pISSN: 1226-7147, eISSN: 2383-9171
https://doi.org/10.17208/jkpa.2025.08.60.4.5

Check for updates

Journal of Korea Planning Association Vol.60, No.4 (2025)
대한국토·도시계획학회지 「국토계획」 제60권 제4호 pp.5-23

Special Issue

Spatial Patterns of Urban Shrinkage in Depopulating Municipalities in South Korea*,**

Kang, Min-Kyeong*** · Park, Han-Na**** · Song, Jaemin*****

Abstract

Population decline serves as both a cause and a consequence of urban shrinkage, increasing local financial burdens and undermining urban sustainability. Analyzing how population decline manifests and evolves spatially within cities is crucial to effectively implementing shrinking smart strategies. However, research that comprehensively analyzes internal spatial change patterns for depopulating cities is scarce. Against this backdrop, the study aims to identify the spatial patterns of urban shrinkage dynamics within depopulating municipalities in South Korea by quantifying spatial changes in urban and non-urban areas within each municipality, applying multi-temporal clustering to identify distinct shrinkage patterns, and finally analyzing the demographic, economic, and physical characteristics of each pattern. Our analysis reveals six distinct patterns of spatial shrinkage: Urban-Centralization and Urban-Led and Rural-Led Shrinkage, each with strong and moderate variations. These patterns demonstrate considerable variations in demographic, economic, and built environment characteristics. The findings offer a valuable basis for spatial planning and policy development aimed at managing urban shrinkage in a smarter way.

Keywords Urban Shrinkage, Population Decline, Spatial Shrinkage Patterns

Ⅰ. Introduction

Population decline is both a primary cause and consequence of urban shrinkage. In declining cities, the reduction of working-age population leads to increased financial pressures on local governments and challenges in sustaining a sufficient level of public service provision. The decline in public service quality further accelerates out-migration, creating a vicious cycle that undermines urban sustainability.

Since 2020, South Korea has entered a phase of population decline, known as the "dead-cross," characterized by a higher number of deaths than births. Despite a minor rise in population following the COVID-19, the fertility rate in 2023 remained at 0.72, the lowest among OECD countries. The national decline in population has emerged as a critical concern. At the local level, population decrease is significantly exacerbated not only by natural reasons, such as low birth rates, but also by social ones, such as migration, particularly in non-Seoul metropolitan areas (Kwon, 2005; Choi, 2010).

Consequently, there has been an increased interest in "shrinking smart" strategies (Lee and Han, 2014; Kwon et al.,

* This work was supported by the BK-21 FOUR program through National Research Foundation of Korea (NRF) under Ministry of Education.
** This paper is a revised and expanded version of a part of Kang, M.K.'s 2024 master's thesis, "A Study on the Spatial Shrinkage Characteristics of Depopulating Cities," which was originally presented at the 2024 Fall Conference of the Korea Planning Association.
*** Master, Graduate School of Environmental Studies, Seoul National University (First Author: k0909mk@snu.ac.kr)
**** Doctorate Candidate, Graduate School of Environmental Studies, Seoul National University (Co-author: hnpark@snu.ac.kr)
***** Associate Professor, Graduate School of Environmental Studies, Seoul National University (Corresponding Author: jaemins@snu.ac.kr)

2018; Park et al., 2020; Nam, 2022). The core strategy of shrinking smart is to foster a compact-network structure by promoting a dense, interconnected urban structure, particularly inside existing urban core areas (Ha and Kang, 2022). Maintaining a density above a specific threshold in these centers ensures the sustainable operation of infrastructure and public services. Enhancing linkages among cores, by connecting medium-sized urban centers, facilitates the borrowing-size effect (Burger and Meijers, 2016 ; Kwon et al., 2018). A compact-network urban structure enables efficient allocation and management of resources, mitigating local financial burdens (Mattson, 2021; Miyauchi and Setoguchi, 2023). To effectively implement shrinking smart strategies, it is crucial to first analyze how population decline manifests and evolves spatially within cities.

While extensive research has explored urban growth patterns, much less is known about urban shrinkage (Reis et al., 2016). In Korea, previous studies have primarily focused on developing indices to measure urban shrinkage (Lee, 2016; Park and Lee, 2017; Song et al., 2021; Heo, 2022; Kang et al., 2023; Bae and Bae, 2023) and classifying cities based on their shrinkage characteristics (Lim, 2018; Koo and Min, 2018; Kim and Cho, 2019; Park et al., 2020; Lee and Oh, 2021). However, research on spatial transformations within shrinking cities remains in its early stages. Recent studies have analyzed only population centers within shrinking cities (Cho and Lee, 2023; Son and Hong, 2023) or identified areas at risk of disappearance within specific neighborhoods and municipalities (Lee and Kim, 2018; Jang, 2023). There is a significant gap in research that comprehensively analyzes internal spatial change patterns for depopulating cities.

Against this backdrop, this study aims to identify the spatial patterns of urban shrinkage dynamics within depopulating municipalities-cities (Si) and counties (Gun)- by analyzing population distribution changes in both urban areas, where population is concentrated, and non-urban areas over a 20-year period between 2000 and 2020. This study complements previous research on population decline, which typically compares or classifies overall population decrease at the municipal level, by noting that even areas with similar levels of population decline may exhibit different internal change patterns. Deriving population decline patterns by considering population changes between urban and non-urban areas aims to illuminate disparate changes in internal spatial structures that might be overlooked by aggregate municipal-level analyses.

We focus on municipalities designated as depopulating areas by the Korean government under the 2021 Special Act on Decentralization and Regional Balanced Development. The study addresses two key research questions: 1) what spatial patterns characterize population distribution changes in depopulating municipalities? and 2) what demographic, economic, and physical characteristics are associated with different spatial patterns? To address these questions, this study employs multivariate time-series clustering to examine the dynamics of population distribution change in urban and non-urban areas, capturing the structural transformations occurring within depopulating municipalities. The findings of this study will serve as a crucial foundation for spatial planning and policy development aimed at managing urban shrinkage, shifting the focus from aggregate population decline at the city level to the internal spatial dynamics of urban shrinkage.

II. Literature Review

1. Theoretical Background of Urban Shrinkage

Historically, population decline in cities is not a new phenomenon. However, until recently, population decline was believed to be temporary, followed by periods of growth (Bontje, 2004; Popper and Popper, 2002). This perspective stems from understanding population decline as part of an urban growth paradigm that follows urbanization-suburbanization- deurbanization-reurbanization cycles (Berg et al., 1982). Under this paradigm, planning theories, methodologies, and policies were developed with the assumption of continuous urban growth (Bontje, 2004; Reis et al., 2016).

Unlike the traditional view of population decline as a temporary phenomenon within the urban growth paradigm, recent perspectives recognize population decline as an irreversible structural crisis (Martinez-Fernandez et al., 2012; Beauregard, 2013; Cieśla, 2013). Research on urban shrinkage began in Germany during the 1990s, focusing on population and economic decline resulting from deindustrialization (Martinez-Fernandez et al., 2012). Since the 2000s, urban shrinkage has been reported globally (Großmann et al., 2008; Audirac and Martines-Fernandez, 2010).

Urban shrinkage is defined as a phenomenon involving long-term and severe population decline, structural economic recession, and increasing vacant spaces (Schilling and Logan, 2008; Hollstein, 2014; Koo et al., 2016). Population decline consistently appears as a primary symptom of urban shrinkage across various studies, as outcomes of industrial decline and suburbanization ultimately lead to population loss (Lee et al., 2018). According to Pallagst (2008), urban shrinkage occurs in densely populated areas experiencing rapid population decline for over two years, accompanied by economic changes. The main causes of urban shrinkage include various factors including demographic, economic, spatial structural, systemic, and environmental causes (Laursen, 2009; Martinez-Fernandez et al., 2012; Lee and Han, 2014). In South Korea, the most prominent causes are demographic factors (low birthrate), and economic and spatial structural factors (migration) (Lee and Han, 2014; Koo et al., 2016).

Demographic factors refer to continuous population decline due to low birth rates and aging, commonly observed in many cities of developed countries (Haase et al., 2014; Elis, 2008). In cities with declining populations, the reduction in economically active population leads to decreased productivity and tax revenue (Seta et al., 2006; Cho et al., 2015). This results in a negative cycle where public service quality deteriorates, properties are abandoned, and further population decline occurs (Koo et al., 2016). Economic factors primarily involve de- industrialization, prominently seen in the Rust Belt region of the northeastern United States (Schilling and Logan, 2008). Manufacturing-centered cities have experienced job losses and economic decline during de-industrialization, ultimately leading to population decrease (Hollander et al., 2009). In South Korea, decline in not only manufacturing but also primary industries (agriculture, forestry, and fisheries) and mining has been discussed as causes of urban shrinkage (Kim, 2010; Koo et al., 2016). Additionally, job concentration in metropolitan areas can be a contributing factor (Ma, 2017; Koo, 2021). Research indicates that quality employment opportunities are particularly important for youth migration (Kim, 2021; Kim and Jeong, 2024). Spatial structural factors include transportation infrastructure development and new town development in outskirt areas (Martinez-Fernandez et al., 2012; Kim, 2010). These developments can lead to residents moving from established urban areas to suburban areas, resulting in downtown hollowing and creating a "donut effect" (Lee and Han, 2014; Koo et al., 2016).

2. Spatial Change Patterns and Characteristics of Urban Shrinkage

Main research topics related to spatial change patterns in depopulating cities can be classified into three categories: urban core area, suburbanization phenomena, and urban perforation.

Research on urban core area growth in urban shrinkage has been primarily addressed in Japanese studies. Kawabe and Watanabe (2021) analyzed cities across Japan, presenting four types of shrinking cities and examining their temporal distribution changes. Between 2000 and 2005, there was a sharp increase in cities where populations in urban core areas decreased while non-urban area populations increased, but this trend significantly decreased between 2005 and 2010. Conversely, cities experiencing decreasing non-urban area populations with increasing urban area populations or urban area population ratios showed an opposite pattern. Iwasaki (2021) suggested that urban population decline is mitigated in cities with a tendency for return to central urban areas, while cities without this tendency experience continued urban population decline.

Regarding suburbanization patterns where new urban areas form separately from existing urban zones, Ribant and Chen (2019) found that only metropolitan areas exhibited both central urban areas and suburban urban areas, with suburbanization characterized by decreasing central area populations and increasing suburban area populations. In smaller urban areas, suburban urban zones were absent, with population decline occurring only in central urban areas. Similarly, Cho and Lee (2023), studying population-declining regions in South Korea, found that suburbanization—where population-dense areas shrink, separate, and form new zones—occurs only in metropolitan areas. However, these findings contradict research by Kim (2010) and Eom and Woo (2014), which found that urban shrinkage in smaller South Korean cities like Yeongcheon, Mungyeong, and Gongju was accelerated by suburban new town development regardless of population size. This discrepancy can be attributed to different criteria for defining urban areas across studies. Ribant and Chen (2019) and Cho and Lee (2023) defined urban areas based on minimum population thresholds, while Kim (2010) used urban area status and Eom and Woo (2014) defined the legal district where City Hall is located as the old downtown and housing development districts as new urban centers. The study focuses on population-declining regions with populations under 200,000 as of 2000 and defines urban areas based on population density, suggesting that suburbanization forming new urban areas in suburbs is unlikely.

Regarding urban perforation, Lang et al. (2020) observed that growing and shrinking areas within cities are geographically mixed in China's Pearl River Delta, defining shrinking areas as urban perforations. They found that shrinking areas typically have traditional manufacturing characteristics with declining manufacturing jobs and severe population outflows. Son and Hong (2023) identified areas where population decline is concentrated as urban perforation zones, analyzing factors such as elderly population ratios, housing numbers, and proportions of buildings over 35 years old. They found that areas with higher elderly populations and older buildings, lower youth populations, and fewer buildings, floor areas, and apartment buildings were more likely to experience population decline in densely populated areas. They also noted relationships with administrative welfare centers, elementary schools, distance to railway stations, and urbanized area ratios. Lee and Kim (2018) revealed a correlation between extinction risk index and housing supply rate in Gongju, indicating that areas at risk of extinction have higher housing supply rates, suggesting numerous vacant houses. Koo et al. (2016) demonstrated that urban vacancies increase due to population decline and urban sprawl, with apartment vacancy rates increasing, related to outflow of working-age population, low birth rates and aging, and declining primary industry employment.

3. Summary

Population decline has become a global phenomenon requiring strategic responses to ensure sustainable development. Shrinking smart strategies have gained prominence as effective approaches to urban shrinkage, aiming to optimize urban functions and enhance quality of life through efficient resource reallocation (Lee and Han, 2014). These strategies center on compact-and-network models that promote densification of center areas in depopulating cities. Even when cities experience identical numerical population declines, their spatial patterns significantly impact urban efficiency. The geographic distribution of population loss—whether concentrated or dispersed—directly affects infrastructure usage, service provision, and overall sustainability. Despite this important relationship, current research has primarily focused on developing shrinkage indices and analyzing municipal-level demographic and economic characteristics, creating a significant knowledge gap in understanding internal spatial dynamics within shrinking cities. This study addresses this gap by analyzing the internal spatial characteristics of depopulating South Korean cities through temporal classification of population changes in urban and non-urban areas. By examining these patterns, this research will provide essential insights for developing more targeted and effective shrinking smart strategies.

Ⅲ. Methodology

1. Study Scope and Data

This study examines 77 depopulating municipalities identified under the 2021 "Special Act on Decentralization and Balanced Regional Development," excluding metropolitan cities and islands due to their distinct population scales and conditions from the original 89 designated municipalities. The temporal scope of the analysis spans from 2000 to 2020, analyzing urban shrinkage patterns through time-series dynamic analysis. This study utilizes 500 m population grid data from the Statistics Geographic Information Service (SGIS) at five-year intervals. This grid-based approach enables separate estimation of populations in urban and non-urban areas, which would not be feasible with conventional municipal-level population data. The distinction between urban and non-urban areas follows the SGIS classification of Urban Centers and Urban Clusters. Urban Centers or Urban Clusters by SGIS are classified as urban areas, while all remaining areas are considered non-urban. These classifications are based on the United Nations' urban classification standards.[1] 〈Table 1〉 presents descriptive statistics of the population in the 77 depopulating municipalities for the years 2000 and 2020.

Table 1. Descriptive statistics of population in depopulating municipalities (unit: persons)

Year	Mean	Std	Min	Max
2000	60,528	32,147	20,257	178,416
2020	50,307	27,691	15,367	156,250

2. Data and Methods

This study employs a three-stage analytical approach to identify spatial shrinkage characteristics in depopulating municipalities.

1) Quantification of Spatial Changes

The first stage quantifies spatial changes within depopulating municipalities between 2000 and 2020. We calculated percentage changes in population for both urban and non-urban areas using the following equation:

$$CP_{(u/n),t} = \frac{(P_{(u/n),t} - P_{(u/n),2000})}{P_{(u/n),2000}} \times 100 \quad (1)$$

where $CP_{(u/n),t}$ represents the population change rate in urban (u) or non-urban (n) areas at time t, $P_{(u/n),t}$ is the population in urban/non-urban areas at time t, $P_{(u/n),2000}$ is the population in urban/non-urban areas in base year 2000, with t denoting the time periods (2005, 2010, 2015, 2020).

2) Dynamic Spatial Pattern Classification

The second stage employs multi-temporal clustering to classify dynamic spatial change patterns. We applied Time Series K-means clustering to five-time points of $CP_{(u/n),t}$, two-dimensional (urban and non-urban areas) data. For measuring distances between time series data, both Euclidean distance and Dynamic Time Warping (DTW) are commonly used. While Euclidean distance compares values at identical time points, limiting its application to time series of different lengths, DTW compares individual vector values, making it more suitable for varying-length time series and widely used in voice and behavior recognition (Kim and Park, 2018). A meaningful analysis of temporal trajectories requires a minimum of four time points, although incorporating more enhances analytical depth (Nguena Nguefack, et al., 2020; van der Does et al., 2023). For clustering similar data points, K-means and K-medoids are typical approaches. K-means clustering identifies k centers and assigns all objects to the nearest center, with centers being the mean of objects in each cluster, making it sensitive to outliers. K-medoids uses actual objects as cluster centers instead of means, making it less sensitive to outliers (Park and Jun, 2009). In this study, Time Series K-means algorithm effectively classified data patterns based on DTW and K-means clustering. The optimal number of clusters was determined using Silhouette Width and Within-cluster Sum of Squared Error (WSSE) criteria, which are useful for evaluating clustering appropriateness and ensuring cluster validity.

3) Characteristic Analysis by Depopulating Type

The third stage analyzes demographic, economic, and built environment characteristics across different shrinkage patterns. Variables were selected based on previous literature as shown in 〈Table 2〉.

Demographic characteristics are captured through six key variables: total population, cumulative births, cumulative deaths, population migration, youth population ratio, and elderly population ratio. These variables allow us to distinguish between natural and social causes of population change while providing insights into demographic structure. Total population represents the number of residents in each depopulating city. Cumulative births and deaths are measured over the study period (2005-2020), while population migration is calculated as the total population change minus natural change (births and deaths). The youth population ratio represents the proportion of residents under 15 years old, while the elderly population ratio indicates the proportion of residents aged 65 and above. Together, these age-structure ratios provide insights into demographic composition.

Economic characteristics are analyzed through six variables: total number of businesses, total employees, primary industry employment ratio, manufacturing employment ratio, and the area and number of new industrial complexes. The number of businesses and employees represents the scale of economic activity in each region. The manufacturing employment ratio indicates the industrial structure. The area and number of new industrial complexes developed between 2000 and 2020 serve as indicators of industrial growth.

Table 2. Population, economic, and built environment characteristic variables

Category	Variable	Description		Unit	Data source
Population characteristics	Total population change	$\frac{P_{2020}-P_{2000}}{P_{2000}}\times 100$	The percentage change in population between the years 2000 and 2020	%	SGIS
	Cumulative birth rate	$\frac{\sum_{i=2005}^{2020} B_i}{P_{2005}}\times 100$	The cumulative birth rate from 2005 to 2020 as a percentage of the 2005 population	%	KOSIS
	Cumulative death rate	$\frac{\sum_{i=2005}^{2020} D_i}{P_{2005}}\times 100$	The cumulative death rate from 2005 to 2020 as a percentage of the 2005 population	%	KOSIS
	Net migration rate	Total population change rate (based on the year 2005)−{Cumulative births rate (based on the year 2005)+Cumulative deaths rate (based on the year 2005)}		%	KOSIS
	Youth population rate change	$\frac{Y_{2020}-Y_{2000}}{Y_{2000}}\times 100$	The percentage change in youth population under 14 from 2000 to 2020	%	SGIS
	Elderly population rate change	$\frac{E_{2020}-E_{2000}}{E_{2000}}\times 100$	The percentage change in elderly population aged 65 and above from 2000 to 2020	%	SGIS
Economic characteristics	Total business establishments change	$\frac{Bu_{2020}-Bu_{2000}}{Bu_{2000}}\times 100$	The percentage increase in the number of business establishments from 2000 to 2020	%	SGIS
	Total employees change	$\frac{Em_{2020}-Em_{2000}}{Em_{2000}}\times 100$	The percentage increase in the number of employees from 2000 to 2020	%	SGIS
	Manufacturing industry employee rate change	$\frac{M_{2020}-M_{2000}}{M_{2000}}\times 100$	The percentage increase in the number of employees in manufacturing industry from 2000 to 2020	%	SGIS
	New industrial complex area	$\sum_{i=2000}^{2019} New\ Industrial\ Complex\ Area\ in\ Year$		km²	ILIS
	Number of new industrial complex	$\sum_{i=2000}^{2019} New\ Industrial\ Complex\ Count\ in\ Year$		units	ILIS
Built environment characteristics	Total housing units change	$\frac{H_{2020}-H_{2000}}{H_{2000}}\times 100$	The percentage increase in the number of housing units from 2000 to 2020	%	SGIS
	Old housing rate change	$\frac{O_{2020}-O_{2000}}{O_{2000}}\times 100$	The percentage increase in the number of housing units aged over 40 years from 2000 to 2020	%	SGIS
	Single-family housing rate change	$\frac{S_{2020}-S_{2000}}{S_{2000}}\times 100$	The percentage increase in the number of single-family housing from 2000 to 2020	%	SGIS
	Apartment housing rate change	$\frac{A_{2020}-A_{2000}}{A_{2000}}\times 100$	The percentage increase in the number of apartment housing from 2000 to 2020	%	SGIS
	Accessibility to living infrastructure (year 2020)	$\frac{1}{m}\sum_{i=1}^{m}(\frac{1}{n}\sum_{j=1}^{n} d_{ij})$	The average distance from the nearest living infrastructure facility of each type m: Number of facility types, n: Total number of grid cells, d_{ij}: Distance from the center of grid cell j to the nearest facility of type i (measured along the road network)	km	NGII
	Urban density change	$\frac{U_{2020}-U_{2005}}{U_{2005}}\times 100$	The percentage change in net population density, measured as population per unit of urbanized area, from 2005 to 2020	%	KOSIS

(Continue on next page)

Category	Variable		Description	Unit	Data source
Built environment characteristics	Land-use diversity change	$\frac{L_{2020}-L_{2005}}{L_{2005}}\times 100$	The percentage change in Shannon entropy index from 2005 to 2020 $L_{year}=\frac{-\sum p_i \ln(p_i)}{\ln(n)}$ pi: The proportion of area I in the whole area, n: the total number of categories (residential, commercial, industrial)	%	KOSIS
	Green area per capita change	$\frac{G_{2020}-G_{2005}}{G_{2005}}\times 100$	The percentage change in green area per capita from 2005 to 2020	%	KOSIS

Built environment characteristics are assessed using a set of key variables. Housing-related indicators include total housing units, the proportion of aging housing stock (defined as housing over 40 years old), the share of single-family housing, and the share of apartment units. These variables indicate both housing supply conditions and prevailing residential patterns within each municipality. Living infrastructure accessibility is measured by the average distance from the center of each grid cell to the nearest facility of each type, using road network-based travel distances. Facility location data are provided by the National Geographic Information Institute (NGII) and include a wide range of amenities: community parks, theme parks, public sports facilities, daycare centers, kindergartens, elementary schools, libraries, public libraries, small libraries, cultural facilities, comprehensive social welfare centers, senior welfare centers, senior classrooms, senior leisure facilities, public health centers, medical clinics, hospitals, general hospitals, emergency medical centers, and pharmacies. Urban form and land-use characteristics include urban density, land-use diversity, and green area per capita. Urban density is calculated as the total population divided by the total urbanised area, capturing the intensity of development. Land-use diversity is quantified using the Shannon entropy index, based on the proportional distribution of residential, commercial, and industrial land areas. Green area per capita is calculated by dividing the total area of green space by the population, representing access to ecological and recreational amenities.

The primary data sources for this study include SGIS, with additional data on industrial complexes obtained from the Industrial Location Information System (ILIS). Additional data such as cumulative birth rate, cumulative death rate, net migration rate, urban density, land-use diversity, and green area per capita were obtained from the Korean Statistical Information Service (KOSIS).

Ⅳ. Results

1. Spatial Patterns of Urban Shrinkage

As shown in 〈Figure 1〉, the Within-Cluster Sum of Squares (WCSS) decreases with more clusters, but a clear "elbow point" is not evident. Inflection points at 4, 6, and 7 clusters suggest multiple candidates. To complement this, we used the silhouette score, which was highest for 6 clusters (0.2915), indicating the best balance between cohesion and separation. Additionally, the 6-cluster configuration revealed the most distinct and interpretable spatial patterns, with clear links to economic and geographic variables. Based on both quantitative and qualitative assessments, we selected the 6-cluster solution for analysis.

〈Figure 2〉 presents the population change trajectories for urban and non-urban areas across six urban shrinkage types. The left and middle panels display time-series trends in population change rates, measured relative to the baseline year 2000, for urban and non-urban areas, respectively. The right panel provides a spatial typology of urban shrinkage,

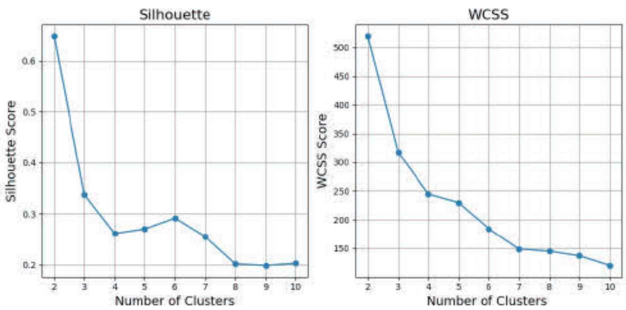

Figure 1. Silhouette score and Within-Cluster Sum of Squares

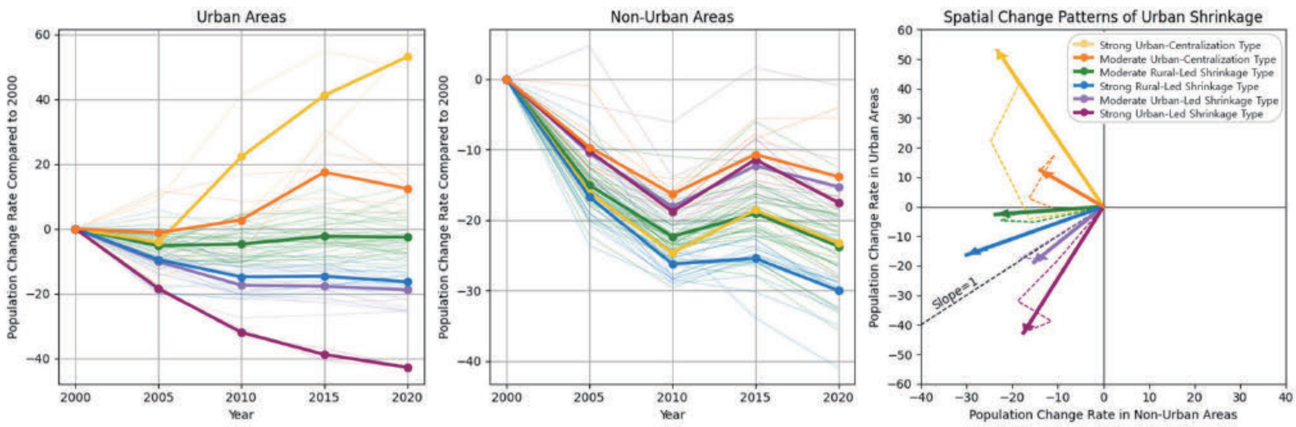

Figure 2. Time series changes in population of urban and non-urban areas by urban shrinkage type

plotting the average population change rate in urban areas (y-axis) against that in non-urban areas (x-axis).

Types located in the second quadrant were labeled as "Urban Centralization Type," reflecting a pattern of population increase in urban areas. The length of the arrows represents the magnitude of change, and this intensity is incorporated into the labels as either "Strong" or "Moderate" Urban Centralization. The Strong Urban-Centralization Type, encompassing Imsil-gun and Haman-gun, represents the smallest cluster characterized by strong urban population growth (53.07%) and significant non-urban decline (-23.27%). In this type, the urban areas have formed around the county administrative centers, and urban density has been further strengthened by the introduction of population-attracting facilities such as military bases (in Imsil-gun) and industrial complexes (in Haman-gun), along with new residential developments.

Types located in the third quadrant show population decline in both urban and non-urban areas. These were further distinguished based on whether the decline was more prominent in urban or non-urban areas, using the line y = x as a reference. Accordingly, they were categorized as either "Rural-Led Shrinkage" or "Urban-Led Shrinkage", with the intensity of decline again classified as "Strong" or "Moderate". As a result, the six final types are named: Strong and Moderate Urban Centralization, Rural-Led Shrinkage, and Urban-Led Shrinkage. Detailed statistics on each type can be found in 〈Appendix〉.

The spatial distribution of these types (Figure 3) reveals complicated patterns. The Moderate Rural-Led Shrinkage Type is concentrated in Chungcheong nam-do, Jeollabuk-do, and Gyeongsangnam-do, often in contiguous areas. The Strong Rural-Led Shrinkage Type is predominantly found in Jeollanam-do and Gyeongsangbuk-do, while Moderate Urban-Led type clusters in Gangwon-do and Gyeongsangbuk-do. This multi-temporal clustering approach, incorporating both urban and non-urban areas, reveals more complex patterns of urban shrinkage than previous studies focusing solely on urban areas. Particularly noteworthy is the distinction between Urban-Centralization Types and Urban-Led Shrinkage Types, which show very different spatial patterns of decline.

2. Analysis of Characteristics by Urban Shrinkage Spatial Pattern Types

To examine whether the six spatial types differ significantly in their demographic, social, and economic characteristics, we applied the Kruskal–Wallis H test, a non-parametric method appropriate for comparing more than three groups without assuming normality. The results revealed statistically significant differences ($p<0.05$) in changes in variables such as the total population, net migration rate, elderly population rate, number of businesses, employees, housing units, single-family housing rate, and accessibility to living infrastructure, suggesting that the spatial types are not only distinct in their patterns of shrinkage but also in their associated socioeconomic conditions.

1) Population Change Compositions

Our study classified spatial shrinkage patterns by examining population changes in urban and non-urban areas.

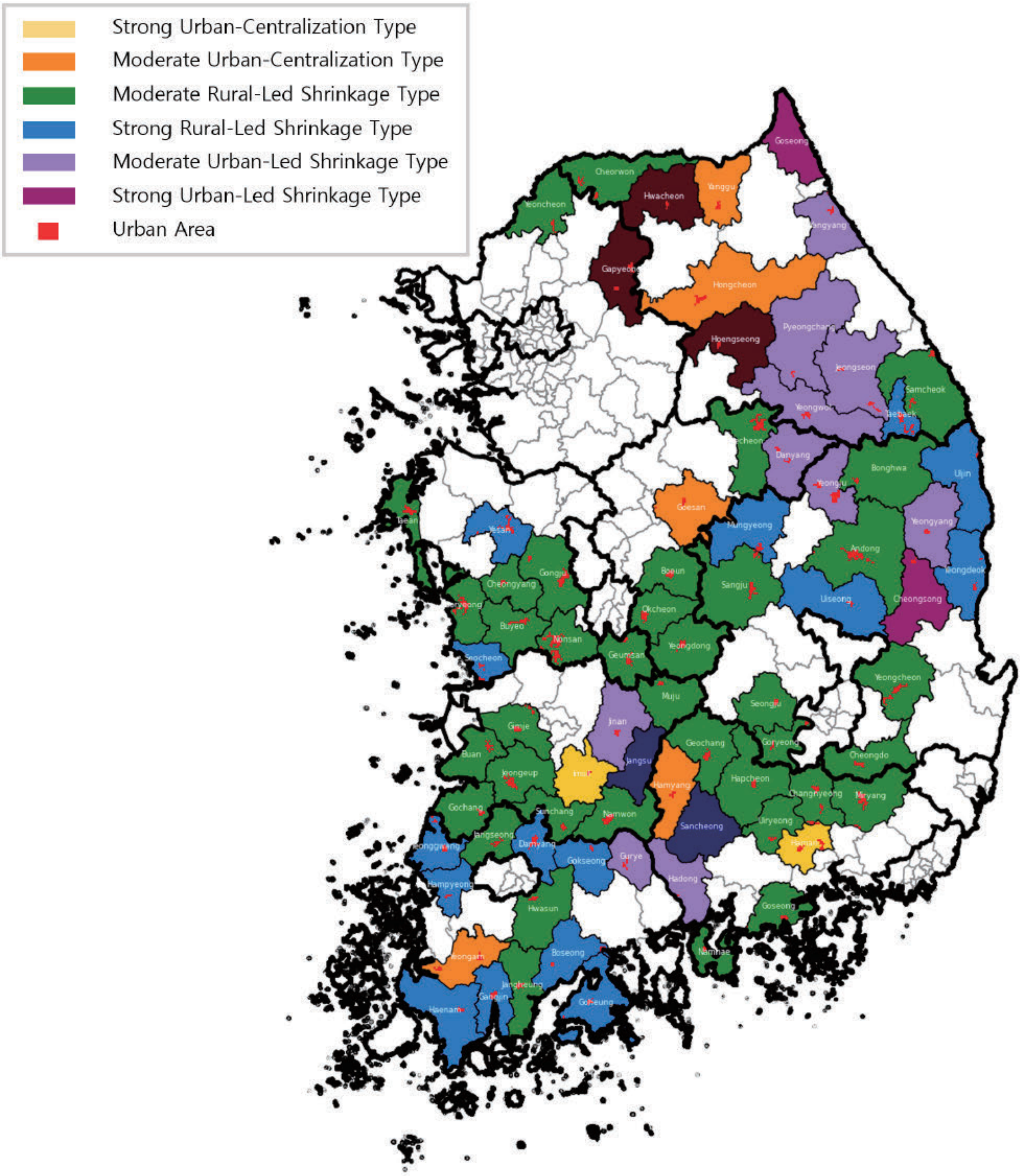

Figure 3. Geographical mapping of urban shrinkage type

Population change comprises natural factors (births and deaths) and social factors (migration). For each type, we analyzed the rate of change in births, deaths, and migration between 2005 and 2020,[2] using mean values within types for comparison (Figure 4).

Natural population factors show consistent patterns across shrinkage types. Death rates average −18.67% city-wide across all types, with non-urban areas experiencing higher rates (−22.02%) compared to urban areas (−16.30%). Birth rates are also relatively uniform, averaging 10.53% city-wide, with urban areas showing higher rates (10.28%) than non-urban areas (7.62%).

Migration patterns, however, vary significantly among types. The Strong Urban-Centralization Shrinkage Type experienced population inflow in both areas, with stronger inflow in urban areas. In contrast, Urban-Led Shrinkage

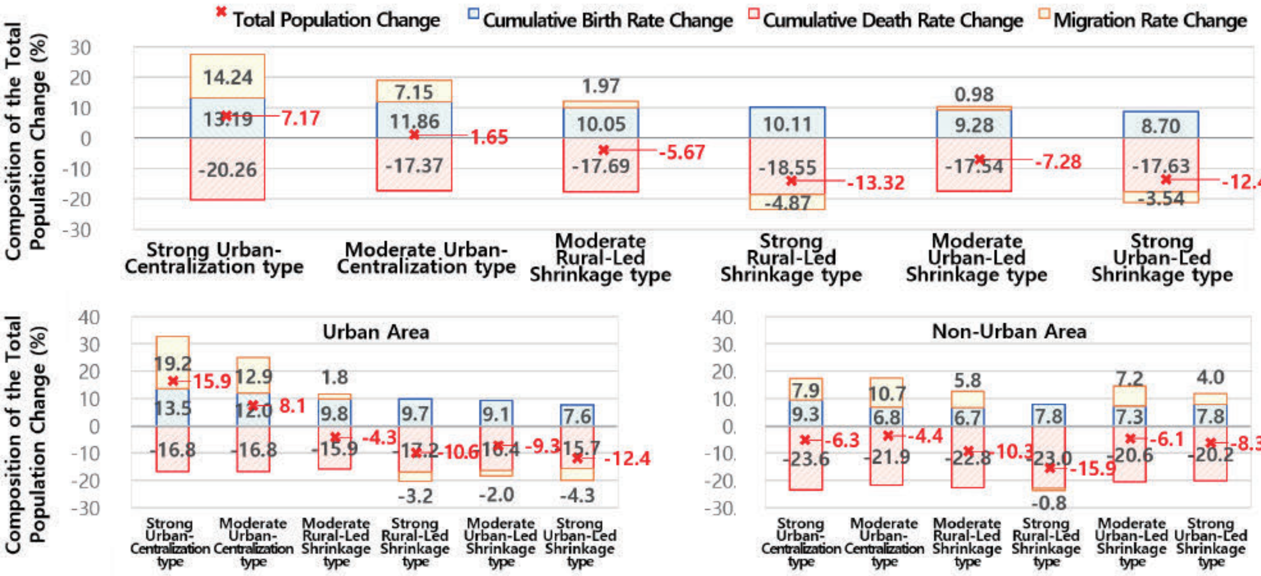

Figure 4. Composition of the total population change

Types show strong urban outflow but significant non-urban inflow. Strong Urban-Led type exhibits either modest inflow or substantial outflow. Notably, except for the Strong Rural-Led Shrinkage Type, all types demonstrate positive population inflow into non-urban areas. While urban areas experienced either population inflow or outflow depending on the type, non-urban areas consistently showed population inflow ranging from 4% to 10% of average population change across all types except the Strong Rural-Led Shrinkage Type. This finding is particularly significant as it indicates that some of the current urban shrinkage patterns are not aligning with the core principle of shrinking smart strategies, which emphasizes strengthening population density in concentrated urban areas.

These findings illustrate that while natural demographic factors remain relatively consistent across types, the distinct spatial patterns of urban shrinkage are primarily shaped by variations in migration patterns. This underscores the predominant role of social factors in determining the spatial characteristics of population decline in shrinking municipalities.

2) Economic and Built Environment Characteristics

Our analysis of spatial patterns in shrinking cities reveals that variations between urban and non-urban areas are associated with differences in demographic, economic, and built environment characteristics, as shown in 〈Figure 5〉. They function as both causes and consequences of population decline (Shin et al., 2021; Nam, 2022; Ribant and Chen, 2019). We examined these characteristics across different shrinkage types by analyzing mean rates of change between 2000 and 2020, with the exception of infrastructure accessibility data which is only available for 2020.

Statistical significance of the differences across shrinkage spatial types was tested using the Kruskal-Wallis test, a nonparametric statistical test suitable for limited number of samples or samples with non-normality (McKight et al., 2010). The test ($p<0.05$) revealed significant differences between shrinkage types in total population change, net migration ratios, elderly population ratios change, total business establishments change, total employment change, total housing units change, single-family housing ratios change, and accessibility to living infrastructure. However, no significant differences were found in cumulative birth and death ratios, youth population ratios change, manufacturing industry employment ratios change, old housing ratios change, and apartment housing rate change. The results are shown in 〈Appendix 3〉.

The detailed characteristics of each type are as follows. The Strong Urban-Centralization Shrinkage Type demonstrates the healthiest demographic structure among all types, with the lowest rates of youth population decline and elderly population increase. It exhibits exceptional economic vitality, showing the largest growth in total business establishments (131.28%) and employment (118.28%). The population-attracting facilities such as military bases in Imsil-gun

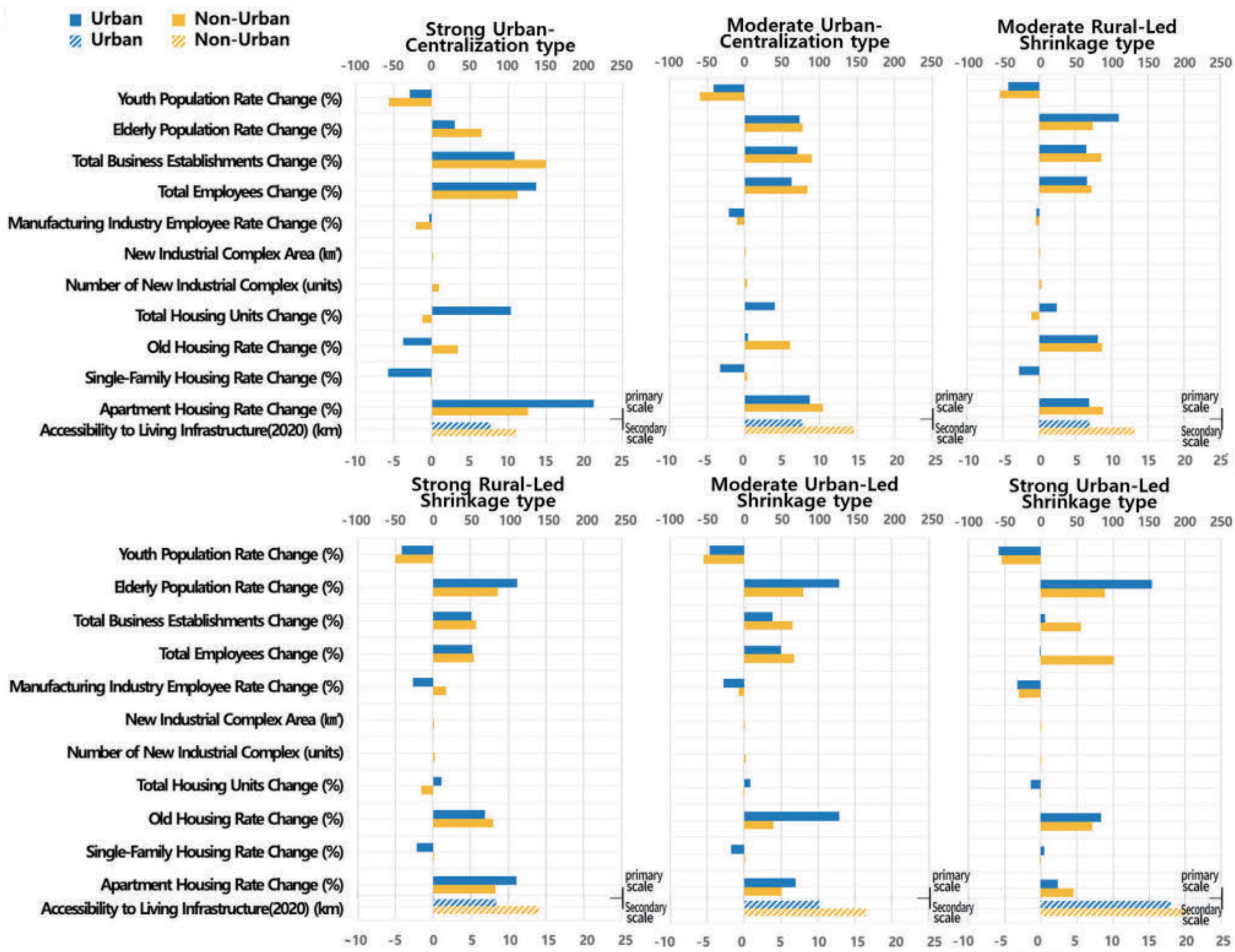

Figure 5. Average rate of change in internal haracteristics of cities by Urban Shrinkage type

and industrial complexes in Haman-gun, along with new residential developments, have driven remarkable industrial growth. Housing development in this type is robust, with housing stock ranking second only to the Moderate Urban-Centralization Type. It also features the best accessibility to living infrastructure among all types. The Moderate Urban-Centralization Shrinkage Type demonstrates patterns similar to the Strong Urban-Centralization Type but with more moderate intensity. It shows overall decline of -6.45%, urban growth of +12.38%, and non-urban decline of -13.82%. This type shows strong economic development, with substantial housing growth and good urban infrastructure accessibility.

The Moderate Rural-Led Shrinkage Type demonstrates modest economic growth (+74.31% businesses, +68.01% employment). Housing development remains stagnant (+3.81% new housing). The Strong Rural-Led Shrinkage Type demonstrates the most severe overall population decline (-26.07%), affecting both urban and non-urban areas. Economic growth indicators are the lowest among all types, with an actual decline in housing units (-5.74%). This type shows manufacturing employment growth in non-urban areas (+17.10%) despite overall decline, suggesting some industrial restructuring. Living infrastructure accessibility is poorer compared to the previous types.

The Moderate Urban-Led Shrinkage Type shows moderate economic growth, and some apartment-centered development. The Strong Urban-Led Shrinkage Type presents the most dramatic urban population collapse (-42.75%) with more moderate non-urban decline (-17.50%). It demonstrates extreme aging, with the share of elderly population growth of +108.90%, stagnant economic development in urban areas (employee change -1.14%), and deteriorating housing conditions. Infrastructure accessibility is poorest among all types, indicating severe urban disinvestment. In fact, new multi-family housing developments near military bases and correctional facilities in the outskirt rather than in the original town centers appear to have further intensified the decline of the urban core and deteriorated housing and infrastructure conditions in Goseong-gun and Cheongsong-gun.

At the municipality level, we compared changes in net population density, per capita green area, and landuse diversity as shown in 〈Appendix 3〉. Overall, net population density declined across most types between 2005 and 2020, reflecting the broader pattern of population loss in shrinking municipalities. Notably, the largest decreases were observed in Strong Urban-Led Shrinkage Type, which indicates that population decline in these areas is occurring primarily within urban centers. The only exception is the Strong Urban-Centralization Type, which experienced a slight increase in density. Changes in green area per capita show an increasing trend in most of the types. However, this increase should be interpreted with caution: it does not necessarily indicate an actual expansion of green spaces, but rather reflects population decline, which results in fewer residents sharing the same amount of land. In other words, the increase in per capita green space is largely a passive outcome of depopulation rather than proactive green infrastructure development. In contrast, the Strong Urban-Centralization Type experienced a notable decline in green area per capita, likely due to densification and new residential developments. These contrasting patterns highlight the importance of distinguishing between physical land use changes and statistical increases driven by demographic shifts when interpreting per capita indicators. Land use diversity generally increased across most types, indicating a tendency toward more mixed-use environments despite declining populations. This may reflect adaptive strategies to sustain local vitality through functional diversification. However, two urban-led shrinkage types experienced a decline in land use diversity, implying increasing land use specialization or abandonment.

These patterns represent both causes and consequences of broader socioeconomic transformations. The Urban-Centralization types likely result from successful urban development policies, infrastructure investments, and employment opportunities that attract population from surrounding areas. Simultaneously, this concentration reinforces economic advantages and stimulates further urban development.

These findings demonstrate that spatial shrinkage patterns cannot be explained solely by the total number of population decline. Diverse phenomena with complex interplay between demographic, economic, and physical characteristics result in different shrinkage patterns. The variations across types suggest the need for tailored policy responses that address both causes and consequences of each specific pattern.

V. Discussion

Despite increasing emphasis on smart shrinkage strategies in response to South Korea's severe population decline, there remains a notable lack of comprehensive research on the spatial patterns of shrinkage within depopulating cities. Strategies that advocate for compact, high-density urban cores must be grounded in an understanding of intra-city demographic shifts, specifically differentiating between urban and non-urban areas. This study addresses this gap by applying the Time Series K-means algorithm to classify spatial population change patterns within shrinking municipalities from 2000 to 2020. It also examines the demographic, economic, and built-environment characteristics associated with each shrinkage type. The findings provide several key policy implications for implementing context-sensitive smart shrinkage strategies.

Our analysis reveals that spatial shrinkage within depopulating municipalities is far from uniform. Of the 77 shrinking municipalities analyzed, only seven exhibit population growth in their urban cores, corresponding to the Moderate and Strong Urban Centralization Types. The most prevalent pattern, Moderate Rural-Led Shrinkage, accounting for nearly half of all municipalities, is characterized by mild population loss in urban areas and severe depopulation in non-urban areas. While this does not indicate a strong urban-core compacting trend, it suggests that in at least more than half of the depopulating cities, urban areas are retaining population more effectively than rural surroundings, aligning with normative smart shrinkage principles that emphasize urban concentration.

For municipalities experiencing moderate or strong growth in urban cores (Urban-Centralization Types), smart shrinkage strategies should aim to reinforce this growth while preventing over-investment in declining peripheral areas. This involves the careful maintenance and upgrading of urban infrastructure and public services, alongside density management to ensure efficient provision of health, welfare, and commercial services (Yoon and Lee, 2019). Vacant homes and lots in the core should be repurposed through infill development, temporary uses, or green infrastructure. Additionally, strengthening connectivity with surrounding areas through functional and institutional integration at the city-region level is critical for sustaining urban-regional synergy (Shin and Woo, 2022; Koo, 2023).

In Moderate and Strong Rural-Led Shrinkage Types, population loss is severe in non-urban areas (up to -24% to -30% since 2000), while urban areas are declining more modestly. These municipalities require strategic planning for underused or abandoned non-urban spaces. As climate change increases the frequency of extreme weather, rewilding and environmental restoration of vacant peripheral land can offer dual benefits by mitigating climate risks and enhancing ecological value (Koo et al., 2016). Conservation corridors and green buffers can be planned to preserve undeveloped land, while long-term strategies for gradual rehabilitation of low-density rural areas can be pursued (Byun et al., 2024; Koo, 2023). Where public services in non-urban areas are to be discontinued or relocated, it is essential to implement measures that enhance accessibility to essential services for remaining residents. In cases where service maintenance costs are prohibitively high, shared service models or joint-use agreements with neighboring jurisdictions may help deliver services more efficiently.

Strong Rural-Led Shrinkage Type and Moderate and Strong Urban-Led Shrinkage Types are marked by over 16% population loss in urban cores, increasing the risk of vacant housing and urban perforation (Son and Hong, 2023). Without timely intervention, this trend can accelerate physical deterioration in urban areas, undermining the potential for future recovery. Uncontrolled scatter-type development in rural areas must be curbed through stricter permitting standards and spatial containment policies (Byun et al., 2024; Koo, 2023). For Urban-Led Shrinkage municipalities, where aging and infrastructure inaccessibility are particularly acute, improving intra-urban mobility is a pressing priority (Byun et al., 2024). Urban revitalization policies should include fiscal incentives, such as tax credits, mortgage subsidies, and housing purchase support, for developers, landlords, and prospective residents to stimulate repopulation in the core (Koo et al., 2016).

Ⅵ. Conclusions

This study analyzed spatial shrinkage patterns in 77 depopulating municipalities in South Korea using multi-temporal clustering analysis, revealing six distinct types of urban shrinking dynamics. Our analysis yields several key findings and implications.

First, this study identifies main patterns of urban shrinkage based on the internal spatial transformation: Urban-Centralization, Rural-Led, and Urban-Led with strong and moderate variations. Our analysis shows that spatial shrinkage patterns vary across cities, with both the Urban Centralization Types and the prevalent Moderate Rural-Led Shrinkage Type demonstrating relatively better population retention in urban areas than in non-urban areas. This suggests that in about 60% of the depopulating municipalities, urban areas seem to function as population anchors.

Second, our analysis reveals that while natural demographic factors (births and deaths) remain relatively consistent across types, migration patterns significantly differentiate shrinkage types. Notably, all types, except for the Strong Rural-Led Shrinkage Type, experienced positive population inflow into non-urban areas, contradicting shrinking smart strategies that emphasize core area densification. While Korean central and local governments implement various policies to attract population, in declining cities, determining where to direct population including existing residents, may be even more critical for sustainability than in growing cities.

Third, we found that demographic, economic and built environment characteristics vary significantly among shrinkage types. The Urban-Centralization Types showstrong economic growth and housing development with better accessibility to living infrastructure, particularly in urban areas. On the other hand, the Urban-Led Type demonstrates significantly higher elderly growth rates, poorer economic activities, reduced housing supplies, and worse living infrastructure accessibility, even in urban areas. However, our analysis is insufficient to determine whether these characteristics have led to different spatial transformation patterns or vice versa. These spatial patterns function simultaneously as both causes and consequences of demographic, economic, and physical environmental changes (Shin et al., 2021; Nam, 2022; Ribant and Chen, 2019), reflecting their mutually reinforcing relationships. This complex causality requires further investigation in future studies.

These findings have important academic and policy implications. Academically, our research contributes to the understanding of urban shrinkage by demonstrating the uneven spatial transformation patterns. While numerous studies examine urban "growth" spatial patterns, research on "shrinkage" spatial patterns remains limited (Kawabe and Watanabe, 2021; Son and Hong, 2023). For policy makers, our findings suggest that current development patterns often contradict shrinking smart principles, necessitating policy realignment. Shrinking cities must acknowledge ongoing population decline and transition toward a downsized planning framework that concentrates urban functions at an appropriate scale (Yang et al., 2024). Moreover, areas facing difficulties in providing adequate public services under reduced population scenarios require special attention. In this context, emerging smart city technologies can play a critical role in bridging service gaps. From a spatial planning perspective, different shrinkage types demand strategic redistribution of urban functions and the selective reuse of underutilized spaces (Yoon and Lee, 2019). Tailored, type-specific interventions are essential, as a one-size-fits-all approach is unlikely to effectively address the diverse challenges, as discussed in the previous section.

Despite these contributions, several limitations of our study should be noted. First, the population grid data from the Statistics Office has missing values, which might have led to underestimation of population in some areas. Second, the UN population density criteria used to define urban areas may be too stringent for small cities in our study. Third, the focus on population indicators alone may not fully capture spatial shrinkage dynamics. Lastly, it should be noted that securing more time points would be desirable to enhance the reliability and precision of time-series analysis results.

Future research should investigate the temporal evolution of these patterns, causal relationships between factors influencing urban shrinkage, and the effectiveness of different policy interventions. While high-density centralization is generally considered desirable for shrinking cities (Ha and Kang, 2022; Lee and Han, 2014; Kwon et al., 2018; Park et al., 2020; Nam, 2022), empirical studies on quantitative effects are lacking. Therefore, future research should examine how different shrinkage types affect urban performance measures such as energy usage and economic outcomes. Additionally, to deepen the understanding of the observed spatial disparities, future research should investigate whether these divergent internal spatial transformations stem from pre-existing socioeconomic and physical characteristics, or whether they are the outcomes of differing patterns of population decline. A more rigorous causal analysis is needed to disentangle these relationships, which would help clarify the mechanisms driving spatial restructuring in shrinking regions.

Note 1. The definition of urban areas in this study follows standardized criteria established by six international organizations, including the European Union, UN-Habitat, and the World Bank. Under these criteria, Urban Centers are defined as areas with population density exceeding 1,500 people per km² grid cell and a minimum total population of 50,000 in contiguous grid cells. Urban Clusters are defined as areas with population density exceeding 300 people per km² grid cell and a minimum total population of 5,000 in contiguous grid cells.

Note 2. While our analysis of population change patterns utilized grid cell data, the analysis of births and deaths employed dong-level (administrative district) data from Statistics Korea. Due to data availability constraints for dong-level statistics, which were only available from 2005 onward, our analysis of population change components (births, deaths, migration) covered the period from 2005 to 2020.

References

1. Audirac, I., Fol, S., and Martinez-Fernandez, C., 2010. "Shrinking Cities in a Time of Crisis", *Berkeley Planning Journal,* 23(1): 51-57.
2. Bae, J.H. and Bae, H.L., 2023. *Current Status and Implications of Regional Competitiveness*, Bank of Korea.
3. Beauregard, R.A., 2013. "Shrinking Cities in the United States in Historical Perspective: A Research Note", in *Shrinking Cities,* edited by Pallagst, K., Wiechmann, T., and Martinez-Fernandez, C., New York: Routledge.
4. Berg, L.V.D., Drewett, R., Klaasen, L.H., Rossi, A., and Vijver-

berg, C.H., 1982. *Urban Europe: A Study of Growth and Decline,* The Costs of Urban Growth (curb) Project, 1, Oxford: Pergamon Press

5. Bontje, M., 2004. "Facing the Challenge of Shrinking Cities in East Germany: The Case of Leipzig", *GeoJournal*, 61(1): 13-21.
6. Burger, M.J. and Meijers, E.J., 2016. "Agglomerations and the Rise of Urban Network Externalities", *Papers in Regional Science*, 95(1): 5-15.
7. Byun, E., Han, S., and Bang, J., 2024. *Compact-Network Approach to Living-Zone Planning in Depopulating Cities,* Architecture Urban Research Institute.
8. Cho, D.H. and Lee, C.H., 2023. "Analyzing Spatial Characteristics of Urban Shrinkage in South Korea: Focused on Changes in Densely Inhabited Districts", *Journal of the Korean Urban Geographical Society*, 26(3): 51-68.
9. Cho, M.H., Kim, J.S., Kang, J.W., Hwang, K.S., Park, S.Y., and Cho, G.S., 2015. *Regional Revitalization Strategies for Gangwan-do in Repose to an Aging Society*, Research Institute for Gangwon.
10. Choi, J.H., 2010. "Instabilities in the Korean Urban Population Growth", *Journal of the Korean Urban Geographical Society,* 13(2): 89-102.
11. Cieśla, A., 2013. "Shrinking City in Eastern Germany: The Term in the Context of Urban Development in Poland", Ph.D. Dissertation, Bauhaus-Universität Weimar.
12. Elis, V., 2008. "The Impact of the Aging Society on Regional Economies", in *The Demographic Challenge: A Handbook about Japan*, 861-877, Brill.
13. Eom, H.T. and Woo, M.J., 2014. "The impacts of Suburban New Town Development on the Decline of Inner Cities", *Journal of Korea Planning Association*, 49(5): 51-66.
14. Großmann, K., Haase, A., Rink, D., and Steinführer, A., 2008. "Urban Shrinkage in East Central Europe? Benefits and Limits of a Cross-National Transfer of Research Approaches", in *Declining Cities/Developing Cities: Polish and German Perspectives*, Instytut Zachodni.
15. Ha, J.H. and Kang, J.E., 2022. "A Study on Calculation of Urban Compactness Index Considering Space Syntax: Focusing on the Declining Local Cities", *Journal of the Korean Association of Geographic Information Studies*, 25(3): 29-58.
16. Haase, A., Rink, D., Großmann, K., Bernt, M., and Mykhnenko, V., 2014. "Conceptualizing Urban Shrinkage", *Environment and Planning A: Economy and Space,* 46(7): 1519-1534.
17. Heo, M.K., 2022. "Development of the K-Regional Extinction Index and Policy Challenges: Focusing on the Regional Economic Circulation Mechanism of Regional Economies", *KIET Monthly Industrial Economics*, 289.
18. Hollstein, L.M., 2014. "Planning Decisions for Vacant Lots in the Context of Shrinking Cities: A Survey and Comparison of Practices in the United States", Ph.D. Dissertation, The University of Texas at Austin.
19. Hollander, J., Pallagst, K., Schwarz, T., and Popper, F., 2009. "Planning Shrinking Cities", *Progress in Planning*, 72(4): 223-232.
20. Jang, M.H., 2023. "Study on Classification of Depopulation Areas According to Crisis of Local Extinction", *The Geographical Journal of Korea*, 57(1): 11-22.
21. Iwasaki, Y., 2021. "Shrinkage of Regional Cities in Japan: Analysis of Changes in Densely Inhabited Districts", *Cities*, 113: 103168.
22. Kang, E.Y., Kim, J.H., and Lee, S.L., 2024. *A Study on Core Indicators in Depopulation Areas*, Statistics Korea Statistics Research Institute.
23. Kang, M.K., 2024. "A Study on the Spatial Shrinkage Characteristics of Depopulating Cities", Master's Thesis, Seoul National University.
24. Kawabe, A. and Watanabe, S., 2021. "An Analysis on Urban Shrinkage Trends of All Japanese Cities by Detecting Relative Densely Inhabited Districts-Changes in Urban Form of Japanese Cities in an Era of Shrinking Population, Part 2", *Japan Architectural Review*, 4(3): 482-494.
25. Kim, K.J., 2010. "Causes and Consequences of Urban Decline in Korean Cities", *Journal of the Korean Urban Geographical Society*, 13(2): 43-58.
26. Kim, S.T. and Park, M.S., 2018. "A Study on Time-series Clustering Analysis based on Dynamic Time Warping", *Journal of The Korean Data Analysis Society,* 20(5): 2319-2332.
27. Kim, S.H. and Cho, M.J., 2019. "A Study on the Classifications of Population Decrease Areas by Demographic Change Characteristics and Actual Conditions of Urban Shrinkage", *Journal of Korea Urban Regeneration Association*, 5(1): 67-81.
28. Kim, Y.H., 2021. "The effects of regional economic and living conditions on youth population migration", Korean Public Administration Review, 55(2): 337-367.
29. Kim, H.C. and Jeong, S., 2024. "The Effect of Job Satisfaction and Job Diversity on the Youth Population Migration in Non-capital Region", Paper presented at the 2024 The Korean Regional Development Association Winter Academic Conference, Seoul: Science and Technology Convention Center.
30. Koo, Y.M., 2021. "Regional Disparities in Population Change and Urban Decline: Implications for the Low Fertility and Disappearing Region Issues", *The Geographical Journal of Korea*, 55(3): 301-320.
31. Koo, H., 2023. "What Threatens the Survival of Cities?: A Structural Understanding of Urban Shrinkage", *The Korea Spatial Planning Review*, 119: 31-50.
32. Koo, H.S., Kim, T.H., Lee, S.W., and Min, B.S., 2016. *Urban Shrinkage in Korea: Current Status and Policy Implications*, Korea Research Institute of Human Settlements.
33. Koo, H.S. and Min, B.S., 2018. *Why Disappearing Urban Neighborhoods Matter: Implications for Policy and Practice*, Korea Research Institute of Human Settlements.
34. Kwon, K.S., Fuminori, T., and Kim, Y.L., 2018. *Strategy and Practice in the Compact and Network City Policy*, Korea Research Institute of Human Settlements.
35. Kwon, S.C., 2005. "Migration to the Capital Region in Korea: Assessing the Relative Importance of Place Characteristics

and Migrant Selectivity", *Journal of The Korean Association of Regional Geographers*, 11(6): 571-584.

36. Lang, W., Deng, J., and Li, X., 2020. "Identification of "Growth" and "Shrinkage" Pattern and Planning Strategies for Shrinking Cities Based on a Spatial Perspective of the Pearl River Delta Region", *Journal of Urban Planning and Development*, 146(4): 05020020.

37. Laursen, L.L.H., 2009. "Shrinking Cities or Urban Transformation", Ph. D. Dissertation, Universitet Aalborg.

38. Lee, H.Y. and Han, S.K., 2014. *Lost Shrinking Cities: Which Direction Should They Take?*, Sejong. Korea Research Institute for Human Settlements

39. Lee, S.H., 2016. "Seven Analyses on 'Regional Extinction' in South Korea", *Regional Employment Trends Brief*, 2016(Spring): 4-17.

40. Lee, S.H. and Oh, S.H., 2021. *Indexing Factors of Regional Population Changes and Typology of Policy Issues*, Korea Institute for Health and Social Affairs.

41. Lee, S.H. and Kim, G., 2018. "A Case Study on the Shrinking City of Gongju-si based on Rasterization". *Journal of the Korean Urban Geographical Society*, 21(3): 35-46.

42. Lee, S.S., Jeon, H.J., and Lee, J.J., 2018. "An Investigation into the Evaluation Criteria, Cases and Causes of Urban Shrinkage", *SH Urban Research & Insight*, 8(3): 83-100.

43 Lim, S.H., 2018. "Types of Depopulated Cities and their Geographical Characteristics", *The Geographical Journal of Korea*, 52(1): 65-84.

44. Ma, K.R., 2017. *The Death List of Regional Cities: 'Compact Cities' as the Only Way to Survive*, Wonju: Kaemagowon.

45. Martinez-Fernandez, C., Audirac, I., Fol, S., and Cunningham-Sabot, E., 2012. "Shrinking Cities: Urban Challenges of Globalization", *International Journal of Urban and Regional Research*, 36(2): 213-225.

46. Mattson, J., 2021. "Relationships between Density and per Capita Municipal Spending in the United States", *Urban Science*, 5(3): 69.

47. McKight, P.E. and Najab, J., 2010. "Kruskal-Wallis Test", *The Corsini Encyclopedia of Psychology*, 1: 1-10.

48. Miyauchi, T. and Setoguchi, T., 2023. "Does Low Urban Density Increase Municipal Expenditure? Population Density as a Performance Target for Compact City Planning in Japan", *Journal of Urban Management*, 12(4): 375-384.

49. Nam, J.H., 2022. *Types of Shrinking Cities and Urban Management Strategy for Urban Shrinkage: Focusing on Overseas Cases*, Gyeonggi Research Institute.

50. Nguena Nguefack, H.L., Pagé, M.G., Katz, J., Choinière, M., Vanasse, A., Dorais, M., Samb, O.M., and Lacasse, A., 2020. "Trajectory Modelling Techniques Useful to Epidemiological Research: A Comparative Narrative Review of Approaches", *Clinical Epidemiology*, 12: 1205–1222.

51. Pallagst, K., 2008. "Shrinking Cities", in *Cities Growing Smaller*, Kent State University's Cleveland Urban Design Collaborative.

52. Park, C.S., Sin, J.Y., Song, J.Y., Park, H.J., Lee, J.K., Song, W.K., and Choi, H.S., 2020. *Urban Model and Sustainable Planning Strategies for Smart Shrinking City (I)*, Korea Environment Institute.

53. Park, H.S. and Jun, C.H., 2009. "A Simple and Fast Algorithm for K-medoids Clustering", *Expert Systems with Applications*, 36(2): 3336-3341.

54. Park, J.K., Kim, H.H., Kim, S.M., and Lim, T.K., 2019. *A Comprehensive Study on Policy Measures for Addressing Regional Population Decline*, Korea Research Institute for Local Administration.

55. Park, S.K. and Lee, J.Y., 2017. *Designation Criteria and Simulation Study of Depopulated Areas*, Korea Research Institute for Local Administration.

56. Popper, D.E. and Popper, F.J., 2002. "Small Can Be Beautiful: Coming to Terms with Decline", *Planning*, 68(7): 20-23.

57. Reis, J.P., Silva, E.A., and Pinho, P., 2016. "Spatial Metrics to Study Urban Patterns in Growing and Shrinking Cities", *Urban Geography*, 37(2): 246-271.

58. Ribant, M. and Chen, X., 2019. "A Typology of U.S. Shrinking Cities", *The Professional Geographer*, 72(1): 152-164.

59. Schilling, J. and Logan, J., 2008. "Greening the Rust Belt: A Green Infrastructure Model for Right Sizing America's Shrinking Cities", *Journal of the American Planning Association*, 74(4): 451-466.

60. Seta, H., Kim, K.I., Byeon, P.S., and Wang, G.I., 2006. *Changes in Urban Spatial Structure and Policy Responses in the Era of Low Population Growth: Focusing on Japan*, Korea Research Institute for Human Settlements.

61. Shin, H. and Woo, M., 2022. "A Study on the Effects of the Characteristics of Urban Regions on Shrinking Cities", *Journal of Korea Planning Association*, 57(6): 25-36.

62. Shin, J.Y., Park, C.S., Park, H.J., Song, J.Y., Kim, N.Y., Song, J.Y., Lee, J.K., Han, D.J., Song, W.K., Kim, H.M., Lee, H.J., Kim, T.H., Park, Y.M., and Choi, J.S., 2021. *Urban Model and Sustainable Planning Strategies for Smart Shrinking City (II)*, Korea Environment Institute.

63. Son, G.Y. and Hong, S.J., 2023. "Spatial Reductions in Small and Medium-sized Cities with Population Decline", *The Korea Spatial Planning Review*, 119: 101-120.

64. Song, M.L., Seong, J.I., Sim, J.H., and Seo, H.J., 2021. *The Significance and Implications of the Regional Regeneration Potential Index*, Korea Rural Economic Institute.

65. van der Does, F. H., Nagamine, M., van der Wee, N. J., Chiba, T., Edo, N., Kitano, M., Vermetten E., and Giltay, E.J., 2023. "PTSD Symptom Dynamics after the Great East Japan Earthquake: Mapping the Temporal Structure Using Dynamic Time Warping", *European Journal of Psychotraumatology*, 14(2): 2241732.

66. Yang, Y., Dong, Z., Zhou, B.B., and Liu, Y., 2024. "Smart Growth and Smart Shrinkage: A Comparative Review for Advancing Urban Sustainability", *Land*, 13(5): 660.

67. Yoon, J. and Lee, S., 2019. "A Study on the Urban Planning's

Implications and the Governmental Policies for Shrinking City in Japan: Focusing on Location Normalization Plan", *Journal of Korea Planning Association*, 54(2): 17-32.

Date Received 2025-03-28
Reviewed(1st) 2025-04-27
Date Revised 2025-05-29
Reviewed(2nd) 2025-06-12
Date Accepted 2025-06-12
Final Received 2025-06-26

Appendix

Appendix 1. List of municipalities by Urban Shrinkage Type

Urban Shrinkage Type	List of municipalities
Strong Urban-Centralization Type (2)	Imsil-gun, Haman-gun
Moderate Urban-Centralization Type (5)	Goesan-gun, Yanggu-gun, Yeongam-gun, Hamyang-gun, Hongcheon-gun
Moderate Rural-Led Shrinkage Type (38)	Geochang-gun, Goryeong-gun, Goseong-gun (Gyeongnam), Gochang-gun, Gongju-si, Geumsan-gun, Gimje-si, Namwon-si, Namhae-gun, Nonsan-si, Muju-gun, Miryang-si, Boryeong-si, Boeun-gun, Bonghwa-gun, Buan-gun, Buyeo-gun, Samcheok-si, Sangju-si, Seongju-gun, Sunchang-gun, Andong-si, Yeoncheon-gun, Yeongdong-gun, Yeongcheon-si, Okcheon-gun, Uiryeong-gun, Jangseong-gun, Jangheung-gun, Jeongeup-si, Jecheon-si, Changnyeong-gun, Cheorwon-gun, Cheongdo-gun, Cheongyang-gun, Taean-gun, Hapcheon-gun, Hwasun-gun
Strong Rural-Led Shrinkage Type (15)	Gangjin-gun, Goheung-gun, Gokseong-gun, Damyang-gun, Mungyeong-si, Boseong-gun, Seocheon-gun, Yeonggwang-gun, Yeongdeok-gun, Yesan-gun, Uljin-gun, Uiseong-gun, Taebaek-si, Hampyeong-gun, Haenam-gun
Moderate Urban-Led Shrinkage Type (10)	Gurye-gun, Danyang-gun, Yangyang-gun, Yeongyang-gun, Yeongwol-gun, Yeongju-si, Jeongseon-gun, Jinan-gun, Pyeongchang-gun, Hadong-gun
Strong Urban-Led Shrinkage Type (2)	Goseong-gun (Gangwon), Cheongsong-gun

Appendix 2. Average characteristics by Urban Shrinkage Type (Year 2000)

Characteristics	Strong Urban-Centralization Type	Moderate Urban-Centralization Type	Moderate Rural-Led Shrinkage Type	Strong Rural-Led Shrinkage Type	Moderate Urban-Led Shrinkage Type	Strong Urban-Led Shrinkage Type
Total population (persons)	43,717.50	44,727.80	71,900.26	62,546.33	44,391.10	31,148.00
Population density (persons/km²)	94.28	53.05	103.85	105.36	57.76	42.02
Youth population rate (%)	17.16	18.98	17.30	16.27	16.96	17.27
Elderly population rate (%)	20.95	17.43	17.89	19.21	16.25	16.75
Total businesses establishments (units)	2,994.50	3,038.20	4,737.74	4,090.27	3,302.90	2,398.50
Total employees (persons)	13,370.00	11,706.60	17,278.53	14,395.07	11,693.10	8,149.50
Manufacturing industry employee rate (%)	35.82	20.84	18.47	15.98	11.02	9.36
Total housing units (units)	15,411.00	14,961.80	23,359.13	21,023.00	14,271.80	10,710.50
Old housing rate (%)	22.39	15.39	15.33	18.16	16.42	14.44
Single-family housing rate (%)	84.08	77.77	76.74	81.19	77.15	80.22
Apartment housing rate (%)	10.09	12.55	15.03	9.08	11.72	10.41

Appendix 3. Average rate of change in characteristics by Urban Shrinkage Type (2000 vs. 2020)

Characteristics	Strong Urban-Centralization Type	Moderate Urban-Centralization Type	Moderate Rural-Led Shrinkage Type	Strong Rural-Led Shrinkage Type	Moderate Urban-Led Shrinkage Type	Strong Urban-Led Shrinkage Type	H-statistic	p-value
Total population change (based on the year 2000) (%)	-4.84	-6.45	-16.62	-26.07	-17.86	-23.16	36.07	0.000*
Total population change (based on the year 2005) (%)	7.17	1.65	-5.67	-13.32	-7.28	-12.48	22.95	0.000*
Cumulative birth rate (based on the year 2005) (%)	13.19	11.86	10.05	10.11	9.28	8.70	9.01	0.108
Cumulative death rate (based on the year 2005) (%)	-20.26	-17.37	-17.69	-18.55	-17.54	-17.63	2.37	0.796
Net migration rate (based on the year 2005) (%)	14.24	7.15	1.97	-4.87	0.98	-3.54	15.66	0.001*
Youth population rate change (%)	-42.69	-50.34	-47.73	-47.21	-51.19	-58.77	9.00	0.109
Elderly population rate change (%)	48.17	66.90	78.76	86.32	89.46	108.90	12.42	0.029*
Total business establishments change (%)	131.28	84.91	74.31	53.91	54.99	42.40	15.40	0.008*
Total employees change (%)	118.78	84.83	68.01	50.94	59.16	73.38	15.69	0.007*
Manufacturing industry employee rate change (%)	-17.35	-9.18	-1.96	1.64	-14.75	-25.72	5.37	0.372
Total housing units change (%)	11.13	15.19	3.81	-5.74	6.58	-3.19	19.53	0.015*
Old housing rate change (%)	13.51	34.96	89.63	75.80	50.99	88.13	8.30	0.140
Single-family housing rate change (%)	-19.00	-10.81	-12.34	-9.02	-6.34	1.03	15.04	0.010*
Apartment housing rate change (%)	185.57	107.03	101.76	133.19	196.04	22.35	9.13	0.104
Accessibility to living infrastructure (year 2020) (km)	10.17	11.53	10.19	11.87	14.13	20.02	11.75	0.038*
Urban density (based on the year 2005) (%)	2.10	-34.39	-23.74	-20.50	-24.73	-40.61	4.57	0.470
Green area per capita (based on the year 2005) (%)	-24.03	15.02	6.07	15.81	32.72	39.18	11.05	0.050*
Land-use diversity (based on the year 2005) (%)	3.43	8.65	23.26	13.92	0.003	-8.38	5.63	0.124

*p-value<0.05

Appendix 4. Average rate of change in characteristics by Urban Shrinkage Type for urban and non-urban areas (2000 vs. 2020)

Characteristics	Strong Urban-Centralization Type		Moderate Urban-Centralization Type		Moderate Rural-Led Shrinkage Type		Strong Rural-Led Shrinkage Type		Moderate Urban-Led Shrinkage Type		Strong Urban-Led Shrinkage Type	
	U	N	U	N	U	N	U	N	U	N	U	N
Total population change (based on the year 2000) (%)	53.07	-23.27	12.38	-13.82	-2.61	-23.69	-16.35	-29.99	-18.84	-15.24	-42.75	-17.50
Total population change (based on the year 2005) (%)	15.92	-6.32	8.13	-4.41	-4.33	-10.33	-10.65	-15.94	-9.29	-6.06	-12.35	-8.33
Cumulative birth rate (based on the year 2005) (%)	13.55	9.31	12.02	6.79	9.79	6.65	9.69	7.82	9.08	7.29	7.60	7.81
Cumulative death rate (based on the year 2005) (%)	16.82	23.56	16.78	21.87	15.93	22.82	17.16	22.97	16.37	20.57	15.67	20.16
Net migration rate (based on the year 2005) (%)	19.19	7.93	12.88	10.67	1.82	5.84	-3.18	-0.79	-2.00	7.23	-4.28	4.03
Youth population rate change (%)	-28.26	-55.96	-41.23	-60.15	-42.24	-54.57	-41.11	-50.29	-45.90	-54.40	-58.02	-54.08
Elderly population rate change (%)	30.25	65.50	72.79	76.78	109.62	74.00	112.17	86.20	128.19	79.89	153.48	88.78
Total business establishments change (%)	108.50	150.24	69.97	89.20	65.25	86.26	51.40	56.84	38.21	65.65	6.23	55.30
Total Employees change (%)	137.29	112.36	62.88	83.77	66.14	71.93	51.61	53.64	50.20	67.99	-1.14	101.40
Manufacturing industry employee rate change (%)	-2.97	-20.80	-20.81	-10.36	-3.81	-4.96	-26.28	17.10	-27.95	-6.98	-33.05	-30.43
New industrial complex area (km^2)	-	1.83	-	0.65	-	1.10	-	1.06	-	0.72	-	0.03
Number of new industrial complex (units)	-	10.00	-	3.40	-	3.55	-	2.73	-	2.10	-	0.50
Total housing units change (%)	104.29	-11.50	40.14	-0.83	24.15	-10.36	11.20	-15.49	8.80	-0.04	-13.61	-1.04
Old housing rate change (%)	-37.05	33.96	3.91	60.19	81.13	86.94	69.38	80.25	129.10	39.39	83.10	70.68
Single-family housing rate change (%)	-56.62	-0.07	-32.77	3.14	-27.62	1.01	-21.80	1.08	-17.69	0.03	4.29	-1.28
Apartment housing rate change (%)	212.80	126.41	86.61	103.78	69.46	87.61	110.79	82.99	69.43	51.25	23.86	45.16
Accessibility to living infrastructure (year 2020) (km)	7.74	11.11	7.71	14.57	6.96	13.10	8.40	14.02	10.23	16.55	17.94	20.42

U: urban areas, N: non-urban areas