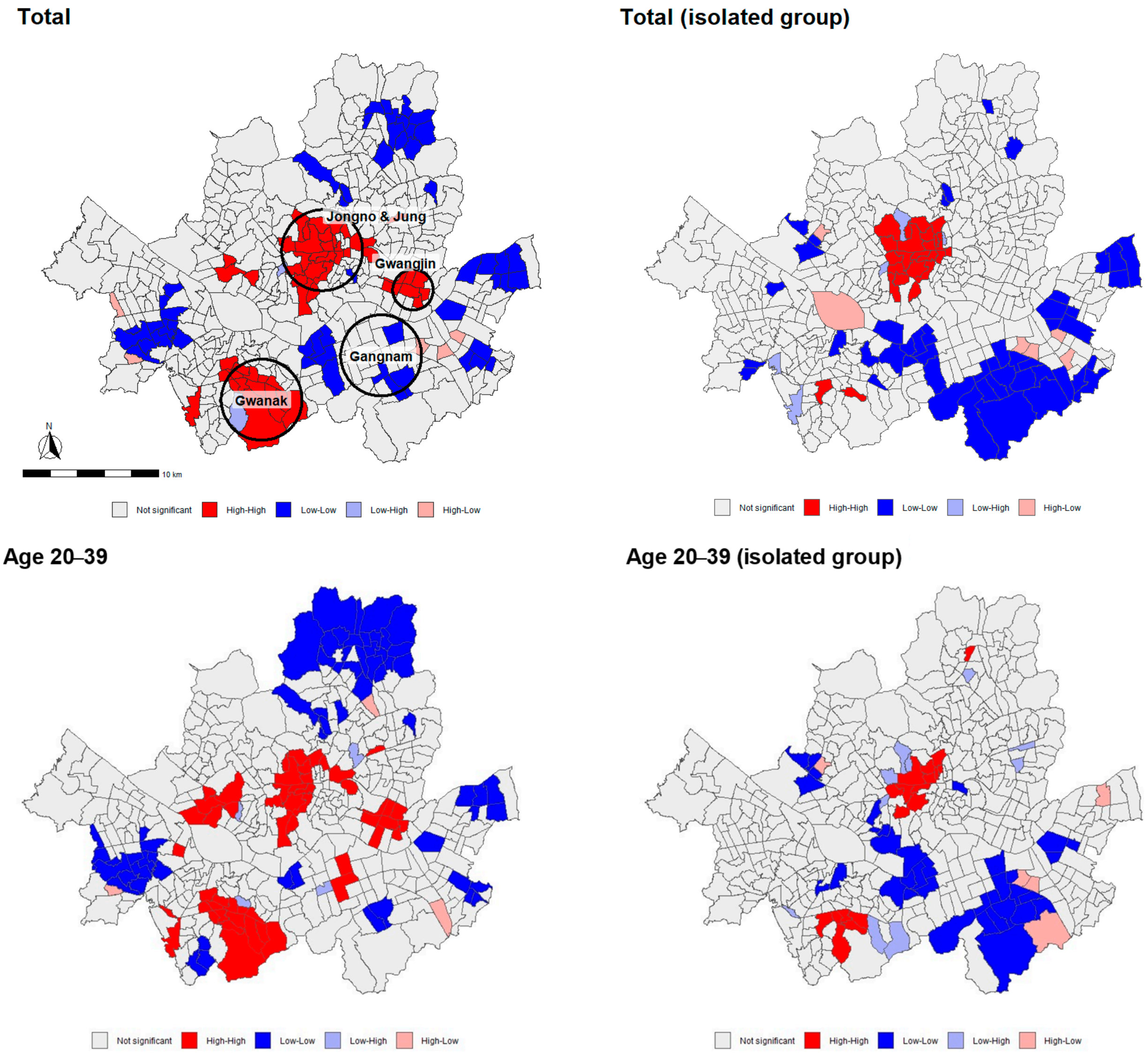

Figure 4. *Cont.*

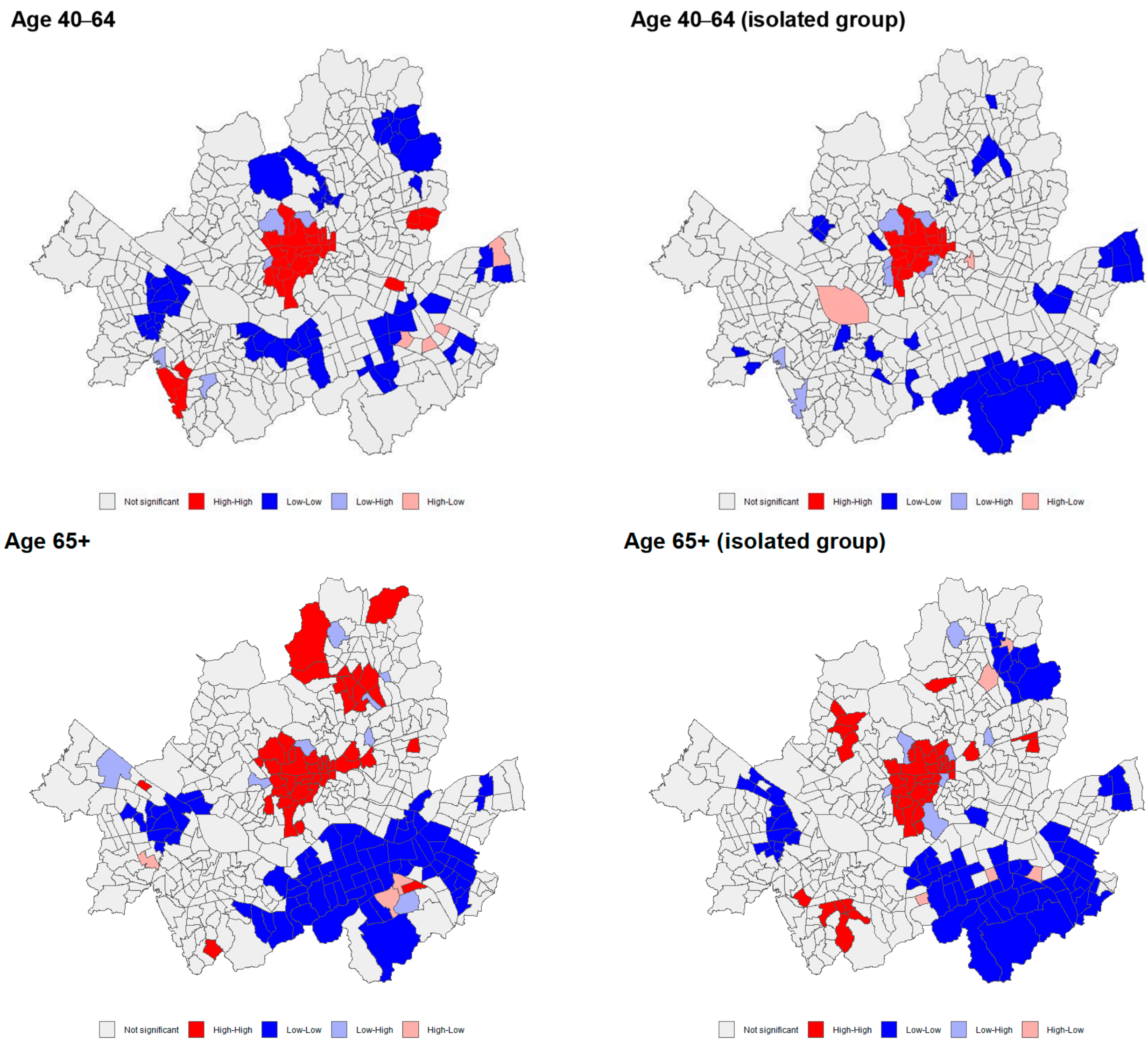

Figure 4. LISA cluster maps of SPHs according to social isolation and age group.

4.2. Influencing Factors of the Spatial Distribution of SPHs

The descriptive statistics for each variable in the model are shown in Table 2. The dependent variable (the number of SPHs as a percentage of the population) was log-transformed because of its skewed distribution. There are 424 dongs in Seoul, but Dunchon 1-dong in Gangdong district was excluded from the analysis because most of the area was under reconstruction; therefore, only 423 dongs were used to estimate the model.

Table 3 shows the spatial autocorrelation of each model and the final model selection. In all the models, spatial autocorrelation existed in the OLS residuals; therefore, LM and robust LM tests were performed to select the estimated model.

Table 4 presents the estimation results for each model. In all the models except Model 6, higher shares of small- and medium-sized houses were associated with a higher concentration of SPHs and socially isolated SPHs. The share of apartments had a significant negative effect on all the models except Model 7. The average rental price per unit area, which indicates the sensitivity to housing costs, was not significant in Model 1. However, we found a significant negative effect in Model 2 and Models 4–8. This result is consistent with previous studies [9,34,35] showing that SPHs tend to live in small- and medium-sized multi-family units and studios with relatively lower prices owing to their relatively low number of members and income levels.

Table 2. Descriptive statistics.

Category	Variables		Mean	SD	Min	Max
Dependent variable	Total	All	0.1941	0.1025	0.0297	0.6298
		Isolated	0.0205	0.0093	0.0041	0.0994
	Young	All	0.0957	0.0830	0.0114	0.5097
		Isolated	0.0075	0.0025	0.0012	0.0236
	Middle-aged	All	0.0610	0.0298	0.0064	0.2602
		Isolated	0.0098	0.0063	0.0012	0.0705
	Older	All	0.0373	0.0143	0.0081	0.1063
		Isolated	0.0031	0.0020	0.0000	0.0121
Independent variable	RENT_PRICE		6.958	2.248	0.0000	18.278
	APT_RATIO		0.5592	0.2985	0.0000	1.0000
	SMALL_RATIO		0.1197	0.1187	0.0000	0.6983
	EMP		11.3106	12.8771	0.4833	114.0459
	UNIV		0.1067	0.3860	0.0000	3.8506
	SUBWAY		0.8758	1.1945	0.0000	7.2117
	BUSSTOP		27.315	14.0756	2.135	98.940
	HOST		41.17	43.09	0.00	444.18
	REST		187.236	191.5832	1.529	1253.921
	PARK		4.110	3.010	0.000	19.137

Table 3. Results of the Moran's *I*, Lagrange multiplier (LM), and robust LM tests.

Category	Model 1 (Total)	Model 2 (Total) ‡	Model 3 (20–39)	Model 4 (20–39) ‡	Model 5 (40–64)	Model 6 (40–64) ‡	Model 7 (65+)	Model 8 (65+) ‡
Selected method	SEM	SLM	SLM	SLM	SEM	SLM	SLM	SLM
Moran's *I*	0.277 ***	0.214 ***	0.316 ***	0.200 ***	0.247 ***	0.169 ***	0.309 ***	0.286 ***
LM lag test	101.79 ***	49.734 ***	109.73 ***	11.011 ***	56.765 ***	41.011 ***	123.51 ***	72.621 ***
LM error test	101.93 ***	29.226 ***	99.208 ***	6.95 ***	69.816 ***	22.579 ***	100.69 ***	46.35 ***
Robust LM lag test	12.903 ***	20.593 ***	19.747 ***	4.699 **	3.346 *	18.941 ***	24.02 ***	26.3 ***
Robust LM error test	22.049 ***	0.085	9.224 ***	0.639	16.397 ***	0.509	1.197	0.029

‡ indicates a socially isolated group. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

However, in Model 3, unlike the results of the other models, the average rental price variable showed a significant positive association with the distribution of the entire youth SPHs. This is similar to that of existing research, which shows that young SPHs tend to pay high rents for proximity to the workplace [9,12,42]. This can be observed in Figure 2, where young SPHs were concentrated in areas such as Gangnam and Mapo, where housing and rental prices are high. However, Model 4 showed that young people at high risk of social isolation did not tend to live in areas with high rent. This indicates that groups with a high risk of social isolation at the same age have a relatively low ability to pay rent.

The preference for transportation accessibility was confirmed by the significant positive effect of subway density on the distribution of young adult SPHs. Model 5, for all the middle-aged SPHs, showed similar results. However, there was no significant preference for areas with high subway access by young and middle-aged SPHs at high risk of social isolation.

There was a significant positive association between the distribution of older adults and bus stop density. However, bus stop density had no significant effect on the elderly population, which is at high risk of social isolation. In Korea, bus stops are concentrated near residential areas owing to the widespread use of village buses. Therefore, the spatial distribution of young adults who prefer to be near their workplace is significantly negatively associated with bus stop density.

Table 4. Results of the spatial econometric estimations.

Variables	Model 1 (Total)	Model 2 (Total) ‡	Model 3 (20–39)	Model 4 (20–39) ‡	Model 5 (40–64)	Model 6 (40–64) ‡	Model 7 (65+)	Model 8 (65+) ‡
SMALL_RATIO	1.515 *** (0.137)	0.313 *** (0.118)	1.543 *** (0.217)	0.414 *** (0.132)	1.276 *** (0.138)	0.207 (0.141)	1.063 *** (0.122)	0.595 ** (0.235)
APT_RATIO	−0.617 *** (0.062)	−0.420 *** (0.050)	−0.831 *** (0.093)	−0.232 *** (0.055)	−0.645 *** (0.062)	−0.442 *** (0.060)	0.011 (0.050)	−1.009 *** (0.102)
RENT_PRICE	0.004 (0.008)	−0.030 *** (0.006)	0.033 *** (0.012)	−0.032 *** (0.007)	−0.020 ** (0.008)	−0.029 *** (0.008)	−0.033 *** (0.007)	−0.040 *** (0.013)
SUBWAY	0.024 * (0.013)	0.003 (0.012)	0.046 ** (0.022)	−0.014 (0.014)	0.024 * (0.013)	0.010 (0.015)	0.011 (0.012)	0.020 (0.024)
BUS	−0.003 ** (0.001)	−0.0001 (0.001)	−0.003 * (0.002)	0.0005 (0.001)	−0.001 (0.001)	−0.001 (0.001)	0.002 * (0.001)	0.003 (0.002)
UNIV	0.061 * (0.037)	−0.013 (0.034)	0.226 *** (0.062)	0.052 (0.038)	−0.130 *** (0.037)	−0.053 (0.040)	−0.090 *** (0.034)	−0.013 (0.067)
EMP	0.009 *** (0.002)	0.007 *** (0.001)	0.014 *** (0.002)	0.008 *** (0.001)	0.006 *** (0.002)	0.009 *** (0.002)	−0.003 ** (0.001)	0.001 (0.003)
HOSP	−0.0003 (0.0004)	−0.0002 (0.0004)	0.004 (0.001)	−0.0003 (0.0004)	−0.001 (0.0004)	−0.00005 (0.0004)	−0.001 * (0.0004)	−0.00001 (0.001)
REST	0.0003 ** (0.0001)	0.0004 *** (0.0001)	−0.00004 (0.0002)	0.0001 (0.0001)	0.0004 *** (0.0001)	0.001 *** (0.0001)	0.0002 ** (0.0001)	0.005 ** (0.0002)
PARK	−0.0008 (0.0005)	−0.00003 (0.004)	−0.021 ** (0.008)	0.009 * (0.005)	−0.003 (0.005)	−0.004 (0.005)	−0.004 (0.005)	−0.001 (0.009)
Constant	2.774 *** (0.080)	0.637 *** (0.004)	0.906 *** (0.139)	−0.141 ** (0.069)	1.859 *** (0.078)	0.161 ** (0.072)	0.554 *** (0.090)	−0.237 * (0.128)
ρ	-	0.368 *** (0.053)	0.462 *** (0.047)	0.215 *** (0.066)	-	0.343 *** (0.055)	0.557 *** (0.047)	0.445 *** (0.051)
λ	0.582 *** (0.053)	-			0.492 *** (0.059)	-	-	-
Obs.	423	423	423	423	423	423	423	423
log likelihood	−83.533	−37.99618	−299.381	−81.845	−84.562	−113.490	−54.702	−333.038
LR test	91.214 ***	43.410 ***	88.545 ***	10.057 ***	56.740 ***	35.678 ***	104.897 ***	63.766 ***
Wald test	123.083 ***	47.403 ***	98.138 ***	10.455 ***	70.296 ***	38.188 ***	139.425 ***	75.824 ***

‡ indicates a socially isolated group. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Employment density, which indicates proximity to the workplace, had a significant positive effect in Models 1–6 but had a significant negative effect in Model 7. University density, however, had a significant positive effect in Models 1 and 3 and a significant negative effect in Models 5 and 7. This reflects the residential characteristics of the life cycle because young and middle-aged people prefer proximity to employment, whereas older people have a lower preference for proximity to work after retirement. However, life-cycle characteristics were not evident in groups at high risk of social isolation. Young adults do not prefer to live near universities, while middle-aged and older adults do not prefer to avoid living near universities. No statistically significant preference for residential areas away from employment centers among the elderly was observed.

In the case of hospital density, which shows proximity to convenience functions, the results were not significant in most models except in Model 7. Park density had a significant negative effect in Model 3, which is consistent with previous research showing that young adult SPHs place more value on proximity to work than amenities [40,42]. For young adult SPHs at high risk of social isolation, park density had a significant positive effect. However, it is difficult to interpret this as a preference for amenity. Many of Seoul's parks are in the transitional zone, which is adjacent to the city center. It is more likely that socially isolated SPHs live in these transitional zones because they cannot afford high rent in the city center.

5. Discussion

The results show that the factors affecting the spatial distribution of SPHs by age group, with and without social isolation, differ, especially in terms of proximity to work and access to transportation. For SPHs, there is a common preference for small- and medium-sized housing, and a higher proportion of single-family, multi-family, and studios than apartments [9,12,42]. However, the strong preference for proximity to work among all the young adult SPHs, as evidenced by the significant positive effects of the subway, university, and employment density, is not as pronounced in young adult SPHs that are at risk of social isolation. While young adult SPHs are generally willing to pay higher housing costs for proximity to work, which is consistent with the existing literature [40], socially isolated SPHs of the same age are not. For middle-aged and older adults, a similar but less pronounced preference for subway accessibility was observed for the overall population but not for those at higher risk of social isolation. Unlike older SPHs, which tend to be more accessible by bus than by subway because they are more concentrated in residential neighborhoods, those at higher risk of social isolation do not prefer bus accessibility. We can clearly see a decrease in the preference for university neighborhoods for middle-aged and older SPHs, but no significant difference is observed for those at high risk of social isolation, as shown in Models 6 and 8.

This finding has implications for SPHs and their social isolation. Previous research has shown that age-specific life cycles explain the spatial distribution of SPHs very well [37]. Young adults, who move more frequently and have a larger travel radius than the other two groups, generally prefer proximity to and accessibility of work [9,12,42]. This reflects their propensity to actively participate in society and interact with others. In addition, middle-aged and older adults typically show a clear preference for living in urban centers or residential areas away from areas familiar to young people, such as universities [9,11,35,38,39]. However, those at higher risk of social isolation do not exhibit these life-cycle characteristics, are more likely to be rent burdened, and show little preference for accessibility. They also do not show the typical characteristics of middle-aged people preferring to live closer to work as they age, or of older people wanting to live in residential areas. This raises the question of whether SPHs at high risk of social isolation are as mobile as typical SPHs. This indirectly indicates that their spatial distribution is not the result of voluntary choices based on individual preferences, suggesting that SPHs at high risk of social isolation may be pushed into marginal neighborhoods regardless of age.

6. Conclusions

This study addressed the issue of social isolation among SPHs in modern cities. The increase in SPHs is closely related to changes in urban life and family structure, and it poses new challenges to the urban social structure. SPHs are an increasingly important demographic group, and the need for research on their social isolation and quality of life has been emphasized. However, owing to data limitations, previous studies either failed to clearly identify socially isolated groups or were limited to specific locations rather than the entire city. As a result, although social isolation in SPHs is very important, studies have not been able to provide a clear answer to the questions of where and how many SPHs are at high risk of social isolation, and what factors contribute to their spatial distribution. To answer these questions, this study combined public census data and private mobile data to identify people facing social isolation among SPHs to examine their specific spatial distribution and influencing factors. We focused on revealing the differences between the overall population of SPHs and those at high risk of social isolation by age group.

The following results were obtained through the application of LISA clustering and spatial econometric models for Seoul. First, SPHs tend to be concentrated in areas with a high proportion of small- and medium-sized houses and non-apartment types of housing.

Second, clear spatial distribution patterns based on life-cycle characteristics exist, with young people clustering near universities and employment centers and older people clustering in residential areas. Third, these life-cycle patterns are not as evident for SPHs, which are at higher risk of social isolation. Typical SPHs show clear preferences for work, education, housing, or accessibility, whereas SPHs at high risk of social isolation show few of these characteristics. Given that these groups have already interacted less frequently with others, they may face more severe isolation in the future. In particular, the fact that they are mostly concentrated in the zones around CBDs with dilapidated facilities, relatively poor neighborhoods, and a high concentration of low-rise residences, such as Jongno and Jung, suggests that they may be pushed to the margins in terms of housing conditions.

While many studies on the spatial behavior of SPHs in East Asia exist, only a few have examined the spatial characteristics of socially isolated SPHs by age group. Our findings contribute to the literature theoretically by revealing that not all SPHs can be considered a group with a high risk of social isolation and that the residential patterns of socially isolated SPHs differ from those of typical SPHs throughout their life cycle. In addition, this study enhances our knowledge by clearly identifying the spatial distribution of single-person households at high risk of social isolation and its influencing factors, which were previously unknown due to data limitations. These findings imply that urban planners and policymakers should consider the diverse characteristics of SPHs to address isolation and promote community engagement. It is important to provide programs and facilities that meet the needs of not only young SPHs but also isolated people who lack social interaction. This allows them to be socially active without being pushed to the margins.

Future studies can be conducted based on our findings. First, the methodology applied in this study can be extended to other research topics and similar regions. Owing to the short time series of the data, this study could not identify the changes in the spatial distribution of socially isolated SPHs and their relationship with the urban built environment. In the future, we will perform research that complements this study by expanding the temporal and spatial ranges of the available data. Second, we need to look at the specific time and space utilization patterns of single-person households at risk of social isolation; for example, how they spend their time instead of going out and communicating less. This could contribute to addressing social problems caused by SPHs at risk of social isolation.

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