Shrinking or Cohesion? : Estimation for a Future Spatial Distribution of Demographic Structure and Building Age in Obihiro Urban Area

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Abstract: Japan has entered to the era of population decline. The purpose of this study is to estimate the distribution of the zones are classified by cluster analysis based on the population and the number of people in house from 2010 to 2035 for Obihiro urban area that is a local city of Hokkaido in Japan by the generation constitution of the residents in each the zone and the distribution of building age. In this study, therefore, the population data which is published by Obihiro city government and the statistic data from the basic survey of urban planning were integrated. And the distribution of future population was estimated by the cohort analysis. In addition, the relation of spatial distribution of population and the building age in the future was analyzed. Finally, by the result of the extracted districts from the future population decline and aging buildings distribution, the direction of the renovation of Obihiro urban area was considered.

Keywords: Depopulation, Generation constitution, Building age, Compact city

1. INTRODUCTION

Japan has one of the highest rates of demographic aging in East Asia, and a natural decline in population was recorded in 2005 for the first time since statistical collection began in 1899. Although the population increased in 2006, a decrease was recorded again in 2007 and annual natural population growth has continued to decline since then(Ministry of Health, Labor and Welfare,2011). The average number of children born per couple in 2010 was 1.39 and has remained low, although a slight trend of recovery has been seen from the value of 1.26 recorded in 2005(Cabinet Office,2011). The ratio of people over 65 years of age to the total population (known as the population aging rate) increased to 23.1% in 2010 and is expected to continue rising in the future(Cabinet Office,2011). This aging issue is considered to significantly affect regional economies and social conditions, including medical and welfare services, as well as employment, residence and business situations. The influence on local cities with insufficient medical and welfare resources is especially large. In urban residential areas, demographic aging and greater numbers of suburban vacant houses have been reported in addition to the long-term decline observed in downtown areas.

Then, in local Japanese cities, current land use patterns will need to be changed and traffic systems renovated for urban development to support economic activity and social capital against the gradual and simultaneous progress of declining birth rates and aging.

In this study, the demographic structure of residents and building age distribution by zone in the local Hokkaido city of Obihiro were clarified, and the spatial distribution of the population and building age by zone for the period between 2010 and 2035 were estimated to support consideration of urban structure in the future.

2. REVIEW OF PAST RESEARCH AND POSITIONING OF THE PRESENT STUDY

This section outlines previous research on population decline and urban residential structure in Japan. In the field of future demographics, Kaneko *et al*.(2006) used the cohort component method to propose estimations of future populations for the period between 2006 and 2078 based on the results of the 2005 Japanese census. In a study on demographics and urban residences, Koike(2010) divided population changes in the Tokyo metropolitan area into natural and social variations using regional mesh statistics and analyzed related trends based on distances from downtown Tokyo and train lines.

In a study on the issues of sprawl and reverse sprawl in urban areas and measures to combat these phenomena, Taniguchi(2008) highlighted related problems by analyzing long-term and microscopic differences in activity and depopulation between sprawling and other urban areas by dividing development approaches used in Okayama City into three types. Uemura *et al*.(2009) summarized building space reduction and other measures against reverse sprawl in Germany, where the onset of population decline occurred earlier than that in Japan, and discussed methods of applying such measures in Japan. Hayashi *et al*. (2009) defined areas characterized by greater financial and environmental burdens and social costs resulting from disorderly land use as social hazards, identified areas vulnerable to natural disasters as natural hazards, evaluated forms of land use seen in individual areas, and proposed improvement of residents' quality of life based on the depopulation of high-risk areas and re-concentration in urban areas. The same authors also discussed how the difficulty of short-term and compulsory land usage changes in Japan makes it more realistic to concentrate populations in urban areas by relocating residents or adopting land use policies that allow gradual relocation depending on the timing of rebuilding housing.

Hayashi *et al*. (2009) discussed the possibility of concentrating populations in urban areas on the assumption that the average life of buildings was around 20 to 30 years. However, Komatsu(2008) estimated the life span of reinforced concrete, steel-frame and wooden houses as 56.76, 51.85 and 54.00 years, respectively, in 2005 based on fixed assets and housing ledgers of prefectural capitals throughout Japan. This suggests that the time taken for the adoption of land usage policies may be significant, while the life span of buildings is increasing.

In a study on Obihiro (the target area of this study), Matsumura and Fukui(2010) investigated relocation in a new-town housing complex in the southeastern part of the city. Many people have moved into the complex since its development began in 1967 in during Japan's period of high growth. The authors discussed how low rents in public housing in the complex have attracted elderly and young people alike, resulting in a generation mixture that affects the promotion of mutual assistance in the community. The report also highlighted a measure for the relocation of senior citizens owning detached houses. Under this approach, area revitalization for community maintenance in housing complexes would be promoted by providing public housing and services for the elderly and offering younger people houses vacated due to senior citizen relocation. Arimura *et al*. (2012) identified the residential generation structure and building age distribution by zone in Obihiro, estimated future population distribution by zone for the period between 2010 and 2030, and determined the spatial distribution of people living in houses in the area. The authors also classified the population structure and building age by zone in 2010 based on clustering analysis to determine the related spatial distribution. However, as clustering analysis of the population structure and building age by zone in the study was performed only for 2010, future changes in these factors could not be estimated.

There are no universal solutions to urban problems in the period of population decline, as effective measures depend on the situations of individual cities. However, if the aim is, for example, to downsize an urban area, it is considered more realistic in terms of planning to determine the timing of reconstruction and induce gradual relocation as proposed by Hayashi *et al.*(2009). As discussed by Matsumura and Fukui (2010), it is also important to understand the relationship between the generational demographic structure of residents in the target area and the age of public housing structures and detached houses when measures related to rebuilding and relocation are considered. The ability to simultaneously determine building age distribution and demographic structure by age in each zone of a city will enable support for the planning of measures such as relocation depending on the life stages of different generations, building space reduction/remodeling depending on the life span of buildings, and provision of owner-occupied detached houses through matching between elderly households and young people in suburbs. It will also support the planning of urban transport measures, such as the future introduction of public transport systems, based on clarification of demographic age structures and building age distribution by zone in cities.

For the estimation of spatial distribution in future populations, it is considered appropriate to use the results of the Grid Square Statistics of Population Census conducted by the Ministry of Internal Affairs and Communications Statistics Bureau. However, the residential land use trend survey results included in these statistics as data on land use cover only the Tokyo metropolitan, Kinki and Chubu areas, and are not applicable to other regions. In addition, as the statistics do not include information on the generational structure of building age in each grid square, it is impossible to analyze the aging of buildings in each zone at the same time with future population structure changes by generation. Meanwhile, the basic survey of city planning conducted roughly every five years has recently been computerized, and its results provide data on the year of construction by building type together with polygon information on buildings. However, these two types of statistics have not been integrated, making it impossible to conduct analysis using uniform spatial units.

Against such a background, the urban area of Obihiro City in Hokkaido was selected for this study due to its status as a local central city, its location on a plain where topography has little influence on urban structure, and the grid-like pattern of its downtown area, which facilitates understanding of the outcomes. In Hokkaido, Jo and Cho are used in some districts to designate the address. Jo shows the direction of east and west. Cho shows the direction of north and south. Results from the Basic Survey of City Planning in the Obihiro Urban Area and the Survey of Population by Jo, Cho, Town, Gender and Age were first integrated, and future populations and building ages by zone for the period between 2010 and 2035 were then estimated. Cluster analysis of current and future population-building age structures by zone was subsequently conducted to allow comparison of future changes in different zones, and the results were used to consider the future direction of urban development in Obihiro.

3. TARGET CITY AND DATA USED

Obihiro – the target city of the analysis in this study – is located on the Tokachi Plain in eastern Hokkaido. The area is known for its flourishing agriculture (with extensive large-scale dry-field farming) and tertiary industries (such as tourism, commerce and service), and urban development is promoted toward the goal of creating a garden city with harmony between built-up and rural parts. Obihiro's population of approximately 170,000 in 2013 makes it the sixth-largest city in Hokkaido and a major central urban area of the Tokachi region. However, its population has decreased since peaking in 2000, and demographic aging has also been identified. The analysis conducted in this study was based on results from the 2009 Basic Survey of City Planning in the Obihiro Urban Area and the December 2009 Survey of Population by Jo, Cho, Town, Gender and Age conducted by the Obihiro municipal government. The Basic Survey results include data on 55,507 buildings in 1,636 zones and on land use. Figures for future populations by age and building age were estimated based on a dataset created by integrating the results of these surveys. Figure 1 shows land use in Obihiro City from the 2009 Basic Survey of City Planning in the Obihiro Urban Area. Figure 2 shows how to correspond the different addresses and codes among both surveys to be one integrated zone. Table 1 is a brief data of integrated zones. Obihiro's total population is 168,657 in 2009, but the result of the population within integrated zones became 153,417, therefore, this study considered 91.0% of population in Obihiro.

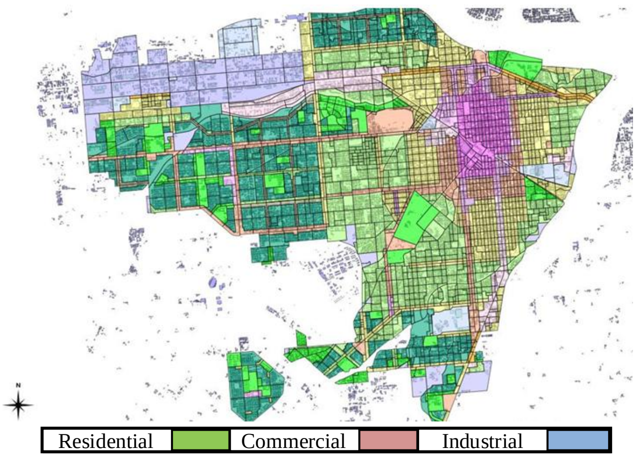

Figure 1. Land use in Obihiro City

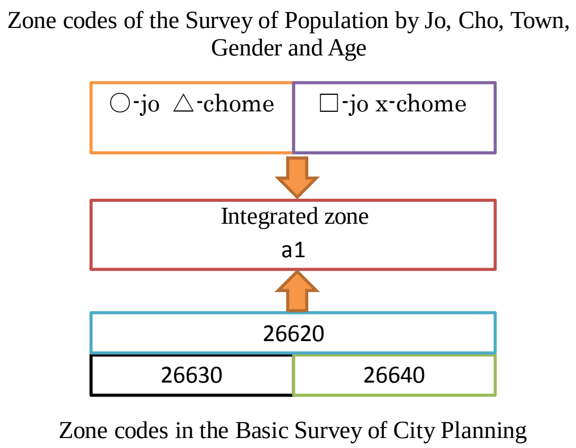

Figure 2. Integration of zone codes

Table 1. Overview of Obihiro City in 2009 (within integrated zone)

Total population	Aging rate	No. of households	No. of buildings
153,417	0.22	77,646	53,957

4. ANALYSIS METHOD

In this study, future population figures covering the period until 2035 were estimated from the results of Obihiro City's Survey of Population by Jo, Cho, Town, Gender and Age using the cohort component method. This approach involves the use of data on population by gender and age in the base year as a starting point. The assumed survival rate by gender and age, the sociodemographic movement rate by gender and age, the female birth rate by age and the gender ratio for live births are then applied to these data to estimate future demographics. Population by gender and five-year age group, which are variables used in this method, were determined and estimated for each integrated zone using information from the 2009 Survey of Population by Jo, Cho, Town, Gender and Age. Reference estimation data by municipality published by the National Institute of Population and Social Security Research (2012) were used to determine the yearly survival rate.

As examples of the cohort component method's application, Eqs. (1) and (2) below show the estimation equations for the five-year age groups of 0 to 4 and 5 to 9, respectively.

$$FP_{0-4} = FP_{w15-49} \times \alpha \times \beta \quad (1)$$

Where,

FP_{0-4} �0 - 4-year-old population (no. of people)

FP_{w15-49} �15 - 49-year-old female population (no. of people)

α �Ratio of children to women

β �Gender ratio of 0 -4-year-old children

$$FP_{t+5} = FP_t \times \chi \times y \quad (2)$$

Where,

FP_{t+5} �Population by age 5 years after year t (no. of people)

FP_t �Population by age in year t (no. of people)

χ �Survival rate

y �Net movement rate

t �Base year

Next, population by age and building age distribution by zone in Obihiro were determined. Figure 3 shows a scatter plot of the average building age for each integrated zone and its standard deviation along with the average age and its standard deviation in 2010, found as described in the previous section. Figure 4 shows the results for each integrated zone in 2035 as found using the cohort component method. It was assumed that there would be no new construction, building loss or intentional building space reduction, and that residents would continue to live in their current locations until 2035. Although these are extreme assumptions, the scenario was adopted because, as discussed by Komatsu, vacant houses have often been abandoned due to the recent life-span extension of buildings and the difficulty of covering removal costs in many local cities. The occurrence of similar situations in some parts of urban Obihiro area was considered highly likely.

Figures 3 and 4 show integrated zones divided into four clusters using the k-means method (an unsupervised clustering approach) to clarify the relationships linking the distribution trends of variables in each zone. In this study, each zone is clustered about eight numerical values which are the average age of the population and building, the standard deviations of both, in 2010 and 2035. Those where the standard deviations for the ages of the population and buildings are greater show larger variations in the ages of residents and building construction periods. Figures 5 show the analysis results based on the use of GIS as a visual representation of the integrated zones divided into four clusters.

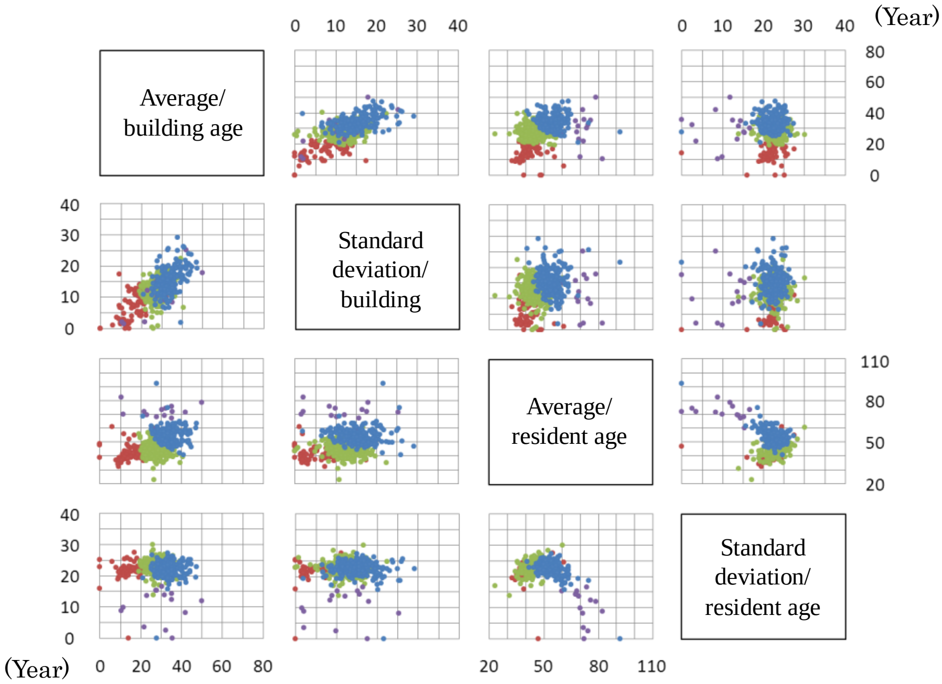

Figure 3. Average building age in each integrated zone for 2010 and the relationship between average building and resident ages and their standard deviations

(Year)

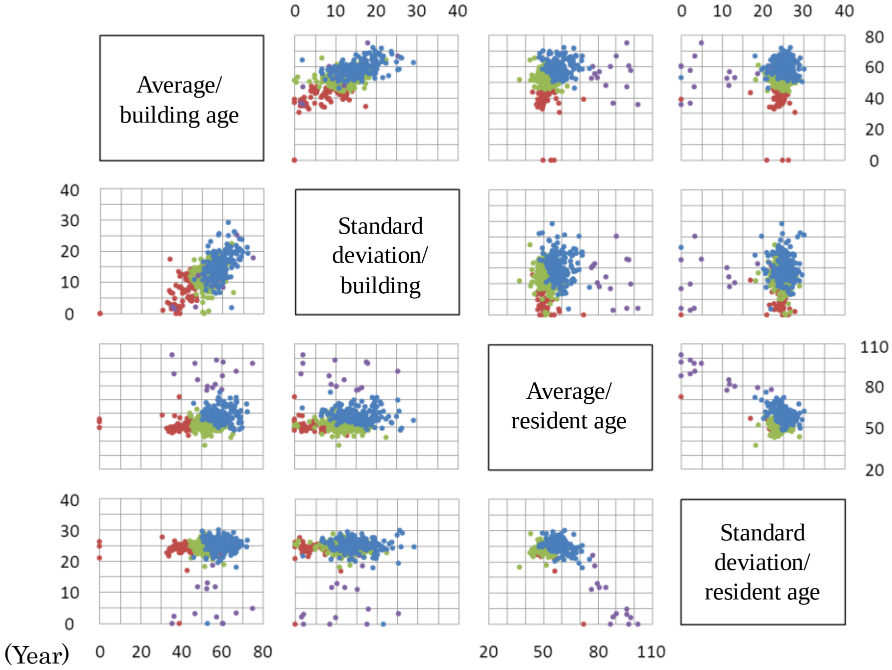

Figure 4. Average building age in each integrated zone for 2035 and the relationship between average building and resident ages and their standard deviations

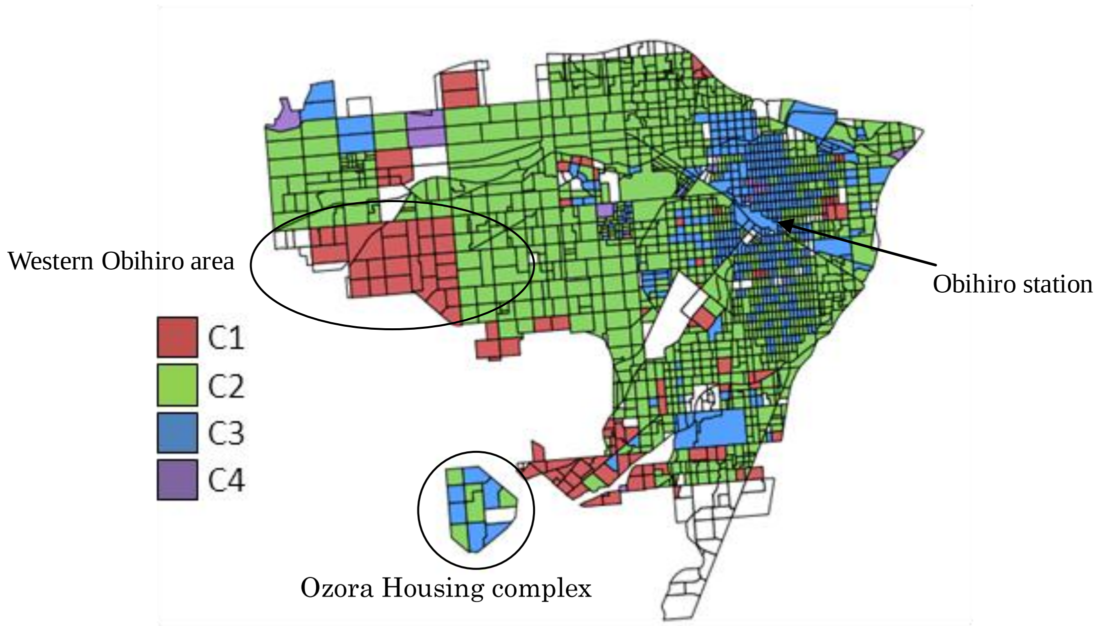

Figure 5. Clustering results (4 clusters)

5. CLUSTER ANALYSIS RESULTS

5.1 Results of cluster analysis

A look at the relationships linking the variables in Figure 3 shows that the function of correlation between the average building age in each integrated zone and the standard deviation of building age is 0.58 (a positive correlation). While the periods during which building construction work was concentrated to a certain degree in zones with a low average building age, the standard deviation tended to be greater in zones with a high average building age due to reconstruction. Although the function of correlation between the average age and the standard deviation of age was -0.05 (almost no correlation), Figure 3 shows that the standard deviation tended to decrease when the average age exceeded around 60 years. The function of correlation between average building and resident ages was 0.39 (a positive correlation). The average building age was 25.0 years and the average resident age was 44.2 years for the Obihiro urban area as a whole. The red, green, blue and purple clusters in Figure 3 were labeled the C1, C2, C3 and C4 groups, respectively, and their characteristics were identified. The C1 group (red) is composed, on average, of residents in the thirties to fifties age group and buildings aged from 10 to 20 years old. As the average building age and the standard deviation of the building age are low and a small number of zones are concentrated in certain parts as shown in Figure 5, it can be inferred that development was conducted in the same recent period. However, as the standard deviation of residents' ages is around 15 to 25 years as in the other groups, it can be said that there were mixed generations of residents. The C2 group (green) has an average resident age of 35 to 55 years and buildings aged 20 to 40 years old; these figures are slightly higher than those in C1. The standard deviation of the building age is greater than that in C1. It can be inferred that the cluster includes zones where some buildings were reconstructed in the past and that the buildings had different ages rather than having been developed in the same period, as the zones are distributed widely throughout the city as shown in Figure 5. The C3 group (blue) is mainly composed, on average, of residents in the forties to sixties age group and buildings aged 25 to 45 years old. The standard deviation of the resident age was large, as in C1 and C2, and that of the building age tended to be higher than those in the other groups. As the group is distributed around the C4 group centered on the station as shown in Figure 5, it can be inferred that the cluster includes many zones where urban areas gradually expanded with the progress of development. The C4 group (purple) is composed of residents with an average age of 60 years or more, and the standard deviation distribution of the resident age is more scattered than those in the other groups. The average building age and the standard deviation of the building age also show a tendency of wide distribution. In this cluster, development began in the earliest stage because the aging of residents and buildings progressed simultaneously in some zones and many zones are distributed around the station as shown in Figure 5.

A look at the data in each integrated zone for 2035 shows that the average building age and the standard deviation of the building age remain low in C1 (shown in red in Figure 4), although the average resident age is from 45 to the sixties bracket and buildings are mainly 30 to 45 years old. The standard deviation of the resident age has not changed significantly since 2010, and there is still a mixture of generations. While the C2 group (green) has an average resident age similar to that seen in C1 (45 to 65 years old), it consists of buildings aged from 45 to 60 years old. The standard deviation of the building age is greater than in C1, as seen in the 2010 data. The C3 group (blue) consists mainly of residents in the fifties to seventies age group and buildings aged from 50 to 70 years old. The standard deviation of the resident age is as large as those seen in C1 and C2, and that of the building age tends to be higher than those of the other groups. The C4 group (purple) consists of the generation in the seventies-and-above age bracket, and the standard deviation of the resident age is more widely distributed than those of the other groups. The average building age and the standard deviation of the building age are also widely distributed.

Figure 5 as a whole shows that average resident and building ages were high (C3 and C4). A similar tendency was observed for the Ozora housing complex. In the western Obihiro area, the average resident and building ages were both higher than those in the area around Obihiro Station and in the Ozora housing complex.

5.2 Changes in each cluster from 2010 to 2035

Changes in average buildings age are constant in each zone because this study is not concerned with new construction, building loss or intentional building space reduction as described in the previous chapter, but the amount of change about average of resident age is different in each cluster. Table 2 shows the smaller the average of resident age in 2010 is, the bigger its increment except for C4 because it contains only 14 zones.

Table 2. The average of each cluster and difference between 2010 and 2035

	2010		2035		2035-2010	
	Building age	Resident age	Building age	Resident age	Building age	Resident age
C1	15.57	42.08	40.57	51.21	25.00	9.14
C2	27.80	45.93	52.80	52.34	25.00	6.41
C3	33.90	54.24	58.90	58.06	25.00	3.81
C4	29.54	71.68	54.54	87.95	25.00	16.27

Figure 6 is a graph showing an average of resident age in a vertical axis and an average of building age in a lateral axis, and shows the clusters in 2010 and 2035. In 2035, overall difference becomes smaller than in 2010. Therefore, the ageing of population and building will progress the whole city in 2035, not excepting C1 contains the zones where the youngest generation lives in as of 2010.

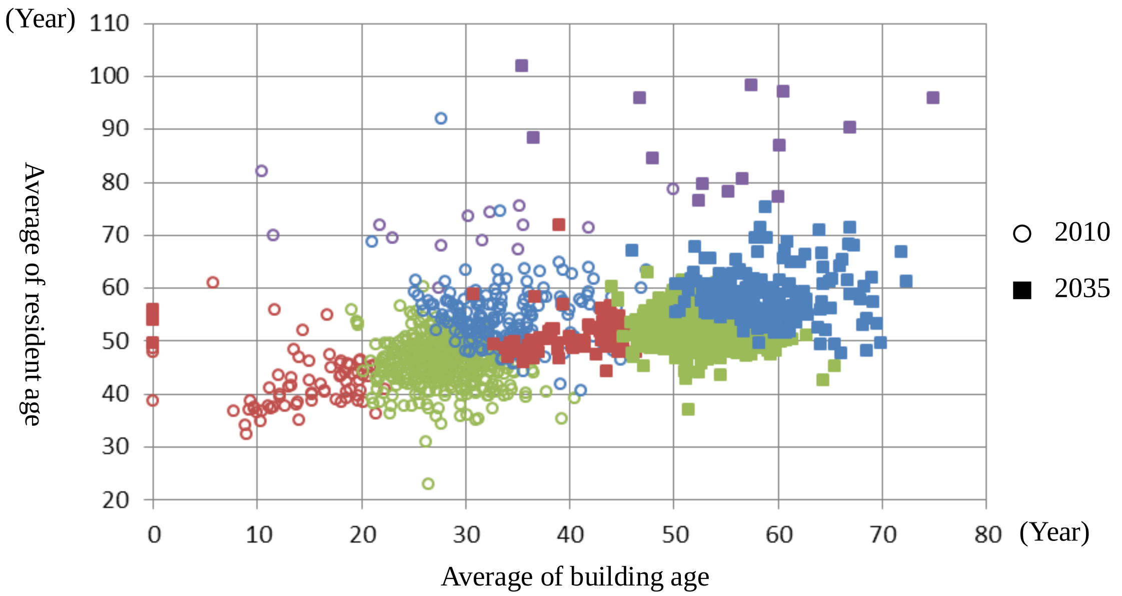

Figure 6. Changes in each cluster from 2010 to 2035

5.3 Discussion

The spatial distribution map for 2010 indicated that population and building ageing rates were increasing in the area around Obihiro Station. It was also found that the population and the younger generation were concentrated on the western side of the city. It is estimated that the aging of both the population and buildings will progress simultaneously, and that zones with an average resident age of 45 to 65 years old and buildings aged 45 to 60 years old will be distributed over an extensive area. Cars are therefore expected to remain the major means of transportation in the Obihiro urban area in 2035. However, if public transport lines are to be established to make the city more compact, it is considered possible to implement active measures to prevent the area around the station (where there are high numbers of residents in the fifties to seventies age bracket and buildings aged from 50 to 70 years old) from becoming a brownfield zone and to create an attractive streetscape. It is also considered possible to use land without waste by constructing low- and medium-rise buildings along public transport lines in order to induce relocation from suburbs and by establishing facilities and mobile environments that are easy for elderly people to use, rather than aiming for a significant population increase. Even if the use of cars is assumed, it will be possible to create an environment that allows autonomous movement by elderly people based on the improvement of personal transport and other environments relating to mobility.

In this study, future populations were forecast based on municipal reference estimation data provided by the National Institute of Population and Social Security Research, and relocation within the Obihiro urban area was not taken into consideration. Future population and building age distribution maps show distribution assuming that no measures are taken (known as a business-as-usual scenario, or B.A.U.). Accordingly, the results of the estimation performed should not be mistaken for firm predictions. Rather, the study should be evaluated for its identification of areas where the population and building age are expected to increase somewhat collectively.

6. CONCLUSION

The results obtained from this study can be summarized as follows:

1) By integrating building data from the Basic Survey of City Planning and the Survey of Population by Jo, Cho, Town, Gender and Age and using the cohort component method, the spatial distribution of building-population structures by age in the Obihiro urban area was determined. Typical zones of these structures for 2010 and 2035 were also identified using cluster analysis.
2) Based on the assumption that the population of the Obihiro urban area will decrease in the future, the integrated zones where building reconstruction and population relocation/concentration are necessary were considered.

In future work, it will be possible to refine the scenario analysis covered in the second half of this paper by modeling the loss of buildings whose service life has ended and conducting cohort analysis of buildings and population statistics using the numbers and positions of new locations as scenario variables. It will also be possible to integrate data by marking boundaries in the Basic Survey of City Planning in accordance with the grids of the Grid Square Statistics of Population Census.

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