Article

How Does the Location of Urban Facilities Affect the Forecasted Population Change in the Osaka Metropolitan Fringe Area?

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Abstract: This study aims to clarify the statistical causal relationship between the locations of urban facilities and forecasted population changes according to types of residential clusters in the Osaka Metropolitan Fringe areas. This paper’s background is the location optimization plan policy formulated by the Japanese MLIT (Ministry of Land, Infrastructure, Transport, and Tourism) in 2015. The methods combined urban ecological analysis, cohort analysis, and Bayesian network analysis. Using the Bayesian network analysis, the causal relationship between the forecasted population change ratio and the urban facility location was analyzed. The results suggest the location of urban facilities for each residential cluster that will prevent a rapid population decline in the future. Specifically, in the sprawl cluster, this study found that residential areas closer to medical facilities will sustain the future population, while in the old new-town cluster, this study found that residential areas closer to train stations will best sustain the future population. However, in the public housing cluster, residential areas more distant from regional resources will best sustain the future population. Therefore, it is worth considering different urban designs in the old new-town and public housing clusters, rather than the location optimization plan policy.

Keywords: population decline; location of urban facility; Osaka metropolitan fringe area; Bayesian network analysis; Japanese location optimization policy

1. Introduction

Japanese urban planning must change significantly because the Japanese population has turned from an increasing to a decreasing trend [1]. Shrinking cities have thus become a policy issue for sustainable society not only in Japan but also in Germany and the United States [2]. In South Korea, Daegu has an urban policy that vacant residential structures are being demolished, and the resulting empty plots transformed into public spaces [3]. In China, research on policy scenarios in response to population shrinkage was also conducted [4]. Among various countries, many policymakers and researchers have discussed the challenges of shrinking cities [5,6]. Based on these discussions, the Japanese Ministry of Land, Infrastructure, Transport, and Tourism (abbreviated as MLIT) formulated the location optimization plan (LOP) policy in 2015 [7] in Figure 1.

The purpose of the LOP policy is to realize sustainable urban visions that focus on residential areas from a long-term perspective [8]. The urban concept is sought in metropolitan fringe areas and regional cities with aging societies [9], and the method of the LOP policy is to specify the zoning locations of urban facilities and residential areas. Such urban facilities include commercial facilities, medical facilities, welfare facilities, child support facilities, and cultural facilities. It is recommended that these urban facilities be located near transit stations based on the urban planning theory of the compact city [10].

Given the background of the LOP policy in Japanese shrinking cities, the research question is whether the presumed causal relationship between the location of urban facilities and forecasted population growths or declines is correct. For example, in medical facilities, the population affects the locations of medical facilities, rather than the locations of medical
facilities affecting the population. The causal relationship may differ depending on the type of residential cluster, which can be a dense cluster, a sprawl cluster, or a suburban cluster. Without understanding the consequences, effective policies cannot be applied to shrinking cities for a sustainable society.

![Figure 1. Basic concept of the Japanese location optimization plan policy (Figure 1 is a diagram of the Japanese MLIT [7] to which the author added English translations).](image)

This study aims to clarify the statistical causal relationship between the location of urban facilities and forecasted population changes according to the types of residential clusters in the Osaka Metropolitan Fringe areas. The quality of urban facilities also influences forecasted population changes, but this study analyzes the relationship between the location of urban facilities and forecasted population changes. That is because the LOP policy focuses on the locations, not the quality, of urban facilities. The results will allow us to determine the best locations for urban facility guidance to prevent rapid population declines under the LOP policy. The LOP policy is a unique method in Japan for the urban planning of shrinking cities. In Germany, one of the urban planning methods for shrinking cities is Stadtumbau Ost, which aims to strengthen urban cores and support the demolition of structures that have become dispensable [11]. Stadtumbau Ost has contributed to the redevelopment of German shrinking cities, as the Stadtumbau program, by integrating with Stadtumbau west in 2017 [12]. Moreover, in Flint, Michigan in the United States, one type of urban planning for shrinking cities involves designing the green innovation zone for down-sizing the neighborhood [13]. Therefore, it is worthwhile to analyze the effectiveness and limitations of the LOP policy in Japan. Determining the LOP policy’s effectiveness will provide urban design ideas for shrinking cities in other countries. On the other hand, the LOP policy’s limitations will provide ideas for new urban designs that complement the LOP policy.

The method of this study is GIS (Geographic Information System) analysis along with statistical analysis in the Osaka Metropolitan Fringe area. This research is based on the neighborhood association scale (abbreviated as the NA scale). The NA scale is the smallest scale of community governance, which is determined by the local government, according to the Local Autonomy Act in Japan. Its NA plays important roles as the foundation for consensus on community welfare based on local relationships. Based on the NA scale, this study analyzed the Osaka Metropolitan Fringe area. The Osaka Metropolitan Fringe area is located in the surrounding suburban areas of the Osaka metropolitan area. These suburban areas are considered problematic, causing an economic decline in shrinking cities [14]. In this paper, the Osaka metropolitan area is comprised of the Osaka, Kyoto, Hyogo, Shiga, Nara, and Wakayama prefectures. The Osaka metropolitan area is the city-region of Osaka, Kyoto, and Kobe city and is one of the largest mega-cities globally, at the same scale as the Beijing, Bangkok, Los Angeles, and Moscow metropolitan areas [15]. The Osaka Metropolitan Fringe area rapidly became urbanized after the 1950s [16]. In the 1960s, urban sprawl was especially severe in the absence of effective urban planning regulations. High-end residential areas were developed as “new-towns” for high-income workers in
the mountains to prevent urban sprawl. The several types of possible residential clusters include the sprawl cluster and the old new-town cluster. Since many of these residential areas are more than 50 years old, the residential clusters face population decline problems and aging ahead of the Tokyo metropolitan and Nagoya metropolitan areas in Japan [17]. Therefore, this study’s results will contribute to understanding the metropolitan areas that will face population declines in the future.

Previously, Friedrichs [18] conceptualized the process of urban decline through a network model consisting of economic decline, population decline, and policy changes. Subsequently, Haase et al. [19] conceptualized a cyclical model in which diverse declines at the global and regional levels cause population declines. In Japan, the Hitachi Kyoto University Laboratory analyzed future scenarios by constructing a network model consisting of 333 causal relationships [28]. The results showed that the decentralized urban scenario is more sustainable in 2050 than the urban concentration scenario [20]. Based on previous studies’ results, this study assumes that population decline is caused by the statistical causal relationship between various social factors. This study’s novelty lies in clarifying the characteristics of forecasted population decline by focusing on the location of urban facilities, which the LOP policy emphasizes.

For the causal relationship, Ai [21] proposed an evaluation score based on regression analysis to forecast population changes and living environmental evaluations that include the location of urban facilities in the Tokyo metropolitan area. Moreover, Ai [22] clarified that residence preferences differed by 10 km from the city center. Based on these studies, the present research applies the Bayesian network analysis to the statistical causal relationships between population decline and urban facility location according to the types of residential clusters. In this way, the present study clarifies the statistical causal network relationship between population decline and the locations of multiple urban facilities.

2. Materials and Methods

The method of this study involves three steps in Figure 2. First, residential areas are categorized by urban ecological analysis. Second, the residential clusters with rapidly decreasing populations in the Osaka metropolitan area are analyzed via cohort analysis. Finally, the causal relationship between the forecasted population change ratio and the locations of urban facilities is analyzed via Bayesian network analysis according to the residential clusters.

![Figure 2. Analysis steps in Chapter 2.](image)

2.1. Urban Ecological Analysis

This study clarifies the types of residential clusters in the Osaka Metropolitan Fringe area via urban ecological analysis. Urban ecological analysis is a method of analyzing spatial patterns using an inductive method with a wide range of statistical data [23]. Kato et al. [16] evaluated urban ecological analysis’s effectiveness by categorizing the types of residential clusters in the northern part of the Osaka metropolitan area. Moreover, Kato [24] analyzed the types of clusters via urban ecological analysis in the Osaka metropolitan area, the same region studied by this paper. The validity of the analysis was also assessed [24]. This research consisted of five steps.

First, the standardization of 53 indicators for the NA scale of the Japanese census in 2015 was analyzed [25]. The 53 indicators are the census data such as “population under 15 years old” and “households who live in detached houses” in Appendix A. Next, the
standardized composition ratio $R_k^x$ was calculated by standardizing each indicator’s data, which is the distribution of data among the 53 indicators using Equation (1):

$$R_k^x = \frac{X_{xi}^k - X_{x_{min}}}{X_{x_{max}} - X_{x_{min}}}$$  \hspace{1cm} (1)

where $X_{xi}^k$ is the number of NA $i$ for indicator $x$ in the residential area $k$, $X_{x_{min}}$ is the minimum value of NA $i$ for indicator $x$, and $X_{x_{max}}$ is the maximum value of NA $i$ for indicator $x$.

Third, the principal component was analyzed using $R_k^x$. Reliable data were obtained as social survey data because the Cronbach’s $\alpha$ coefficient of the principal component analysis was 0.985. Cronbach’s alpha is the measure of reliability and internal consistency of data. Fourth, using the Guttman Kaiser criterion, seven principal components were extracted. Reliable data were obtained because the total variable amount of these seven principal components was 78.8%. Finally, using their seven principal component scores, residential clusters were categorized via hierarchical cluster analysis. Then, by analysing the $R_k^x$ of each indicator for each residential cluster, each cluster’s name was determined (Appendix A).

Subsequently, to clarify the residential clusters located in the metropolitan fringe area, the “urbanized area ratio” was analyzed using the National Land Information Download Service [26]. The urbanized area ratio is the ratio of the residential areas that were designated as urbanized areas by their local governments. The average distance from the center of the metropolitan area, Umeda (Osaka city), Karasuma (Kyoto city), and Sannomiya Station (Kobe City), was then calculated. As a result, the residential clusters were clarified with over 50% of the “urbanized area ratio” and an average city center distance of over 10 km for “the average distance from the center” based on residential preferences. This analysis clarified the residential clusters located in the Osaka Metropolitan Fringe area.

2.2. Cohort Component Method

The cohort component method clarified residential clusters with rapidly declining populations in the Osaka Metropolitan Fringe areas. This process involved using the cohort component method with Japanese census data from 2015 [24]. For the analysis, this study used the “Future Population/Household Forecasting Program” (version 1.3), which was developed by the National Institute for Land and Infrastructure Management in Japan [27]. The cohort component method estimates the forecasted population of each cohort by assuming the future values for the two population change factors of each NA. These factors are the “ratio of women and children” and “net movement ratio.” This section analyzes the cohort component method because remarkable population changes are expected in the Osaka metropolitan area, such as large-scale population changes due to suburban developments and new railway construction. It is preferable to use the cohort component method in NA in areas where the past population experienced remarkable changes or where the past population change rate is not suitable for estimating the forecasted population.

Using the cohort component method, the forecasted population change ratio $D_{2040}$ of each NA was calculated. Using these data, $D_{2040}$, the population change ratio between 2020 and 2040 was estimated with Equation (2). Then, a boxplot diagram of the $D_{2040}$ of each residential cluster was analyzed. Using this boxplot diagram, the residential clusters with rapidly declining populations were clarified:

$$D_{2040} = \frac{P_{2040} - P_{2020}}{P_{2020}}$$  \hspace{1cm} (2)

where $P_{2040}$ is the population of 2040 using the data of “Future Population/Household Forecasting Program [27]”, and $P_{2020}$ is the population of 2020 using the data of “Future Population/Household Forecasting Program [27]”. 
2.3. Bayesian Network Analysis

For the residential clusters with rapidly declining populations, a statistical causal relationship between the $D_{2040}$ and urban facility location was analyzed using the Bayesian network analysis. The Bayesian network is a stochastic model that represents the quantitative relationship between individual variables with conditional probability. One of the features of this model is a network of causal relationships. The probabilistic estimation of the network makes it possible to predict uncertain events. Compared to similar statistical analysis methods, such as structural equation model analysis, neural network analysis, and decision tree analysis, the Bayesian network analysis allows for the flexible analysis of non-linear and non-normal relationships between variables. This study used BayesiaLab 8.0 [25] as its Bayesian network construction algorithm. Moreover, the Maximum Weight Spanning Tree Algorithm was adopted for the optimal local search for each child node [28]. The Maximum Weight Spanning Tree Algorithm makes it possible to compute big data, such as the census data, which this study analyzed, faster than other algorithms [29].

Using the Bayesian network analysis, the causal relationship between $D_{2040}$ and the urban facility location was analyzed according to the types of residential clusters. The $D_{2040}$ was examined in Section 2.2. The urban facilities are the GIS location data of fourteen types of urban facilities used by urban planning within the point data provided by the National Land Information Download Service [26]. The fourteen urban facilities are elementary schools, evacuation facilities, police stations, fire stations, post offices, medical institutions, welfare facilities, cultural facilities, city parks, local industrial facilities, attraction facilities, regional resources, railway stations, and bus stops. These data are all point data related to urban planning provided by the National Land Information Download Service [26]. The LOP also induces commercial facilities, but, since the National Land Information Download Service [26] does not provide GIS data of the commercial facilities, this study excluded commercial facilities from the analysis. This study created fourteen indicators used to calculate each residential area’s distance to each urban facility based on these location data. Here, “distance” means the distance from the residential area’s outer limits to the nearest urban facilities. In other words, the distance is zero if there are urban facilities within the residential area. The standardized composition ratio was then calculated by standardizing each indicator’s data using Equation (1). In the Bayesian network analysis, cluster analysis was performed between each node and Pearson correlation coefficients r. Similarly, this paper also estimated a conditional probability table (CPT) for the $D_{2040}$ of each residential cluster. The Bayesian network analysis results suggest the locations of urban facilities that could mitigate the forecasted rapid population decline.

3. Results

3.1. Categories of Residential Clusters

Using the urban ecological analysis in Section 2.1, thirteen residential clusters were clarified. These thirteen residential clusters are the same as those analyzed by Kato [24]. Among these thirteen residential clusters, Appendix A shows six residential clusters located in the Osaka Metropolitan Fringe areas. The Osaka Metropolitan Fringe areas contain over 50% of the “urbanized area ratio” and have an average city center distance of over 10 km for “the average distance from the center.” These clusters include dense clusters (31.2 km), public housing clusters (26.7 km), non-residential clusters (43.9 km), sprawl clusters (38.2 km), high-rise residential clusters (25.9 km), and old new-town clusters (26.7 km). Of these six types of residential clusters, the non-residential clusters were excluded from the analysis because this study focuses on analyzing residential areas. The residential clusters were plotted on the map shown in Figure 3, indicating the location characteristics of each residential cluster.
3.2. Population Decline of Each Residential Cluster

Finally, the features of the five residential clusters are discussed using the data from Appendix A. The dense clusters include those high in “population who live in their own houses” (R = 0.07), “population who live in a privately rented houses” (R = 0.10), and “population who live in houses for employees” (R = 0.08). The public housing clusters are high in “population who live in public housing” (R = 0.12) and “households who live in apartments” (R = 0.10). The sprawl clusters have a high average distance from the city center (27.9 km). However, they also have a comparatively low “population under 15 years old” (R = 0.02), “population between 16 and 64 years old” (R = 0.03), and “population over 65 years old” (R = 0.04) among the residential clusters with more than a 50% urbanization rate. The high-rise residential clusters are high in “population who live in their own houses” (R = 0.13), “households who live in apartments” (R = 0.08), and “households who live in 11 (or more) story buildings” (R = 0.04). Finally, the old new-town cluster is high in “population who live in their own houses” (R = 0.05), “households who live in detached houses” (R = 0.05), “households who live in 1- or 2-story buildings” (R = 0.03), “population who work in other prefectures” (R = 0.05), and “population who go to school in other prefectures” (R = 0.05).

Figure 3. Location of the residential clusters in the Osaka metropolitan area (Figure 3 shows the same results as the urban ecological analysis by Kato [24]).
The $D_{2040}$ for each residential cluster was calculated and drawn using a box–beard diagram (Figure 5). As a result, Figure 5 shows that the residential clusters located on the Osaka Metropolitan Fringe area face population decline, focusing on the first quartile (abbreviated as Q1) and the median (abbreviated as Me). These clusters include the public housing cluster ($Q1 = -57.9, Me = -46.9$), the sprawl cluster ($Q1 = -48.5, Me = -33.5$), and the old new-town cluster ($Q1 = -47.5, Me = -36.0$) from among the residential clusters outlined in Section 3.1.

Finally, three types of residential clusters were defined by considering previous studies. The public housing cluster was defined as residential areas constructed by public institutions as affordable housing. Population decline is inevitable in the public housing cluster because residents of public housing are limited to older adults, single-parent families, and foreigners who need housing based on laws and ordinances. Therefore, in the face of widening social gaps, Hirayama [30] considers the decrease in affordable housing within public housing clusters to be more problematic than declines in population. Figure 3 shows that the public housing cluster is dispersed in the metropolitan fringe area. Secondly, the sprawl cluster was defined as urban residential areas with a lack of urban infrastructure, characterized by narrow streets and useless small vacant lots developed around farmlands since the 1970s [31]. This change has continued slightly into the present [32]. Although...
the sprawl cluster was evaluated as problematic from the perspective of efficient land use, this cluster features highly walkable neighborhoods [24]. Figure 3 shows that the sprawl cluster is located between the inner-city clusters and the old new-town clusters. Finally, the old new-town cluster was defined to include planned and large-scale suburban residential areas featuring detached houses for high-income workers [22]. Figure 3 shows that the old new-town cluster is located in hillside areas. Appendix A shows that many residents of the old new-town cluster commute from the hilly area to the city center. However, many residents of the old new-town cluster have aged in the decades since they moved in. Therefore, the old new-town cluster represents urban challenges for older adults because it was developed on hillside areas with slopes that make it challenging to walk [33].

3.3. Formatting of Mathematical Components

Using the Bayesian network analysis outlined in Section 2.3, the causal relationship between the \( D_{2040} \) and the location of urban facilities was analyzed according to the types of residential clusters, as shown in Figures 6–8. Thick edges indicate the results of the pearson correlation coefficient. The CPT of each residential cluster is estimated in Tables 1–3. The red tabs indicate higher numbers in the Tables, while the green tabs include lower numbers. As a result, Figures 6–8 illustrate that urban facilities prevent rapid population decline. Furthermore, the types of urban facilities were found to vary according to the residential cluster. However, no urban facilities were found to have substantial effects on \( D_{2040} \). Finally, these urban facilities were considered for each residential cluster.

![Bayesian network of the sprawl cluster.](image-url)
Figure 6. Bayesian network of the sprawl cluster.

Figure 7. Bayesian network of the old new-town cluster.

Figure 8. Bayesian network of the public housing cluster.

Table 1. Conditional probability table (CPT) of the $D_{2040}$ for the sprawl cluster.

| Forecasted Population Change Ratio $D_{2040}$ | $\leq -0.53$ | $-0.53 < -0.35$ | $-0.35 < -0.17$ | $-0.17 < -0.06$ | $-0.06 < 0.06$ | $0.06 < 0.42$ | $0.42 < 1.03$ | $1.03 < 1.03$ |
|---------------------------------------------|----------------|-----------------|-----------------|-----------------|----------------|----------------|----------------|----------------|
| $\leq 0.001$                                | 8.4            | 26.7            | 28.9            | 19.8            | 10.7           | 4.3            | 1.2            | 0.0            |
| $\leq 0.002$                                | 15.5           | 26.3            | 25.2            | 20.0            | 8.9            | 3.1            | 1.0            | 0.0            |
| $\leq 0.003$                                | 11.1           | 27.5            | 27.7            | 18.6            | 11.3           | 2.8            | 1.0            | 0.0            |
| $\leq 0.005$                                | 16.9           | 32.8            | 25.1            | 14.8            | 6.6            | 3.8            | 0.0            | 0.0            |
| $\leq 0.008$                                | 17.1           | 32.5            | 26.0            | 13.8            | 4.1            | 4.1            | 2.4            | 0.0            |
| $\leq 0.012$                                | 21.8           | 34.6            | 20.5            | 12.8            | 5.1            | 3.8            | 1.3            | 0.0            |
| $> 0.012$                                   | 25.7           | 36.5            | 21.6            | 12.2            | 2.7            | 1.4            | 0.0            | 0.0            |

Each number is represented by a green to red graduation. Specifically, the red tab has higher numbers, and the green tab has lower numbers.
Table 2. CPT of $D_{2040}$ for the old new-town cluster.

| Forecasted Population Change Ratio $D_{2040}$ | $\leq -0.40$ | $\leq -0.19$ | $\leq 0.08$ | $\leq 0.52$ | $\leq 1.22$ | $>1.22$ |
|---------------------------------------------|---------------|---------------|-------------|-------------|-------------|---------|
| Train Stations                              |               |               |             |             |             |         |
| $\leq 0.003$                                | 17.8          | 32.7          | 29.8        | 12.5        | 4.8         | 2.3     |
| $\leq 0.008$                                | 26.6          | 34.2          | 23.7        | 10.4        | 3.8         | 1.3     |
| $\leq 0.014$                                | 28.2          | 40.4          | 19.1        | 8.5         | 2.4         | 1.4     |
| $\leq 0.022$                                | 34.5          | 36.0          | 14.8        | 9.1         | 5.3         | 0.4     |
| $\leq 0.040$                                | 37.9          | 36.2          | 12.1        | 6.9         | 4.3         | 2.6     |
| $>0.040$                                    | 41.4          | 31.0          | 13.8        | 10.3        | 3.4         | 0.0     |

Each number is represented by a green to red graduation. Specifically, the red tab has higher numbers, and the green tab has lower numbers.

Table 3. CPT of $D_{2040}$ of the public housing cluster.

| Forecasted Population Change Ratio $D_{2040}$ | $\leq -0.44$ | $\leq -0.09$ | $\leq 0.62$ | $>0.62$ |
|---------------------------------------------|---------------|---------------|-------------|---------|
| Regional Resources                          |               |               |             |         |
| $\leq 0.043$                                | 45.0          | 44.3          | 10.4        | 0.3     |
| $\leq 0.077$                                | 43.9          | 42.7          | 9.9         | 3.4     |
| $\leq 0.127$                                | 41.8          | 42.7          | 13.3        | 2.2     |
| $>0.127$                                    | 34.0          | 48.5          | 14.4        | 3.1     |

Each number is represented by a green to red graduation. Specifically, the red tab has higher numbers, and the green tab has lower numbers.

First, in the sprawl cluster, Figure 6 shows that $D_{2040}$ was affected by medical facilities, welfare facilities, primary schools, and post office locations. Here, medical facilities are shown to have the most significant effect on $D_{2040}$ ($r = -0.0855$). In other words, the closer a residential area is located to medical facilities, the less rapidly the population will decline (Table 1).

Second, in the old new-town cluster, Figure 7 shows that the locations of railway stations, welfare facilities, and post offices affect $D_{2040}$. It was found that the location of railway stations has the most significant effect on $D_{2040}$ ($r = -0.0789$). In other words, the closer a residential area is located to train stations, the less rapidly the population will decline (Table 2).

Finally, in the public housing cluster, Figure 8 shows that the regional resource locations also affect the $D_{2040}$. ($r = 0.0866$). In other words, the more distant residential areas are from regional resources, the less rapidly the population will decline (Table 3). Here, regional resources refers to “natural phenomena recognized as topography, geology, and natural landscapes that form the basis of the natural landscape” from the National Land Information Download Service [26]. Moreover, regional resources are located in mountainous areas. Therefore, residential areas farther away from local resources are closer to urban centers.

4. Discussion and Conclusions

In this study, the relationship between urban facilities and forecasted population change was statistically investigated for the Osaka metropolitan area’s residential clusters. The results indicated the ideal locations of urban facilities in each residential cluster to prevent a rapid population decline in a sustainable future. The Bayesian network analysis results were discussed for the three residential clusters from the perspectives of locations, transportation, and social attributes.

Specifically, in the sprawl cluster, this study found that the residential areas closer to medical facilities can better sustain the future population. Kato et al. [31] determined that sprawl cluster residents seek medical facilities in residential areas. Figure 6 validates these results and indicates that this factor affects not only medical facilities but also primary schools and welfare facilities. The reason for this influence may be related to the living...
areas of the residents in the sprawl cluster. Sprawl clusters are more walkable than other clusters, though the sprawl cluster was evaluated as problematic from the perspective of efficient land use [24]. Therefore, hospitals and welfare facilities necessary for the elderly and primary schools necessary for children may impact the future population. Therefore, the LOP policy that directs urban facilities to walkable areas is likely to be effective urban planning in a sprawl cluster. These results will be informative for other countries with widespread sprawl clusters and declining populations.

In the old new-town cluster, this study also found that residential areas closer to train stations can better sustain the future population. The reason for this result may also be related to the living area of the sprawl cluster residents, as many residents in the old new-town cluster commute to urban centers such as Osaka and Kyoto. Moreover, the old new-town residents in the hilly area use their cars daily. Therefore, these residents may want to be closer to stations than to urban facilities in their neighborhoods. However, it is impossible to guide the locations of railway stations. Therefore, old new-town clusters located far from train stations should consider different urban designs than the LOP policy. Moreover, older adults who once commuted to the city center have now come to retire and live in their old new-town clusters. Therefore, for older adults in the old new-town cluster, mobility as a service may be required to replace the driving of cars.

In the public housing cluster, this study found that residential areas more distant from regional resources can sustain the future population. If residential areas are farther away from local resources, they are also closer to urban centers. Therefore, ensuring that residential areas are close to the city center can also help sustain the population in the future. As affordable housing, public housing has limited occupancy requirements. For example, governments often restrict resident selection, such as limiting residency to older adults, single-parent families, and foreigners who need housing based on laws and ordinances. Therefore, the location of particular urban facilities is unlikely to impact the D2040. Rather than population declines, the decrease in public housing clusters was more problematic [30]. However, no exact factors could be determined in this analysis.

Finally, it is a meaningful result that the influencing factors differ so significantly between the different clusters. The three residential clusters were discussed from the perspectives of locations, transportation, and social attributes. Among them, the most significant factor is the difference in the social attributes of the residents. For example, in the old new-town cluster, many residents want train stations with easy access to urban centers because they commute to urban centers. On the other hand, in the sprawl cluster, many residents want welfare facilities and elementary schools in the neighborhood because they live in walkable neighborhoods. The results of urban facilities’ location are verified from the perspective of intention to live by Kato et al. [31], who performed the decision tree analysis based on the data of a questionnaire survey of 3000 citizens. The results of this study also demonstrated that the effects are minimal, based on the correlation coefficient r between each factor in Figures 6–8. Moreover, this study also found that urban facilities like train stations cannot guide the location. Based on the theory of Transit-Oriented Development, train stations were thought to be attracted to the population and other types of services. However, this conclusion suggests that the theory may be practical in cities with growing populations, not NA with declining populations. The three clusters have locational problems in that the clusters are located far from the railroad lines. Therefore, it is worth considering different urban designs in the old new-town cluster and public housing cluster, rather than the LOP policy. The Japanese MLIT [34] has tried to use the LOP policy as part of its disaster management plan, rather than the original vision of planning for shrinking cities in Japan. Since Japan is very prone to natural disasters, such as earthquakes and tsunamis, disaster management plans have always been central urban planning themes. However, the original goal of population decline with rapid aging is also an essential topic for long-term sustainable society in Japan [6]. This study shows that the LOP policy is effective in sprawl clusters. These results may help shrinking cities where sprawl clusters are widespread. For example, in China, where the population is expected
to decline rapidly compared to Japan in the future, the LOP policy may be useful for urban design. On the other hand, for the old new-town cluster and public housing cluster, we should consider methods other than the LOP policy by referring to other countries’ urban policies for shrinking cities.

In Japan today, technologies related to the Cyber-Physical Systems are being developed based on the vision of Society 5.0 [35]. For example, remote work, telemedicine, and self-driving buses have already been realized through social experiments. Moreover, the COVID-19 pandemic has accelerated such social changes. For future smart cities realized through these digital changes, we should not only focus on urban images that aim at creating a compact city by guiding urban facilities but also on alternative urban images according to the types of residential clusters. In other words, shrinking cities could become creative sustainable cities in ways that are different from those of cities with growing populations [36]. For example, Kato et al. [31] evaluated the effectiveness of a “scenario in which vacant land is used” as an alternative to compact city images. Furthermore, a “scenario in which vacant land is used” could reduce public health risks and better ensure community resilience and well-being in shrinking cities [37]. We need to achieve a sustainable society in shrinking cities by considering new urban designs that complement the LOP policy.

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**Appendix A**

**Table A1.** The $R_2$ of each indicator for each residential cluster (Table A1 features the same data as Table A1 in Kato [21]).

| Inner-City Cluster | Business Center Cluster | Mining Industry Cluster | Dense Cluster | Public Housing Cluster | Non-Residential Cluster | Agriculture Cluster | Sprawl Cluster | High-Rise Residential Cluster | Mountain Cluster | Old New-Town Cluster | Suburban Agriculture Cluster | Rural Cluster |
|-------------------|-------------------------|------------------------|--------------|-----------------------|------------------------|---------------------|----------------|-------------------------------|----------------|--------------------|-----------------------------|--------------|
| **N**             | 1937 5472 728 672 889 7403 4998 628 7251 2546 2914 1033 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
| Urbanized area ratio (%) | 84.5 86.2 45.1 77.1 72.4 55.2 23.6 66.2 61.8 40.7 59.1 21.3 24.9 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
| Average distance from the center (km) | 19.3 34.5 59.9 31.2 26.7 43.9 71.6 38.2 25.9 56.1 26.7 63.1 52.1 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
| Population under 15 years old (%) | 0.06 0.01 0.03 0.06 0.05 0.00 0.04 0.02 0.09 0.01 0.03 0.01 0.10 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
| Population between 16 and 64 years old (%) | 0.09 0.02 0.04 0.09 0.08 0.00 0.06 0.03 0.12 0.01 0.05 0.02 0.14 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
| Population over 65 years old (%) | 0.10 0.02 0.04 0.07 0.12 0.00 0.09 0.04 0.11 0.01 0.05 0.03 0.15 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
| Population of Foreigners (%) | 0.09 0.02 0.02 0.04 0.07 0.00 0.01 0.02 0.03 0.00 0.01 0.00 0.05 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
| Population who live in their own houses (%) | 0.09 0.02 0.04 0.07 0.05 0.00 0.07 0.03 0.13 0.01 0.05 0.02 0.15 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
| Population who live in public housing (%) | 0.01 0.00 0.00 0.01 0.12 0.00 0.01 0.00 0.01 0.00 0.00 0.00 0.01 |                       |              |                       |                       |                    |                |                               |                |                    |                             |              |
Table A1. Cont.

| Cluster                      | Population who live in private rented houses (%) | Population who live in houses for employees (%) | Population who live in shared houses (%) | Households who live outside of houses (%) | Households who live in detached houses (%) | Households who live in traditional nagaya-houses (%) | Households who live in apartments (%) | Households who live in 1- or 2-storey buildings (%) | Households who live in 3- to 5-storey buildings (%) | Households who live in 6- to 10-storey buildings (%) | Households who live in 11- (or more) storey buildings (%) | Population who work in agriculture and forestry (%) | Population who work in a fishery (%) | Population who work in the mining industry (%) | Population who work in the construction industry (%) | Population who work in the manufacturing industry (%) | Population who work in the electricity, gas, and water supply industries (%) | Population who work in the information industry (%) | Population who work in the transport industry (%) | Population who work in the retail industry (%) | Population who work in the financial industry (%) | Population who work in the real estate business (%) | Population who work as researchers or professionals (%) | Population who work in the service industry (%) | Population who work in the entertainment industry (%) | Population who work in education (%) | Population who work in the medical/welfare industry (%) | Population who work in a joint service industry (%) | Population who work in another service industry (%) | Population who work as civil servants (%) | Population who work at home (%) | Population who work in their own city (%) | Population who work in other cities (%) | Population who work in other wards of their own cities (%) | Population who work in other cities of their own prefectures (%) |
|------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| Inner-City Cluster           | 0.10                             | 0.02                             | 0.02                             | 0.10                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.07                             | 0.02                             | 0.01                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             | 0.02                             | 0.00                             |
### Table A1. Cont.

| Cluster                                | Population who work in other prefectures (%) | Population who go to school in their own city (%) | Population who go to school in other wards of their own cities (%) | Population who go to school in other cities (%) | Population who go to school in other wards of their own cities (%) | Population who have lived in the area since birth (%) | Population who have lived in the area for 1 year (%) | Population who have lived in the area for the past 5 years (%) | Population who have lived in the area for the past 10 years (%) | Population who have lived in the area for the past 20 years (%) | Population who have lived in the area for over 20 years (%) |
|-----------------------------------------|---------------------------------------------|-------------------------------------------------|------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Inner-City Cluster                     | 0.03                                        | 0.04                                            | 0.07                                                            | 0.03                                          | 0.01                                              | 0.07                                            | 0.01                                            | 0.07                                            | 0.04                                            | 0.08                                            | 0.07                                            |
| Business Center Cluster                | 0.01                                        | 0.01                                            | 0.02                                                            | 0.07                                          | 0.01                                              | 0.01                                            | 0.01                                            | 0.01                                            | 0.01                                            | 0.04                                            | 0.02                                            |
| Mining Industry Cluster                | 0.02                                        | 0.04                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Dense Cluster                          | 0.03                                        | 0.04                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Public Housing Cluster                 | 0.01                                        | 0.04                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Non-Residential Cluster                | 0.00                                        | 0.04                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Agriculture Cluster                    | 0.01                                        | 0.07                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Sprawl Cluster                         | 0.03                                        | 0.07                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| High-Rise Residential Cluster          | 0.01                                        | 0.01                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Mountain Cluster                       | 0.00                                        | 0.04                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Old New-Town Cluster                   | 0.01                                        | 0.04                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Suburban Agriculture Cluster           | 0.01                                        | 0.04                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |
| Rural Cluster                          | 0.01                                        | 0.04                                            | 0.06                                                            | 0.04                                          | 0.06                                              | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            | 0.06                                            |

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