Spatial Structure of Aging in Four Regional Central Cities in Japan : Sapporo, Sendai, Hiroshima and Fukuoka

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Abstract Aging in urban areas will be a main subject in some countries in the 21st century if urbanization is the global theme of the urban space development in the 20th century.   Although the phenomenon of aging has been studied thoroughly in demography, economics, and health science, the spatial structure of aging in urban areas remains little understood.   This report describes an intensive investigation conducted of Japan's four regional central cities : Sapporo, Sendai, Hiroshima, and Fukuoka, and aimed to clarify the pattern and trend of aging in urban areas through grasping the characteristics of residential segregation by age group.   Results showed that the spatial pattern of segregation roughly appears as a concentric shape that is closely related to the development period of urban area in the time dimension, as well as related closely to the distances from the city center in the spatial dimension.   Furthermore, because we confirmed the neighborhood change will obey the rule of "aging in place," it can be inferred that aging neighborhoods will spread out from the city center to the suburbs, and that renewal of neighborhoods obeys the same order.   Through recognition of the spatial structure of aging in urban areas, we hope this study will provide a theoretical basis for the spatial planning and optimal configuration of resources in an aging society.

Key words : aging, residential segregation, neighborhood change, Japan

1.   Introduction

Japan has entered the era of a super-aging society in 2005.   In 2014, the elderly population rate reached 25.9% (MIAC, 2014).   It is projected that more than a third of the population will be elderly (65 years or older) in 2035 (NIPSSR, 2014).   The declining birthrate and growing proportion of elderly population have become the most important social problems in Japan. The spatial order (mainly including three dimensions : spatial regularity, spatial structure, and spatial process (Ishimizu, 1974)) of aging at different scales is becoming a topic of concern to geographers.   At the national scale, the aging regions have been spreading from sparsely populated villages to densely populated urban regions (Mori, 1997).   At the city or metropolitan scale, local enclaves of extreme aging have been reported, but the spatial order of aging has not been clarified systematically.   Aging neighborhoods first appeared in inner cities (Ishimizu, 1981 ; Takayama, 1982) ; then aging in suburban residential estates was reported (Kinjyo,

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1983). This study sheds light on how aging neighborhoods are expected to spread throughout urban area, especially its patterns, determinants and trends. This research contributes in local demographic forecasting and provides information to urban physical and social planning policies.

Aging in suburbs is a main characteristic of urban space transition in Japanese cities. During the rapid economic growth period in Japanese cities from the 1960s through the 1970s, *Newtowns* were constructed on the outskirts of large cities to meet the housing pressure of inflowing population (Fukuhara, 1998). After several decades, these *Newtowns* were transformed to *Old towns* because of the rapid increase of elderly population since around 2000, attributable to baby boomers (in Japanese *Dankai* generation, those born during 1947-1949) were incorporated into the elderly population after 2000. Multidisciplinary approaches were used to analyze the reasons for aging in the suburbs. Urban geography and other related fields such as urban planning and real estate research give some explanations from different perspectives : First, from the perspective of demography, the age structure of inhabitants in newly developed suburbs had always a strong polarized characteristic. Residents aged from their 30s to 40s and their children shared an overwhelming amount of residents compared to other age groups. By the end of the 1990s, the parent generation began to join the elderly population. Moreover, their children became independent and moved out elsewhere. A substantial increase occurred in the proportion of the elderly population (MHLW, 2000 ; Naganuma *et al.*, 2006 ; Ito, 2010). Secondly, from the perspective of urban planning, almost all *Newtown*s were designed as pure residential areas as a part of the urban context. Although the development of Japanese *Newtown*s was referred from British experience, the concept is somehow different (Omichi, 1966). In addition to the variety of population size (i.e. from thousands to hundreds of thousands), some fundamental distinctions apply to Japanese *Newtown*s. Japan's *Newtown*s were invariably located inside of commuter zones in a metropolitan area, recognized as a bedroom community. Apart from nursery schools, primary schools, and basic commercial facilities, they have insufficient ability to supply more functions such as recreation and employment. Compared to self-contained and well-balanced British *Newtown*s, Japanese *Newtown*s became places purely for living. Finally, from the perspective of the housing market, probably because of some institutional and common attitude reasons, Japan's secondhand housing market is underdeveloped compared to those of other advanced countries. The share of secondhand housing in the total housing market in Japan was about 13.5% in 2008. Although that share is becoming larger in recent years, it is about one-sixth that of western countries (MLIT, 2014). Most younger families with housing needs generally choose more remote and newly developed suburban estates instead of purchasing secondhand housing in aging communities.

From the late 1990s, the so-called "back to the city", or *Toshin-kaiki* movement first began in Tokyo, Osaka, Nagoya, and then in smaller cities ; thereby the city center regained population gradually (Yamagami, 2003). Most scholars explain this phenomenon as attributable to the abrupt collapse of the real estate bubble after 1991. The rapid decline of land prices in central urban areas enabled the development of high-rise residential buildings. Therefore

population recovered thereafter (Yabe, 2003 ; Tomita, 2004 ; Miyazawa and Abe, 2005 ; Koizumi *et al*., 2011).   Some scholars have tried to give explanations through using the life cycle model of neighborhood change.   By observing the original residents living in the city center become aged and gradually decreased, land lots formerly belonging to elderly households were released and redeveloped into apartments.   Therefore, the new influx of population became possible in city centers (Sonoda, 2010).   Furthermore, some studies have analyzed Japan's social change, including demographic shifts and diversification of family types, e.g. from large households to small households because of the increasing of single-person households, and DINK families.   As is true also for some changes in employment situation, increasingly numerous female workers and *Tanshinfuninshya* : people who live apart from their own family to work in another city (Yui, 2006 ; Kubo and Yui, 2011a).   Furthermore, the change of life modalities, such as people pursuing amenities by living in the city, are increasing in recent years (Sakakibara *et al*., 2003 ; Kubo and Yui, 2011b).   All of these demands have made city centers a new frontier of housing development.

This study assesses features of the coexistence of the two phenomena of current Japanese cities ; i.e. aging in inner suburbs and population recovering in city centers as a process that is explainable by the spatial pattern of residential structures in most Japanese cities.   This study attempts to build a model to establish a connection between the two phenomena.   Consequently, to clarify the spatial order of aging at a city scale, as well as the regularity of neighborhood change, we chose four regional central cities : Sapporo, Sendai, Hiroshima, and Fukuoka as the study area.   The data we used for the study are based on National Population Censuses 2000 and 2010 and related geospatial data derived from National Land Numerical Information. The analyses are mainly conducted through the application of Geographical Information System platform (GIS, ArcGIS 10.2.1 version ; Esri).   First, we examine the existence of residential segregation by age groups in each city.   Secondly, we investigate the causes of this differentiation and analyze the characteristics of spatial distribution of each age group.   Finally, we try to generalize the pattern and trend of aging, as well as the regularity of neighborhood change.

2.   Previous Studies and the Study Areas

2.1   Research on residential differentiation and neighborhood change in cities

Research on residential areas began in the 20th century (Booth, 1902).   From the 1920s, the Chicago School of Human Ecology undertook studies to elucidate the spatial patterns of urban land use from an ecological perspective.   Research on residential differentiation became a hot issue in the field of urban studies.   A study by Shevky and Bell (1955), which laid the foundation of social area analysis, was based on the theory of social change, using a multivariate classification procedure to overcome the shortcomings of the Chicago ecologists.   In the 1960s, as the popularization of quantitative analysis in social science, factorial ecology analysis became the main method of urban residential area research.   Factorial ecology measures the

social, economic, and demographic characteristics of census tracts.

Difference, diversity, and identity are key concepts in postmodern readings of the city. Differences in cities are constructed across many dimensions including class, ethnicity, lifestyle, gender, sexuality, age, and able-bodiedness. Of particular significance for geographers, social differences often take on a spatial or territorial identity (Castells, 1997), which contributes to the construction of communities in the city. Consequently, studies of the overall urban structure have been shifted to the formation and development of communities. The concept of community cohesion[1] and subculture theory[2] support the view that the process underlying neighborhood change engenders a sorting of the urban population into a mosaic of social domains.

The initial studies of neighborhood dynamics were conducted by identifying stages in the process of neighborhood change (Hoover and Vernon, 1962 ; Temkin and Rohr, 1996). Downs (1981) put forward a five-stage model of neighborhood change, and summarized the factors that might increase a neighborhood's susceptibility to decline or revitalization (Pacione, 2009). Neighborhood change in North American cities has been facilitated by the decrepitude of housing conditions, accompanied with the replacement of former inhabitants. Decrepit and low-rent housing located in the city center became the main residential areas of immigration and low-income families ; along with improvement of income and social status, they left the city center and moved outward to reach a higher-level community. Then, the city center again became occupied by new immigrants and minorities. In the case of Asian cities, especially Japanese cities, socioeconomic and ethnic factors are not as marked as in the cities in North America. Moreover, the durability of housing is shorter. Family status and lifestyle factors are recognized as the main reasons for residential differentiation (Watanabe, 1978 ; Nakazawa and Kawaguchi, 2001 ; Tani, 2002).

In the mainstream of urban residential differentiation research, especially the studies of family status as impact factor, household size, and age structure are often considered. The spatial differences of age structure are often regarded as an incident factor (McKenzie, 1933 ; Okui, 1940 ; Newcomb, 1957 ; Hoover and Vernon, 1962) reflected in the physical conditions of housing or social-economic status, but are not regarded as an independent factor to influence residential differentiation. In recent years, studies of aging in urban areas have attract much attention in Japan[3]. However, most of those studies were limited only to reports of specific cases based on statistics or questionnaire surveys, and do not conduct a systematic analysis. Furthermore, few studies have examined the spatial differences of age structure and the neighborhood change into a unified context. The analyses of Robson (1973) and Matsumoto (2004) provide the possibility of bridging the gap separating neighborhood change and residential differentiation by age structure. Their studies reach a consensus that the lifecycle of neighborhood is defined by the life course of households.

This study specifically addresses residential differentiation in Japanese cities. Irrespec-

tive of the socio-economic and ethnic factors, we used the basic attributes of person-age as the main variable.　Age hints at the stage of life, household structures, and even income and other attributes to some degree.　This study considered residential differentiation by each age group, not limited to the elderly population, to identify the stage of "evolution" of the neighborhood. This study was conducted to reveal the spatial structure of aging in urban areas, and to ascertain the regularity of neighborhood change in Japanese cities.

2.2　Study areas

This study examines four Japanese regional central cities as study areas : Sapporo, Sendai, Hiroshima and Fukuoka.　The following reasons explain their selection.

(1)　These four regional central cities are distant from the three largest metropolitan areas[4].　The geographical independence makes it suitable and easier to determine a coherent urban area.

(2)　The populations in all the four cities are over 1 million[5].　*Newtown* development occurred from the 1960s uniformly, compared to that in other designated cities outside of the three largest metropolitan areas[6].　Moreover, the four cities have more diverse communities than smaller cities.

(3)　The urban spatial structure is roughly approximated as a concentric pattern, with a single city center.

3.　Residential segregation by age groups

3.1　Measuring segregation

Considerable controversy has persisted over the measurement of segregation.　Massey and Denton (1988) used an extensive literature search and cluster analysis to identify 20 different indexes of segregation and classify them into five key dimensions of segregation.　Fundamentally, they are evenness, exposure, concentration, centralization, and clustering.　A particular issue is the effect of spatial scale of analysis of the results, as indices of segregation increase concomitantly with decreasing population size of the spatial units being used.　This could engender invalid comparisons being made between levels of segregation in studies using different area units as a base.　Care must therefore be taken to make comparisons at comparable scale levels.

Two measures of segregation are currently in general use : The index of dissimilarity (Duncan and Duncan, 1955) and the index of isolation (Lieberson, 1981).　The index of dissimilarity (D) compares the residential locations of pairs of groups (e.g. whites and blacks) and gives a measure of the net percentage of a population group who would have to be relocated to produce an uniform community.　The index values range from 0 to 1 (or from 0% to 100%) ; if the two groups were evenly distributed in all areas (e.g. census tracts) of the city, the index would be 0 (or 0%), whereas if the city were segregated completely and census tracts were inhabited

exclusively by one group or the other, the index would be 1 (or 100%).

[1]
$$D = \sum_{i=1}^{n} \left| \frac{a_i}{A} - \frac{b_i}{B} \right|$$

Where,

a_i = population of subgroup a in statistic area i ;

A = population of subgroup a in all statistic areas ;

b_i = population of subgroup b in statistic area i ; and

B = population of subgroup b in all statistic areas.

One shortcoming of using D is that it does not take account of the fact that in a city in which two groups reside, one of which is much larger than the other ; there will be a greater probability of a member of the smaller group coming into contact with a member of the larger group than vice versa.   The index of isolation (P^*) measures both the potential for contact within groups or between groups and enjoys the advantage of using the same data inputs as D. Like the D this index runs from 0 (for a very small group that is quite dispersed) to 1 (meaning that group members are entirely isolated from other groups).   It must be stated that this index is affected by the group size : it is almost invariably smaller for smaller groups, and it is likely to rise over time if the group becomes larger.

[2]
$$P^* = \sum_{i=1}^{n} \left(\frac{a_i}{A} \right) \left(\frac{a_i}{t_i} \right)$$

Where,

a_i = population of subgroup a in statistic area i ;

A = population of subgroup a in all statistic areas ;

t_i = total population in statistic area i.

We calculated the index of dissimilarity (D) and the index of isolation (P^*) of each city for year 2010 based on national Census Small Areas (Chochomoku units).   Table 1 shows the average value of D of the four cities.   Then we highlight the maximum and minimum values for age groups in rows.   Results show the following : (1) D in adjacent age groups is less than D in nonadjacent age groups in the case of people older than their 20s, i.e. the adjacent age groups live less segregated than the nonadjacent age groups after their independence (over 20 years old).   (2) D in ages 0s and 30s, and 10s and 40s are smaller because the former age groups are children of the latter age group.   (3) The maximum value of D is between 0s and people in their 70s and older, i.e. families with children and families with elderly people are the most segregated.   Table 2 shows the value of P^* in each city.   We marked two age groups with the top two maximum values.   In all four cities, we found that the 30s and persons in their 70s or older got the highest isolation index than other age groups.   It can be inferred that the residential

Table 1   Average Index of Dissimilarity of Four Cities in 2010

	0s	10s	20s	30s	40s	50s	60s	70s +
0s	–	17.63%	24.95%	13.17%	16.41%	23.87%	27.79%	32.70%
10s	17.63%	–	22.27%	19.34%	11.86%	17.30%	23.17%	28.77%
20s	24.95%	22.27%	–	16.59%	19.38%	21.52%	26.50%	31.11%
30s	13.17%	19.34%	16.59%	–	13.44%	20.79%	25.03%	29.80%
40s	16.41%	11.86%	19.38%	13.44%	–	15.58%	22.28%	27.55%
50s	23.87%	17.30%	21.52%	20.79%	15.58%	–	13.75%	21.17%
60s	27.79%	23.17%	26.50%	25.03%	22.28%	13.75%	–	15.96%
70s+	32.70%	28.77%	31.11%	29.80%	27.55%	21.17%	15.96%	–

Note : (1) Values were calculated according to Chochomoku units.
(2) Dark grey and light grey means the maximum and minimum value for each age group, respectively.
(3) Scope of statistics was defined as the 30 km buffer area from each city's center rail station (in this study, we chose Sapporo Station, Sendai Station, Hiroshima Station, and Tenjin Station).

Data source : National Census, 2010.

Table 2   Index of Isolation of Four Cities in 2010

	0s	10s	20s	30s	40s	50s	60s	70s+
Sapporo	9.84%	11.31%	15.73%	16.52%	14.90%	14.98%	16.18%	19.99%
Sendai	11.82%	12.12%	16.15%	18.35%	15.11%	15.13%	15.39%	19.54%
Hiroshima	11.78%	11.62%	15.45%	16.97%	14.35%	13.68%	16.97%	20.42%
Fukuoka	11.35%	11.45%	15.17%	16.92%	13.97%	14.11%	14.93%	18.10%

Note : (1) Values were calculated according to Chochomoku units.
(2) Scope of statistics was defined as the 30 km buffer area from each city's center rail station (in this study, we chose Sapporo Station, Sendai Station, Hiroshima Station, and Tenjin Station).

Data source : National Census, 2010.

areas of elderly people and young adults are more isolated from other age groups.   The following sections 3.2 and 3.3 present analyses of the spatial distribution of each age group and the causes of this phenomenon.

3.2   Mapping segregation

We attempt to represent the pattern of residential segregation visually by age groups through GIS.   Results showed that the Chochomoku unit (Census Small Areas), used in section 3.1 are not suitable for this analysis.   Since the Chochomoku unit is too small (especially in the city center area) and the pattern was not easily identifiable.   Therefore, we aggregated the statistic tracts to Oaza unit[7].   We calculated the specialization coefficient of six age groups (from 20s to 70s and older) in all Oaza units.   Then we assigned the age group that have the maximum specialization coefficient to an Oaza unit.   The corresponding age group was recognized as the dominant residents in each Oaza unit.   Figure 1 portrays the pattern of residential
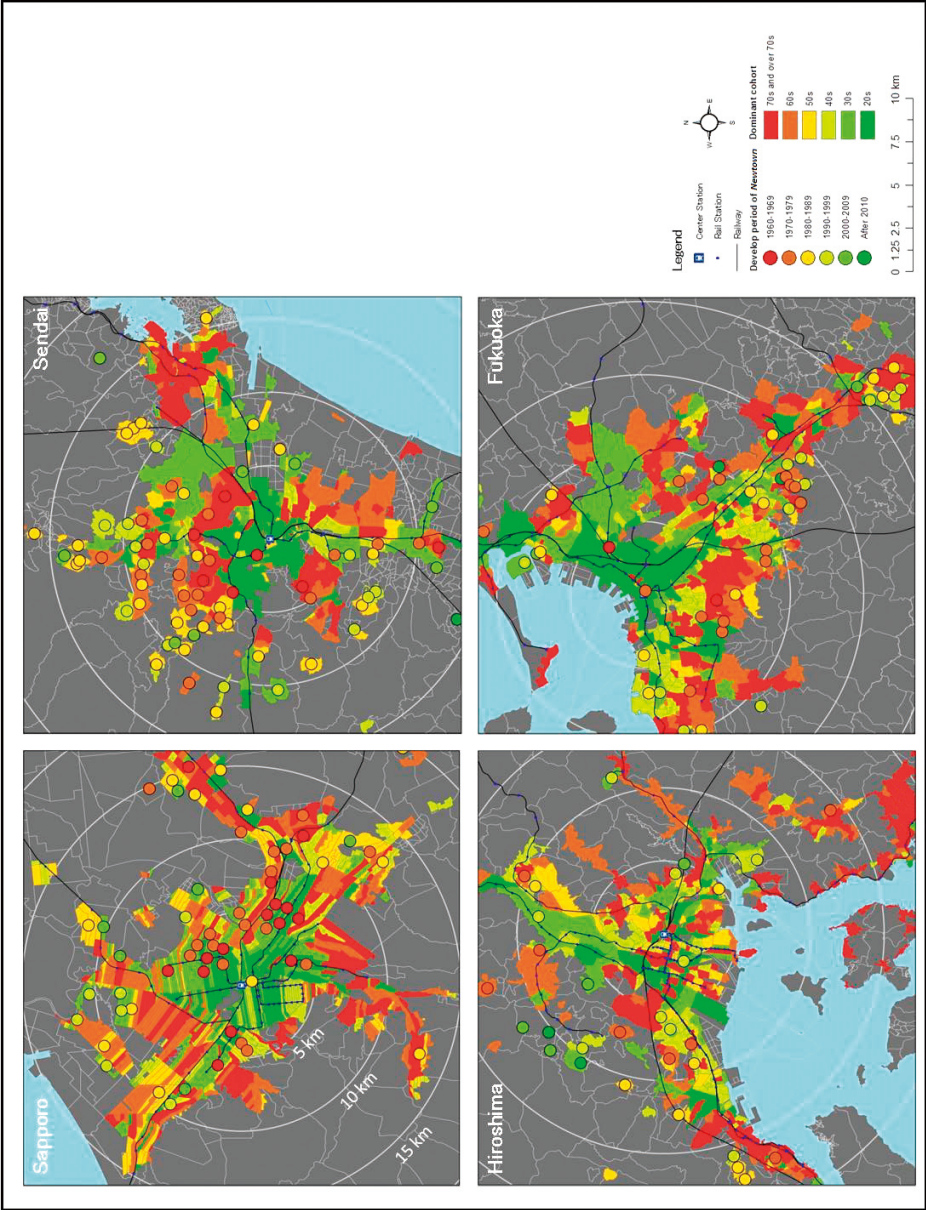
Figure 1   Residential segregation by age group in 2010.
  Note：(1) Divisions of age groups are based on data of the year 2010.
  (2) The youngest age group which can be recognized as having the ability to live independently is 20s.
  (3) To delete the influence of "noise" values, e.g. in rural areas with a significantly high proportion of elderly population, we only selected the
  Oaza units with a population density over 1000 people per square kilometer (considered as an urbanized area).
  (4) The development period of Newtown was determined by the start year of construction and the finish year.
  Source：National Census, 2010
  National Land Numerical Information

segregation by age groups in the four urbanized areas.   We were able to observe some common features : (1) people in their 20s, 30s, and part of 40s occupied mainly the inner areas ; (2) people in their 60s, and people in their 70s and older are the dominant age groups in the inner suburban areas ; (3) people in their 40s and 50s are more prevalent in outer suburban areas ; (4) some 30s residential areas are located in the urban peripheral areas, where the frontier of new residential development is located.   We also overlay the layer of the distribution of *Newtowns* above each segregation maps.   It was readily apparent that the development period of *Newtowns* has a certain corresponding relation with the dominant age group.   Aside from the city center, the earlier developed *Newtown* is more likely dominated by elder residents.   This regularity is especially clear in the case of Sendai city.

3.3   Cause of Segregation

We next analyze why residential segregation according to age groups happened and what factors determined its spatial pattern.   From the perspective of residential differentiation, people with similar lifestyles and needs more likely make similar decisions when choosing residential areas.   Congregations of similar households form neighborhoods with their own identities. In western countries, this agglomeration process is implemented through the intra-city movement of individual family (Rossi, 1955).   Because it is hard to obtain unified residential relocation records for each city over a long time span (e.g. several decades), it is impossible to ascertain the reason of residential segregation directly by age group through analyzing the character of intra-city population movement.   However, we can infer from the age structure of the individual urbanized areas (i.e. urbanized areas according to development period) at the current stage.   In other words, through analyzing the age structures of the individual urbanized areas we can ascertain the remaining ratio (percentage of population who did not change residential area since the development of the area) of a specified age group to some extent.   Although this result is not intuitive, it can provide some material to conduct further analyses.

Densely Inhabited Districts (DID) are urban areas that are designated based on statistical data which meet certain criteria[8] ; DID have been designated in each census since 1960. According to the individual DID area data of 1960-2010, the current urbanized area in 2010 are divisible into six parts as the following.   The area built up before 1960 (old town where CBD located), and the area built up during the 1960-2000s in every 10 years.   Using the national population census data in 2010, we investigated the age structure of each area in four cities as shown in Table 3.   Although the age distribution in areas varies among the four cities, we can confirm the trend through calculating the average percentage of each age group in the four cities.   The built up area developed before the 1960s is inhabited mainly by people in their 20s and 30s.   The areas developed in the 1960s are inhabited mainly by people in their 30s and those in their 70s and older.   The areas developed in the 1970s are inhabited mainly by people in their 60s and in their 70s and older.   The areas developed in the 1980s are inhabited mainly by people in their 50s and 60s.   The areas developed in the 1990s are inhabited mainly by peo-

Table 3   Age Structure by Development Period in 2010

Sapporo

Development Period	0s	10s	20s	30s	40s	50s	60s	70s +	Total	over 65	Approx. Radius of DID Area (km)
before 1960	6.5%	7.7%	16.5%	17.2%	14.5%	12.5%	11.9%	13.1%	100%	18.2%	4.5
1960s	7.4%	8.5%	12.3%	15.5%	14.0%	13.2%	13.7%	15.3%	100%	21.4%	6.1
1970s	7.7%	9.2%	9.7%	13.6%	12.8%	13.5%	16.6%	16.9%	100%	24.2%	8.3
1980s	7.1%	10.0%	11.1%	12.1%	12.4%	16.4%	16.5%	14.4%	100%	21.0%	9.3
1990s	8.5%	13.7%	10.7%	12.0%	15.9%	16.7%	12.0%	10.6%	100%	15.2%	9.8
2000s	17.4%	14.2%	7.5%	20.6%	16.9%	9.0%	7.5%	6.7%	100%	9.9%	10.0

Sendai

Development Period	0s	10s	20s	30s	40s	50s	60s	70s +	Total	over 65	Approx. Radius of DID Area (km)
before 1960	7.2%	9.2%	17.5%	15.8%	13.7%	12.5%	10.9%	13.1%	100%	17.7%	3.7
1960s	8.2%	9.6%	13.7%	15.2%	13.4%	12.3%	12.1%	15.6%	100%	21.1%	4.8
1970s	8.6%	10.0%	11.5%	14.7%	13.1%	12.0%	14.0%	16.0%	100%	22.7%	6.2
1980s	8.6%	10.3%	11.5%	14.9%	12.3%	13.9%	16.2%	12.3%	100%	19.1%	7.0
1990s	10.0%	11.7%	13.0%	15.9%	14.6%	14.6%	11.0%	9.2%	100%	13.6%	7.6
2000s	16.8%	15.4%	6.7%	19.4%	18.1%	13.8%	9.0%	0.7%	100%	3.9%	7.8

Hiroshima

Development Period	0s	10s	20s	30s	40s	50s	60s	70s +	Total	over 65	Approx. Radius of DID Area (km)
before 1960	8.2%	8.6%	12.2%	15.5%	13.5%	12.3%	13.9%	15.8%	100%	22.0%	4.9
1960s	10.1%	10.1%	11.9%	16.5%	14.0%	11.5%	12.6%	13.3%	100%	19.0%	6.0
1970s	10.2%	10.3%	10.5%	15.6%	13.4%	11.6%	14.5%	14.0%	100%	20.6%	7.3
1980s	8.7%	10.0%	10.0%	13.3%	12.0%	14.3%	17.3%	14.4%	100%	21.8%	8.0
1990s	13.8%	16.6%	13.9%	17.8%	17.9%	13.2%	6.2%	0.6%	100%	2.8%	8.1
2000s	19.0%	17.5%	4.0%	16.7%	18.2%	11.6%	10.4%	2.5%	100%	6.8%	8.1

Fukuoka

Development Period	0s	10s	20s	30s	40s	50s	60s	70s +	Total	over 65	Approx. Radius of DID Area (km)
before 1960	7.7%	8.6%	16.9%	17.8%	14.4%	12.3%	11.0%	11.2%	100%	15.7%	4.8
1960s	9.3%	10.3%	12.4%	15.3%	13.6%	12.9%	12.7%	13.5%	100%	19.0%	6.1
1970s	9.8%	10.3%	11.7%	15.2%	12.8%	12.6%	13.9%	13.7%	100%	19.9%	8.6
1980s	10.1%	10.3%	11.9%	15.1%	12.5%	13.4%	14.4%	12.4%	100%	18.4%	9.4
1990s	10.8%	12.8%	11.4%	14.5%	14.5%	14.9%	12.2%	8.9%	100%	13.7%	9.8
2000s	17.4%	15.4%	7.9%	17.8%	16.8%	11.8%	7.8%	5.0%	100%	7.9%	10.1

Table 3   Continued

Average

Development Period	0s	10s	20s	30s	40s	50s	60s	70s +	over 65
before 1960	7.4%	8.5%	15.6%	16.7%	14.1%	12.4%	12.0%	13.2%	18.4%
1960s	8.6%	9.5%	12.4%	15.5%	13.8%	12.7%	13.0%	14.5%	20.1%
1970s	9.0%	9.9%	10.8%	14.6%	13.0%	12.6%	14.9%	15.2%	21.9%
1980s	8.5%	10.1%	11.2%	13.7%	12.3%	14.7%	16.0%	13.5%	20.1%
1990s	10.0%	13.1%	11.8%	14.3%	15.3%	15.3%	11.3%	8.9%	11.3%
2000s	17.6%	15.6%	6.7%	18.5%	17.5%	11.7%	8.6%	3.7%	7.1%

Note : (1) Scope of statistics was defined as the 30 km buffer area from each city's center rail station (in this study, we chose Sapporo Station, Sendai Station, Hiroshima Station, and Tenjin Station).

(2) The top two age groups in each area are highlighted in yellow.

Data source : National Census, 2010.

ple in their 40s and 50s.   The newly built up areas after 2000 are inhabited mainly by people in their 30s and 40s, and by children in their 10s (Table 4).   Furthermore, people in their 30s constitute a larger share than other age groups in the four cities because they are the child generation of baby boomers.   Elderly populations are most likely concentrated in the areas built during 1970s, except in Hiroshima city.

It might be inferred that the main inhabitant's age group in each urbanized area is correlated strongly with the developed period of the area.   This regularity determined the spatial pattern of segregation by age.   Otherwise, when we consider why it occurred, three hints will be apparent from the data.   First, the residents' remaining rate is high.   When we specifically examine the areas developed in the 1970s, more than 30% of people in their 60s and people in their 70s and older population still reside there : over 30% of residents did not move from the area after 40 years, assumed there was no inflow movement happened.   Secondly, the age structure shows a lack of balance.   It is apparent that newly developed areas after 2000 are inhabited primarily by people in their 30s, people in their 40s, and their children's generations.   This situation might not differ in other areas at the beginning of development period. Thirdly, population exchanges among different areas rarely occur.   Excluding the inner city, part of 30s and 40s flow in the redeveloped areas after 1990.   Therefore, changes in the age structure occurred once with a high proportion of elderly population in the 1970s and 1980s reported by the previous studies (Kagawa, 1987 ; Kagawa, 1990 ; Tanabe and Hasegawa, 1982).   In other areas distant from the city center, it was difficult to find population exchange, except in some neighborhoods near subway stations (Feng and Isoda, 2015).   As a result, residential segregation by age groups in Japanese cities is caused mainly by low household mobility.

4.   Regularity of neighborhood change

4.1   Transfer rule of neighborhood change

One more research objective in this study is to bridge the gaps between residential segregation and neighborhood change.   In this study, we examine the alteration of a dominant age group in an Oaza tract as a neighborhood change.   We conducted a time-series analysis to ascertain the character of the neighborhood changes in the four cities.   We used the national population census in year 2000, and mapped of the residential segregation in 2000, in the same way as in Figure 1.   Therefore, we can monitor the change of dominant age group in 10 years at the same Oaza unit[9].   Figure 2 shows that neighborhoods dominated by 20s in 2000 were also dominated by the same age group in 2010, a few of them transfer to 30s-dominated neighborhoods ; people in their 30s, 40s, 50s, and 60s who dominated neighborhoods in 2000 are almost transferred to domination by people in their 40s, 50s, 60s, and people in their 70s and older, respectively, i.e. these neighborhoods are "aging in place."   It must be emphasized that over 20% of 70s and older dominated neighborhoods were transferred to younger neighborhoods from 2000 to 2010, except those which are "aging in place".   We can find most of these transferred neighborhoods are resided in inner city areas with good accessibility.

We conclude that except for most 20s and a part of 30s dominated neighborhoods (mostly rental apartments in the inner city), the neighborhood change in the urbanized area occurred mainly at the same places through the change of dominant cohort.
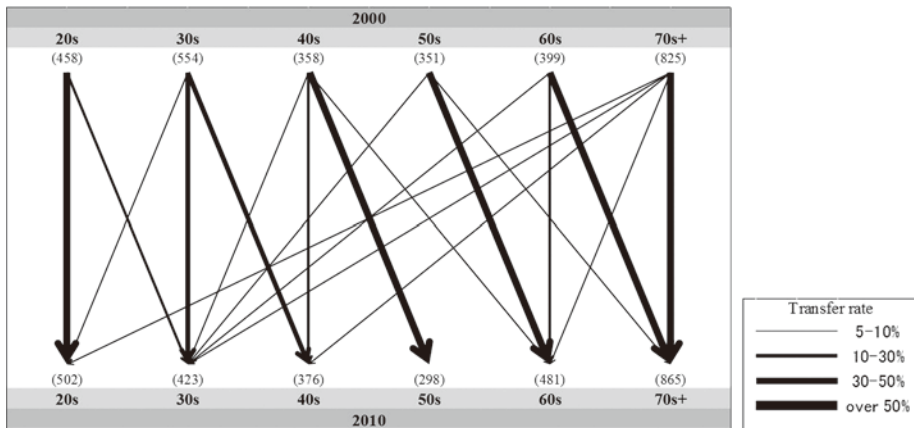

Figure 2.   Neighborhood change during 2000–2010.
Note : (1) All figures are total numbers for four cities.
(2) Number in ( ) is the number of neighborhoods, the same as the Oaza units in this study.
Source : National Census, 2010
National Land Numerical Information

4.2   Spatial structure of aging

Using national population census data for 2000 and 2010, we sketched the density gradient of elderly population (over 65 years old) in the four cities (Figure 3).   Compared with the year 2000, the density of elderly population in the year 2010 saw a general upward trend.   However, the location of peak values and the overall trend of the average density curve did not change too much in these 10 years.   Therefore, "aging in place" is a major feature of the spatial structure of aging.   In addition, according to the distribution of elderly population rate change shown in Figure 4, the peak of growth is mainly distributed in the area of 8–9 km from the city center, most of these areas are *Newtowns in* inner suburbs developed in the 1960s and 1970s (Figure 1). Consequently, according to the features of residential segregation by age groups we figured out in the previous sections, we can infer that the spread of aging neighborhoods from inner sub-urbs to outer suburbs in the future, which echoes that of Ishimizu (1981) and Konagaya (2002).
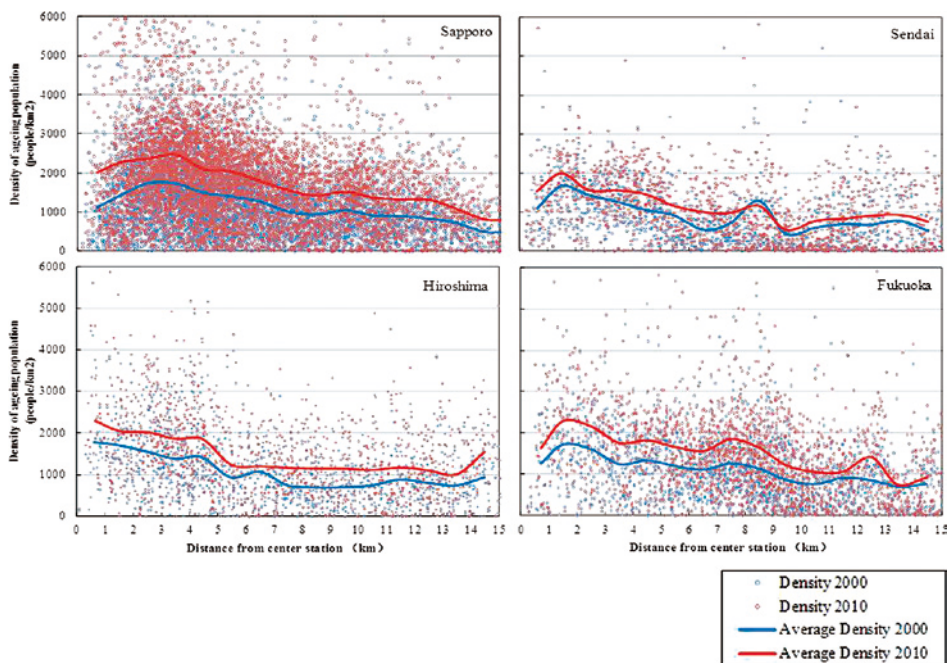
Figure 3.   Density of elderly population during 2000–2010.
Note : Calculations were based on Chochomoku units.
Source : National Census, 2000, 2010

4.3   Spatial pattern of neighborhood change

Section 4.1 only described the transfer rule of neighborhoods dominated by different age groups.   This section includes specific examination of their spatial characteristics.   Figure 5 depicts the spatial trend of neighborhood change.   The following observations were made : (1) in these 10 years, the shares of neighborhoods being dominated by people in their 20s, 30s, 40s, and 50s are becoming increasingly numerous in the core areas (about 0–3 km from center station), while people in their 60s and people in their 70s and older are decreasing.   (2) The share of neighborhoods being dominated by people in their 60s are growing in outer suburbs, whereas people in their 70s and older are becoming more numerous in the inner suburbs.   We can infer that younger neighborhoods are gradually occupying the city core area, whereas aging neighborhoods are gradually moved away from the city center and spreading outward.   The transfer rule we showed in section 4.1 and the spatial pattern of neighborhood change indicated the regularity of neighborhood change, i.e. the renewal of the neighborhood first occurred in the center areas and then spreads out until the neighborhood is dominated from an elderly to a young population, represented as a series of replacement processes between the young population and elderly population.
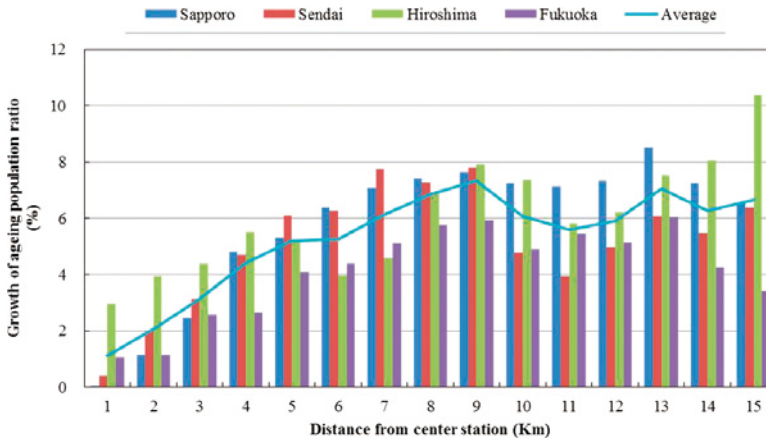

Figure 4.   Changes in elderly population during year 2000–2010.
Note : Calculations were based on Chochomoku units.
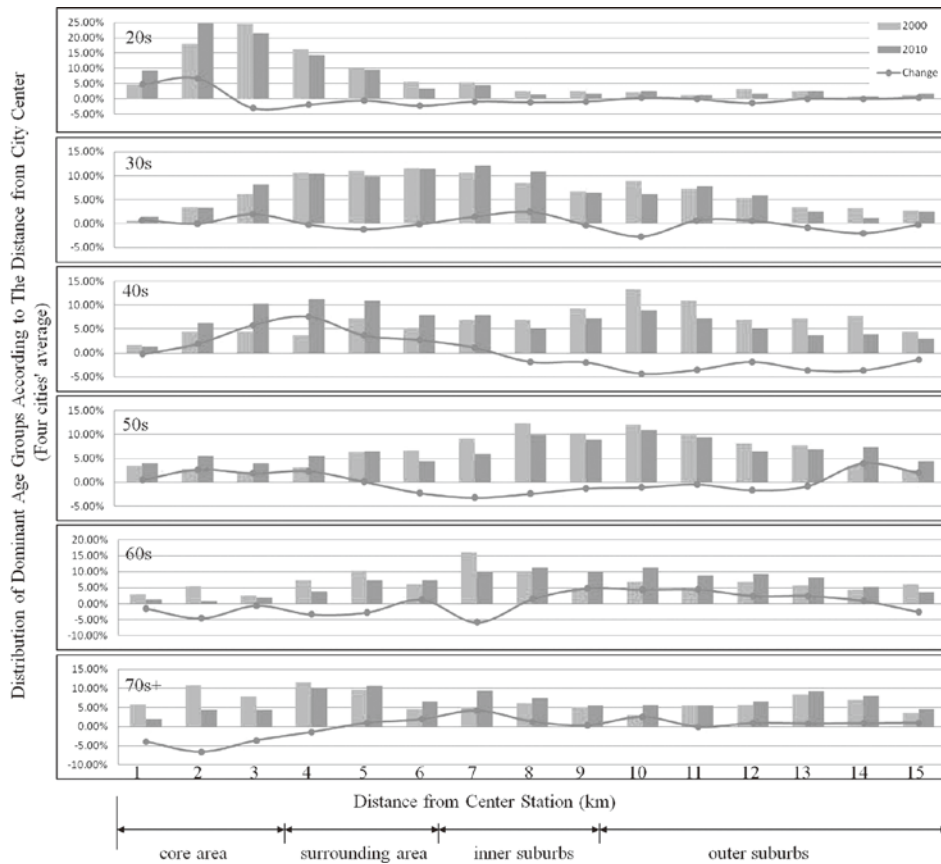Source : National Census, 2000, 2010.

Figure 5.　Distribution neighborhoods dominated by individual age group during 2000–2010.

5.　Conclusions

We observed phenomena related to residential segregation by age groups in all the four regional central cities in Japan : Sapporo, Sendai, Hiroshima, and Fukuoka.　The spatial pattern of segregation is closely related with the development period of urban area in the time dimension, as well as closely related with the distances from city center in the spatial dimension.　In general, the spatial pattern of segregation shows a roughly concentric shape at the current stage.　The city center and surrounding areas developed before the 1960s are mainly occupied by people in their 20s and 30s, and partly by elderly population, which collectively dominate the neighborhoods.　The inner suburbs developed during the 1960s and 1970s are mainly occupied by elderly people, who settled in the neighborhoods when they were at age 30s and 40s.　The outer suburbs developed during 1980s and 1990s as neighborhoods mainly occu-

pied by people in their 40s, 50s, and 60s.   In the peripheral areas of the cities are newly developed residential areas occupied by people in their 30s and 40s and their child generations.

The residential segregation by age groups can be explained by the of intra-city household immobility.   Through analysis of the national population census of year 2000–2010, we discovered that excluding the neighborhoods dominated by people in their 20s and 30s, over 70% of neighborhoods are "aging in place."   Unlike with western countries, the intra-city household immobility has determined the regularity of neighborhood change in Japanese cities.   Therefore, the identity (or status) of neighborhoods is closely related to the life stage of the dominant age group.   Age, as an important indicator of the life stage (such as marriage, birth of child, independence of children, retirement, etc.) will strongly influence the neighborhood identity.

More importantly, occupation of space by individual age groups and the regularity of neighborhood change leads to two inferences.   The spatial structure of aging will spread out from
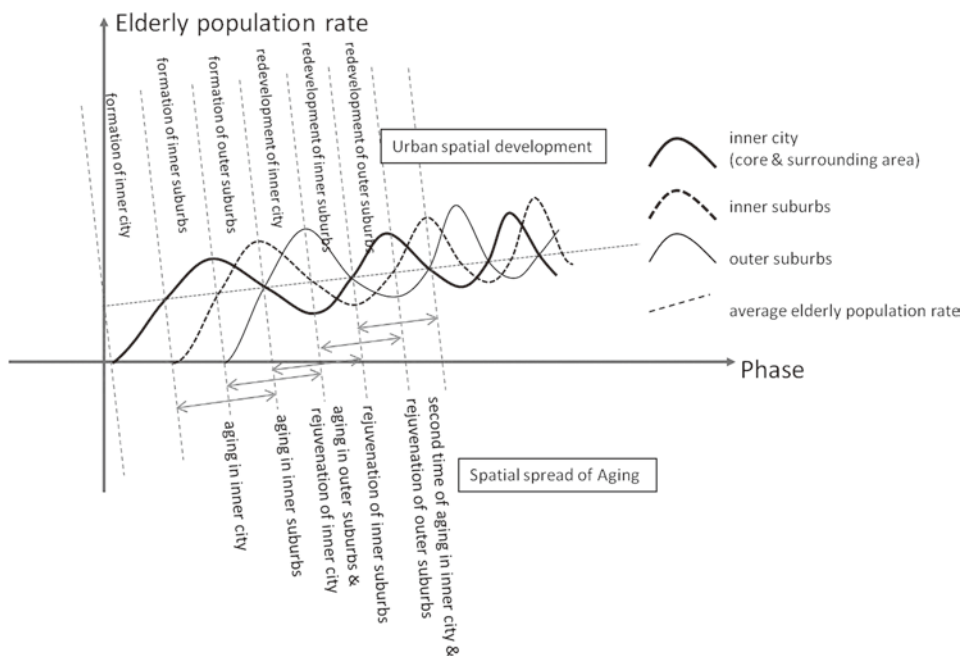

Figure 6.   Conceptual model of the spatial structure of neighborhood aging and renewal.
Note : We assume that no ennormous immigration will hapen, the population decline will continue, and the average elderly population rate in urban area willgradually growing.
(1) the spatial spread of aging is following the same process of urban spatial development ;
(2) aging will happen independently in inner city, inner and outer suburbs ;
(3) aging and rejuvenation appear alternately, but degree of aging will be higher than the previous phase and rejuvenation will be weaker than the previous phase.

city center to suburbs.　The other is the renewal of neighborhood (change of dominant age group) also expand from city center to the outskirts.　However, the update cycle will vary from area to area, which is beyond the scope of this study.　According to the above conclusions, we explore the model of spatial structure of aging and renewal of neighborhood formulated by the phenomenon of residential segregation by age groups (Fig. 6).

Note

1)　According to Finsterbusch (1980), the concept of community cohesion refers to the amount and quality of social relations and interactions in a neighborhood and to attraction to or identification with the area.

2)　The existence of distinctive socio-spatial urban subcultures is the result of the process of segregation and congregation of groups in the city (Pacione, 2009, pp. 377).

3)　Tokyo (Yano *et al*., 1990), Nagoya (Saino, 1989), Osaka (Takayama, 1983), Kyoto (Kagawa, 1991), Fukuoka (Naganuma *et al*., 2008 ; Saino, 1992), Sapporo (Saino, 1990), Hiroshima (Yui, 2003), Sendai (Ito, 2010), Okayama (Mori, 1997), and Kanazawa (Kagawa, 1990).

4)　Sapporo is located in the Hokkaido Region.　Sendai is located in the Tohoku Region.　Hiroshima is located in the Chugoku Region.　Fukuoka is located in the Kyushu Region.

5)　The respective populations in Sapporo, Sendai, Hiroshima, and Fukuoka municipal areas are 1.9, 1.0, 1.1, and 1.5 million in 2010.　The respective populations in the metropolitan area (in this study areas covered 30 km from center station) are 2.3, 1.6, 1.8, and 2.9 million in 2010.

6)　So-called Cities Designated by Government Ordinance have been established since 1956 : they are cities that have a population greater than 500,000 and which have been designated as such by an order of the cabinet of Japan under Article 252, Section 19 of the Local Autonomy Law.　Designated cities are delegated many of the functions normally performed by prefectural governments in fields such as public education, social welfare, sanitation, business licensing, and urban planning.　The city government is generally delegated the various minor administrative functions in each area, whereas the prefectural government retains authority over major decisions.　Sapporo, Sendai, Hiroshima, and Fukuoka respectively became designated city in 1972, 1989, 1980, and 1972.

7)　Oaza consists of Chochomoku units.　Each Oaza and Chochomoku has a unique code and the code of Oaza and Chochomoku share the same first nine digits.　The Chochomoku units which belong to the same Oaza were merged to Oaza units in GIS platform.

8)　Densely Inhabited Districts are the urban areas that are designated based on statistical data and which meet the following criteria, and which have been designated in each survey since the 1960 Population Census of Japan.

1)　A district containing basic unit blocks, etc. with a population density of 4,000 and more per square kilometers, such districts are mutually adjacent in a municipality

2)　A district consisting of the above adjacent basic unit blocks, etc. with population is 5,000 and more at the time of the Population Census of Japan.　(Statistics Bureau, Ministry of Internal Affairs and Communications)

http://www.stat.go.jp/english/data/chiri/did/1-1.htm

9)　Our analysis was based on 2010 Oaza units because the coverage area of some census tracts differed in 2000 and 2010.　We unified the census tract first through transforming procedures in GIS platform.

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