TIME SERIES ANALYSIS OF AGE STRUCTURE FOR AGED SOCIETY IN THE TOKYO METROPOLITAN AREA

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ABSTRACT

In the Tokyo metropolitan area, population aging is becoming more serious year by year, and a decline of population is expected. Aging trends are significantly different by area; there are areas in which aging is especially rapid and areas into which young people continuously move. Rapid aging in particular areas makes service in public and private sectors less effective or profitable because elderly people consume this service less than young or middle-aged people. Thus rapid aging leads to difficulty for these service providers and then lessening availability for consumers, resulting in worsening quality of life. That makes the area less attractive for young people, which in turn results in further population imbalance in the form of aging.

In such conditions, railway companies and local governments wish to realize generation-mixed-communities in the vicinity of railway stations. Clarifying the difference of aging trends is important in an aged and depopulation society like Tokyo.

This study aims to analyze trends of age structure along urban railway lines and over central areas. The findings of this research should prove useful for railway companies and local governments in developing urban planning strategies to realize mixed-generation communities along railway corridors and in the vicinity of stations.

Keywords: aged society, age structure, population migration, time series analysis, railway

INTRODUCTION

The total population of Japan has started to decline and population aging is becoming more serious year by year. The National Institute of Population and Social Security Research (JPSS) forecasted in 2012 that the total population of Japan will decline to 87 million in 2060, approximately two-thirds of that in 2010 (128 million). The number of people 65 years and over will be 35 million, approx. 40% of total population. Figure 2 shows the estimated aging rate (rate of population 65 years and over) of various countries (United Nations (2011)). It is clear that Japan is the most rapidly aging nation in the world and that several countries also will experience rapid aging like Japan.

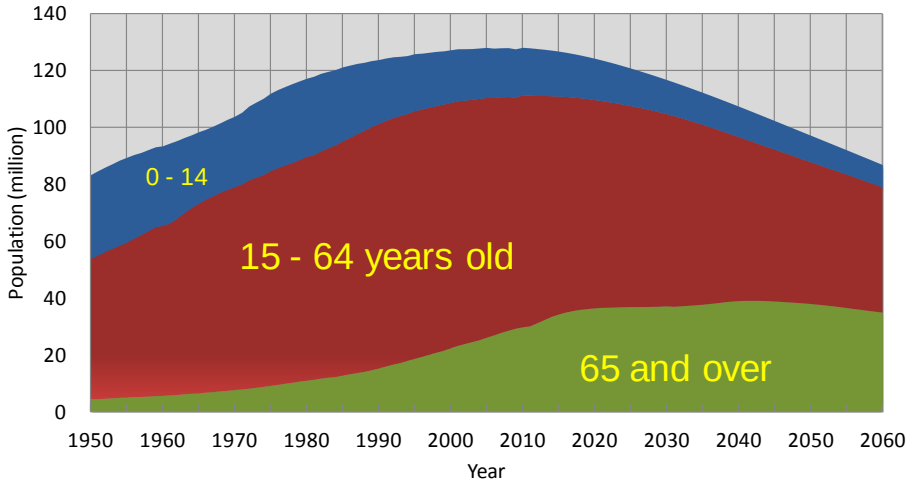

Figure 1 – Population of Japan

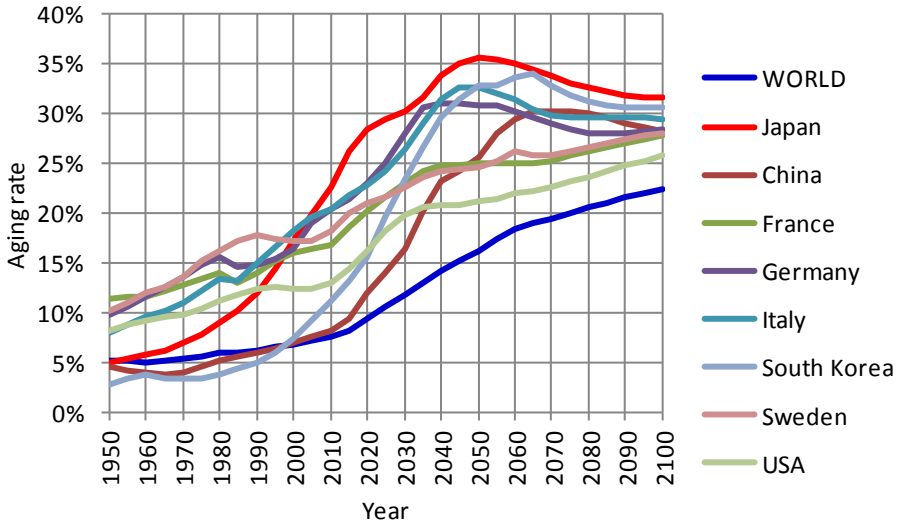

Figure 2 – Aging rate of countries

In the Tokyo metropolitan area, extremely rapid aging and a decline of population is expected. JPSS also forecasted in 2007 that in the Tokyo metropolitan area (Tokyo, Kanagawa, Saitama and Chiba), population of residents age 65 and over will grow to 10.6 million in 2035, approximately 1.8 times that of 2005. This speed of aging is faster than that of any other metropolitan area in Japan. Moreover, JPSS also forecasted that a decline of total population will start in a decade in the Tokyo metropolitan area. The Tokyo metropolitan area must immediately cope with this situation.

Aging trends are significantly different by area; there are areas in which aging is especially rapid, and areas into which young people continuously flow. In 1997 the number of people who flow into the 23 wards of Tokyo exceeded that of people who flow out for the first time in 34 years, and the wards' total population started increasing again. This increase is now continuing. On the other hand, in some new towns built in 1960s and 1970s - now sometimes called "old towns" - aging and decrease of population are especially rapid because of the concentration of particular age groups.

If aging advances in an area, demands for services diminish. For example, aging results in the decrease of total railway demand because the decrease of commuter demand exceeds the increase of demand on private business when elderly people retire. This is a significant concern for railway companies (HIBINO et al. (2007)). Therefore, rapid aging in particular area leads to difficulty for these service providers and then lessening availability for consumers, resulting in worsening quality of life. That makes the area less attractive for young people, which in turn results in further population imbalance in the form of aging. In such conditions, railway companies and local governments wish to realize generation-mixed-communities in the vicinity of railway stations.

The objective of this study is to clarify the difference of aging trends inside the Tokyo metropolitan area focusing on railways. This is an important perspective in aged and depopulation society like Tokyo.

METHODOLOGY

In Japan, there are several studies on age structure and population migration inside metropolitan areas (e.g. OE (1996), SHIMIZU (2004), MIYAZAWA et al. (2005) and FUJII et al. (2005)). Some of them focus on areas along railways (e.g. HIBINO et al. (2000) and KOIKE (2010)). Based on these previous studies, this study focuses on railway lines and stations.

This study uses indexes that indicate the change in age structure: number of population fluctuation and rate of population fluctuation. These indexes are defined as the equations shown below:

$$\Delta P_i^y = P_i^y - P_{i-5}^{y-5} * \alpha_{i-5}^{y-5}$$

$$R_i^y = \frac{\Delta P_i^y}{P_{i-5}^{y-5}}$$

ΔP_i^y : number of population fluctuation when people of *i-5* to *i-1* years in year *y-5* become *i* to *i+4* years old in year *y* (unit:person)
R_i^y : rate of population fluctuation when people of *i-5* to *i-1* years in year *y-5* become *i* to *i+4* years old in year *y* (unit:%)
P_i^y : population of *i* to *i+4* years old in year *y* (unit:person)
α_i^y : quotient of population of *i+5* to *i+9* years old in Japan in year *y+5* divided by population of *i* to *i+4* years in Japan in year *y* (unit:%)

This study analyzed population (five-year age groups) data by national census. 500m/1000m-mesh-based data of 1980-2005 census and municipality-based data of 1980-2010 are used. The latter is used in the comparison among municipalities.

In suburban areas, mesh-based population was tallied up along urban railway lines. There are three reasons. First, in the Tokyo metropolitan area, the modal share of railway is high. 79% of commuters to the 23 wards of Tokyo take a train (Tokyo Metropolitan Region Transportation Planning Commission (2008)). Second, many people tend to recognize an area as along a railway. Third, there are railway lines operated by many companies in suburban areas. The urban development strategies of railway companies are more influential than those of local governments in such areas. Figure 3 shows the methodology of tallying up mesh-based population. Population of 1km meshes the centroid of which is within 2 km (25 minutes on foot) from a station were tallied up. If a mesh is within 2 km from more than two stations on the same line, the population was divided by the number of stations and tallied up. The population of each station was tallied up by each line. In central areas, on the other hand, population was not summed up along a line. This is due to there being a dense railway network served by a relatively small number of operators. Therefore railway companies are not so influential in characterizing areas in central Tokyo as they are in suburban areas.

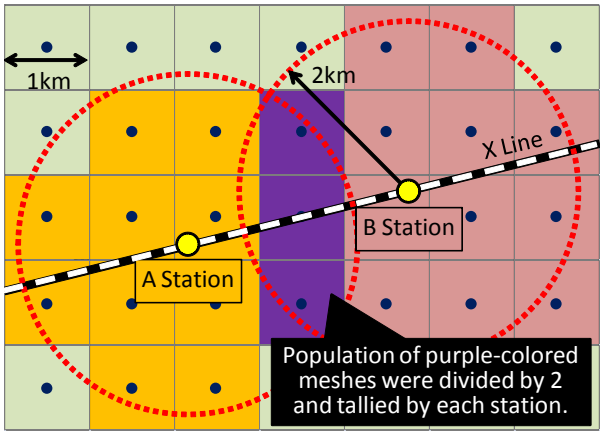

Figure 3 – Methodology of tallying up mesh-based population data

TIME SERIES ANALYSIS OF AGE STRUCTURE ALONG RAILWAY LINES

This section focuses on suburban areas and analyzes the trends of age structure along the railway lines. The Figure 4 and Table 1 show the target 16 railway lines.

Table 1 – Railway lines surveyed in this study

No.	Name of Line	Corporation	No.	Name of Line	Corporation
1	Keikyu Line	Keikyu	9	Ikebukuro Line	Seibu
2	Sotetsu Line	Sotetsu	10	Tojo Line	Tobu
3	Toyoko Line	Tokyu	11	Tohoku Line	JR East
4	Den-en-toshi Line	Tokyu	12	Isesaki Line	Tobu
5	Odawara Line	Odakyu	13	Joban Line	JR East
6	Keio Line	Keio	14	Keisei Line	Keisei
7	Chuo Line	JR East	15	Sobu Line	JR East
8	Shinjuku Line	Seibu	16	Keiyo Line	JR East

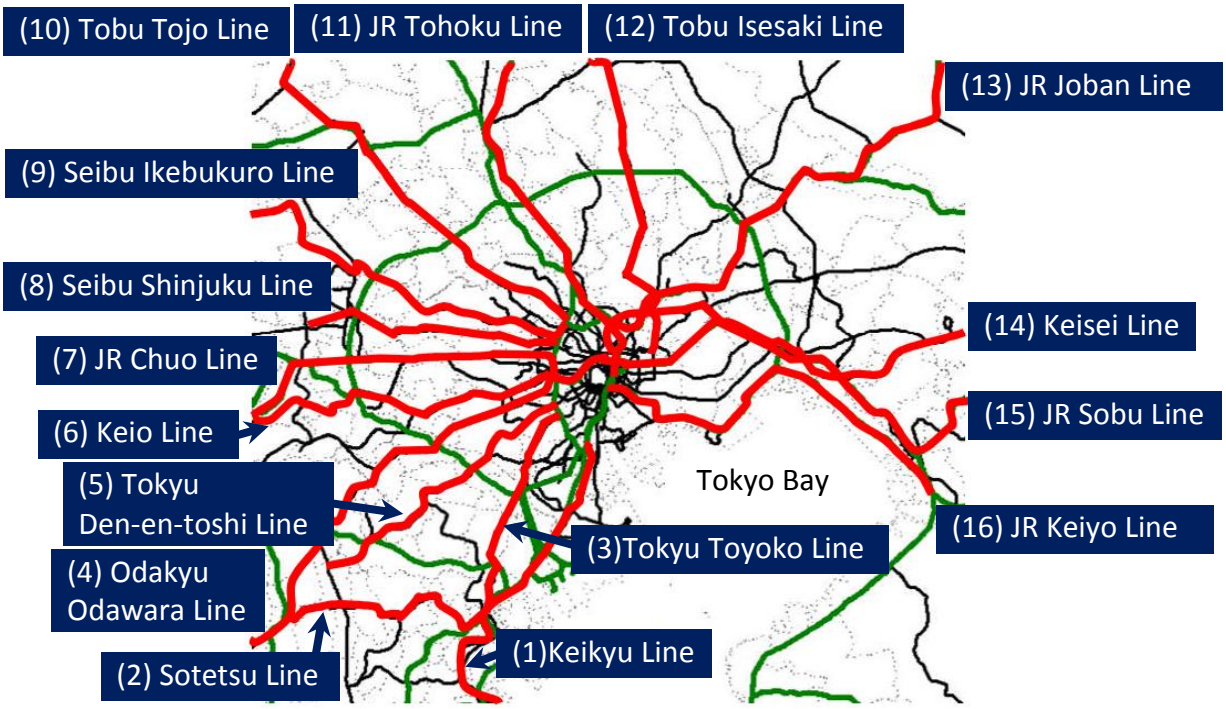

Figure 4 – Railway lines surveyed in this study

Trends of age structure along railway lines

Comparison focused on total population

Figure 5 shows the total population in 1995 and 2005 (as compared to 1980 = 100%) along each line. Trends of population fluctuation are different by line. In 1995, populations along the JR Chuo Line, the JR Tohoku Line and the Tokyu Toyoko Line were smaller than those in 1980. Along other lines (e.g. the Tobu Tojo Line, the Seibu Ikebukuro Line and the Tokyu Den-en-toshi Line) populations in 1995 were larger than those in 1980. In 2005, there were significant population increases along several lines such as the JR Keiyo Line (139% of that

in 1980) and the Tokyu Den-en-toshi Line (126% of that in 1980). Along the Tobu Isesaki Line and the Keikyu Line, on the other hand, total population was as much as that in 1980.

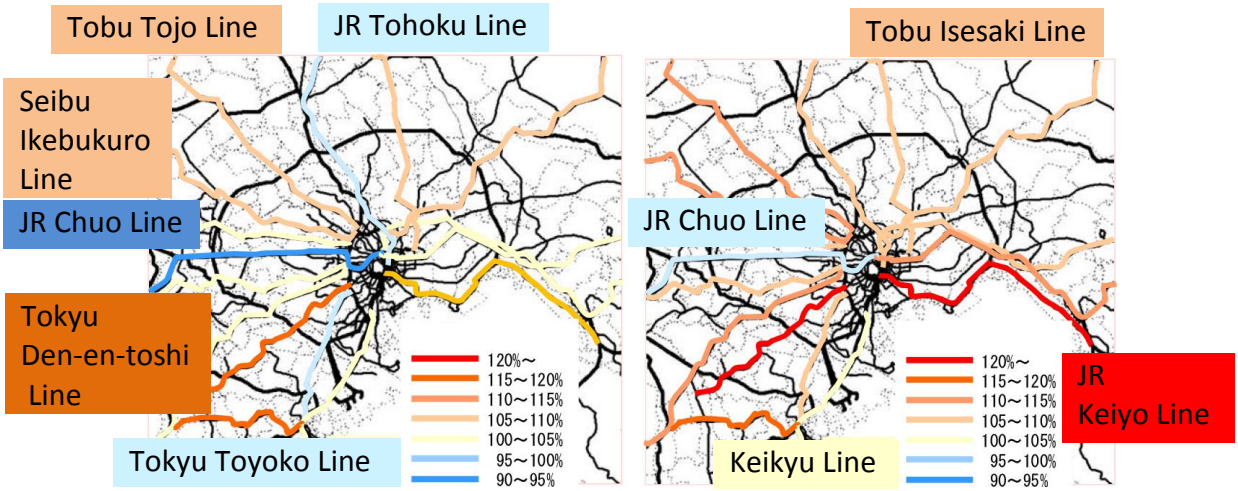

Figure 5 – Total population in 1995 and 2005 along each line (as compared to 1980 = 100%)

Comparison focused on age structure

Figure 6 shows the change in age structure along the Tokyu Den-en-toshi Line and the Tobu Isesaki Line. Along the Den-en-toshi Line the change in age structure is small. This is because young people have been flowing into this area and people in middle age have been flowing out continuously. Along the Isesaki Line, on the other hand, the figure of the graph remains unchanged but it has been sideslipping. This means that the number of people who flow in/out was small in this area. There were many people of 55-59 years in 2005, so now in the early 2010's this area is rapidly aging.

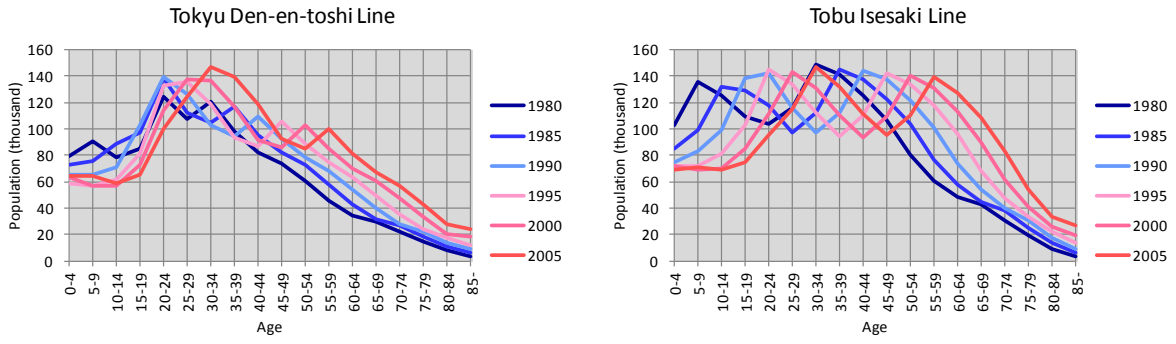

Figure 6 – Change in age structure along railway lines

Figure 7 shows the number of population fluctuation. The numbers of population increase or decrease of 15 to 44 year-olds along the Den-en-toshi Line are larger than those along the Isesaki Line. This fact results in the difference between the trends of age structure of two lines.

This means that population migration of 15 to 44 year-old residents has the greatest effect on population age structure.

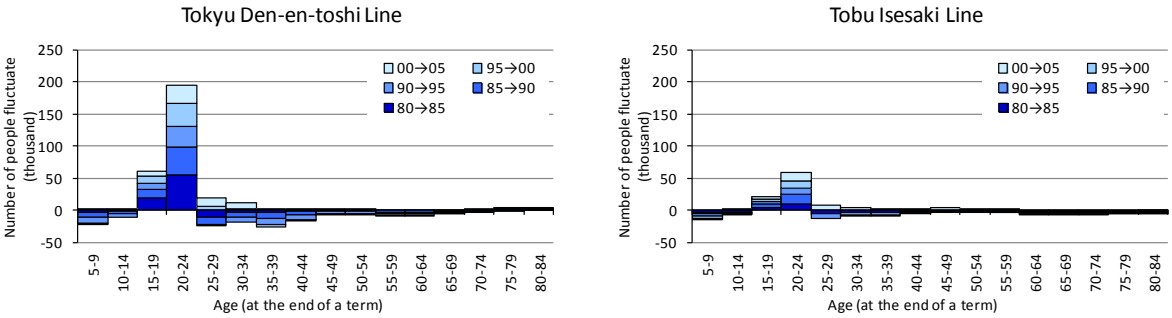

Figure 7 – Number of population fluctuation

Trends of age structure around each station on a line

Figure 8 and 9 show the number of population fluctuation tallied up by each station on the Tokyu Den-en-toshi Line and the Tobu Isesaki Line. The stations on the left edge of each graph, Shibuya and Asakusa, are the central terminal of each line. From 1980 to 1985, the population of 25-44 year-olds decreased near the central terminal on both lines. This is because some residential areas were rapidly developed into commercial areas there in those days. In suburban areas, on the other hand, population of each generation increased. On Den-en-toshi Line, population increase of 20-24 year-olds was more significant near the central terminal than in other areas. From 2000 to 2005, on Isesaki Line, population of each generation increased near the central terminal but there was small population fluctuation in suburban areas. On the Den-en-toshi Line, the same as from 1980 to 1985, population increase of 20-24 year-olds was more significant near the central terminal.

These facts show that the trends of population fluctuation differ by distance from the city center even along the same line. Therefore, it is useful to analyze the trends of age structure focusing on the distance from the central terminal as in this study.

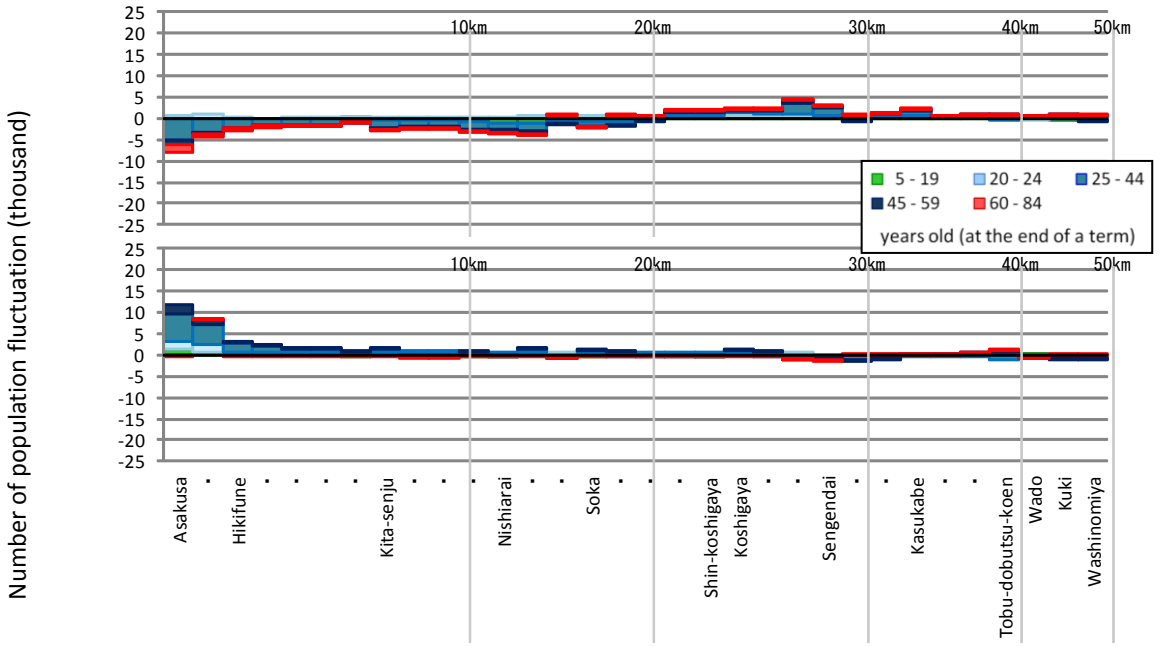

Figure 8 – Trends of population fluctuation around each station on Tobu Isesaki Line

(upper is from 1980 to 1985, lower is from 2000 to 2005)

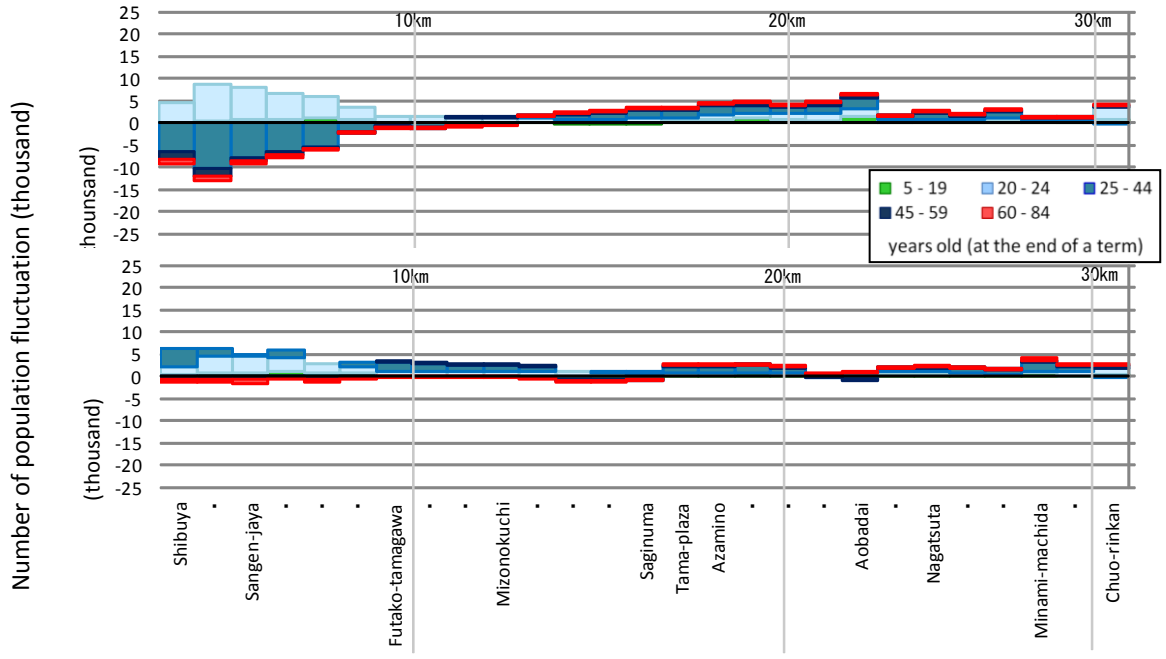

Figure 9 – Trends of population fluctuation around each station on Tokyu Den-en-toshi Line

(upper is from 1980 to 1985, lower is from 2000 to 2005)

TIME SERIES ANALYSIS OF AGE STRUCTURE OF THE CENTRAL TOKYO AREA

This section focuses on the 23 wards of Tokyo as the central Tokyo area. In this area 500m mesh data are available. So the analyses of this chapter are mainly based on 500m mesh data. Figure 10 shows the area of the 23 wards of Tokyo. This area has approx. 620 sq. km and is covered by about 2,600 500m meshes.

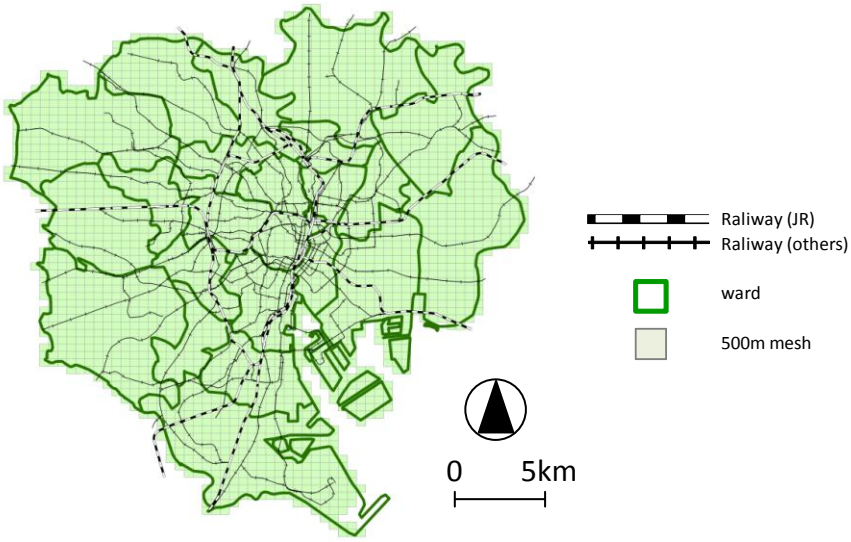

Figure 10 – The 23 wards of Tokyo

The change in age structure of the 23 wards of Tokyo

Figures 11 and 12 show population trends of each age group in the 23 wards of Tokyo. The total population reduced from 1980 to 1995 and increased again afterward. In 2010 there were 8,946,000 people living in this area.

The number of people of 25-44 years significantly increased. In 2010, there were 3,026,000 people. This is 27% increase from 1995. This increase rate is 14% in the Tokyo metropolitan area (Tokyo, Kanagawa, Saitama and Chiba) and 2% in Japan. In 2010, there were 1,805,000 elderly (65 and over) people. The aging rate was 20.2%. Though the major feature of the age structure of the 23 wards of Tokyo was a smaller number of children (14 and under) and a large number of elderly people compared with the Tokyo metropolitan area, this rapid increase of 25-44 population slowed the rising of the aging rate and the aging rate of Tokyo's 23 wards fell below that of the Tokyo metropolitan area.

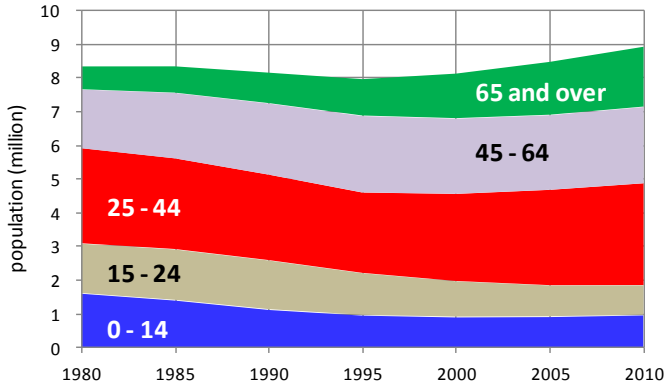

Figure 11 – Populations of age groups, the 23 wards of Tokyo

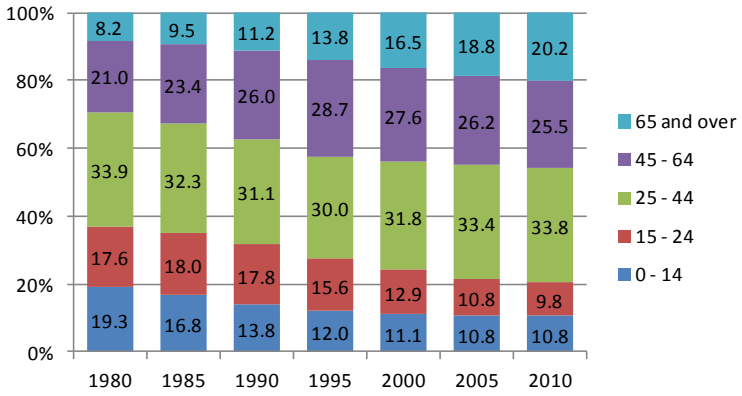

Figure 12 – Population rates of age groups, the 23 wards of Tokyo

Figure 13 shows the change in age structure of the 23 wards of Tokyo. This graph indicates that the change in age structure of this area is small like along the Tokyu Den-en-toshi Line.

Figure 13 – Change in age structure of the 23 wards of Tokyo

Figure 14 shows the population of each generation. For example, the dark blue line in the left graph shows that in the 23 wards of Tokyo, the population of the generation born in the

late 1940s was approximately 800,000 in 1980 (when they were in their early 30s) and approximately 600,000 in 2010 (when they were in their early 60s).

In the Tokyo metropolitan area, the number of each generation increased when they were in their early 20s and decreased when they were in their late 20's to 40's. In the 23 wards of Tokyo, this increase and decrease were more significant. This trend, however, has changed. Though the number of generations born before the late 1960s was at its peak when they were in early 20s, that of generations born after the early 1970s continued increasing even when they were late 20s. This change occurred in the late 1990s, when the reconcentration of residents started.

Thus, when reconcentration started, the population of several generations who were over 25 then turned into an increase, which resulted in a significant increase of number of 25-44 people.

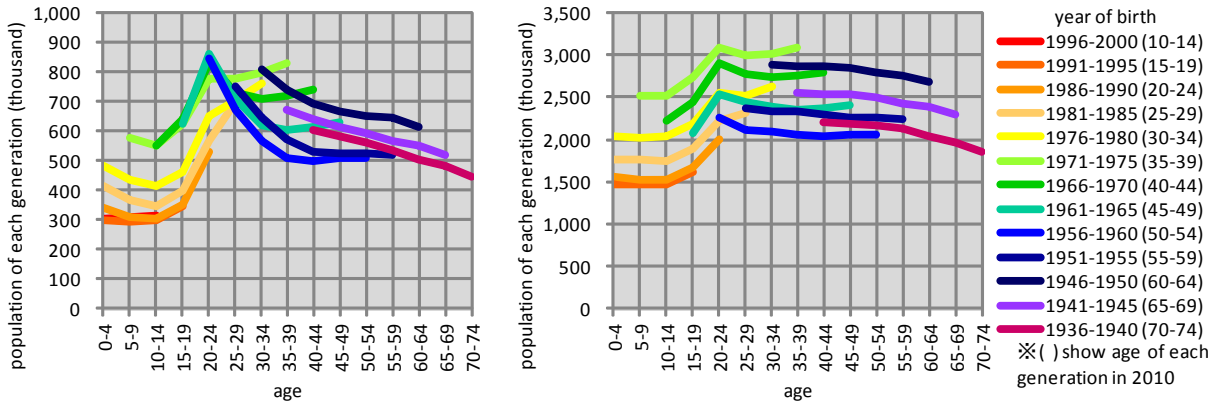

Figure 14 – Population of each generation

(the left is the 23 wards of Tokyo, the right is the Tokyo metropolitan area)

Various trends of age structure by areas

Figure 15 shows the aging rate of each 500m mesh. Aged areas are distributed mainly in the northeastern area. In the southwestern area, on the other hand, there are not so many aged areas. There is a special young area in the eastern littoral area.

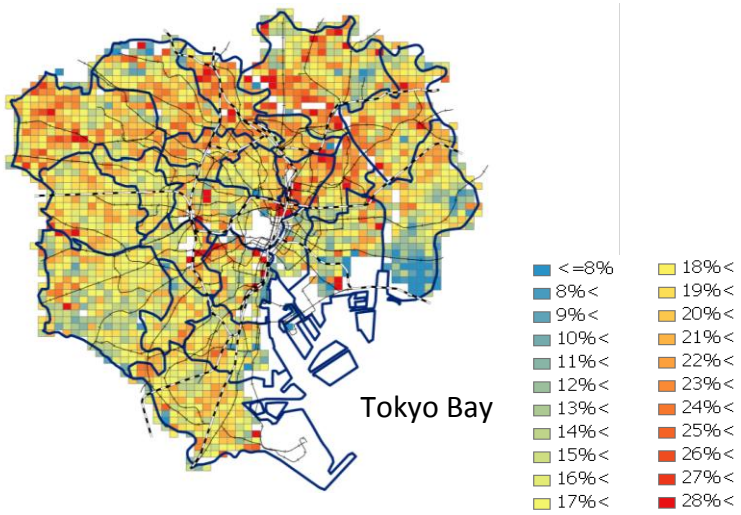

Figure 15 – Aging rate, 500m mesh, the 23 wards of Tokyo (2005)

Comparison of age structures of wards

In this section, the age structures of Nakano ward, Adachi ward and Chuo ward are compared. These wards have characteristic age structure. Figure 16 shows the location of the 3 wards.

As Figure 17 shows, age structure of Nakano ward remains unchanged. This is because the inflow of young people and outflow of middle-aged people are both large. This trend of aging is similar to that of the 23 wards of Tokyo and more significant than it. In Adachi ward, on the other hand, the figure of the graph has been sideslipping because of small people flow in/out. Last 15 years total population of Chuo ward doubled. The main cause of this is a large amount of flow-in of people in their thirties during the 2000s. This lowered the aging rate, and that of Chuo ward is now lower than that of any other ward.

Thus, in the central Tokyo area, aging trends are significantly different by area and mainly militated by the inflow/outflow of people in their twenties and thirties.

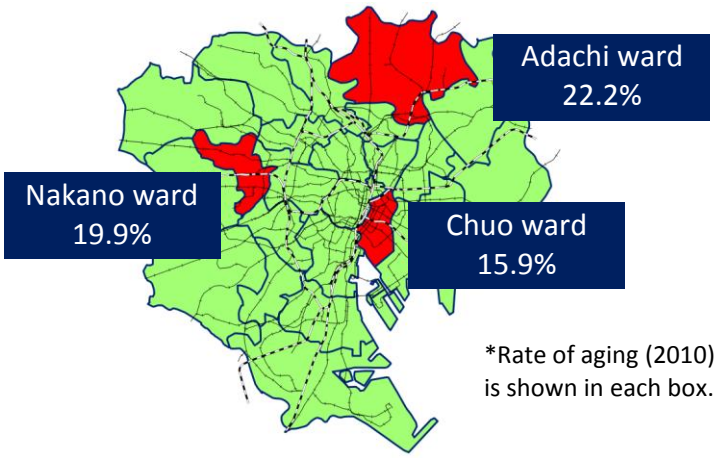

Figure 16 – Location of Nakano ward, Adachi ward and Chuo ward

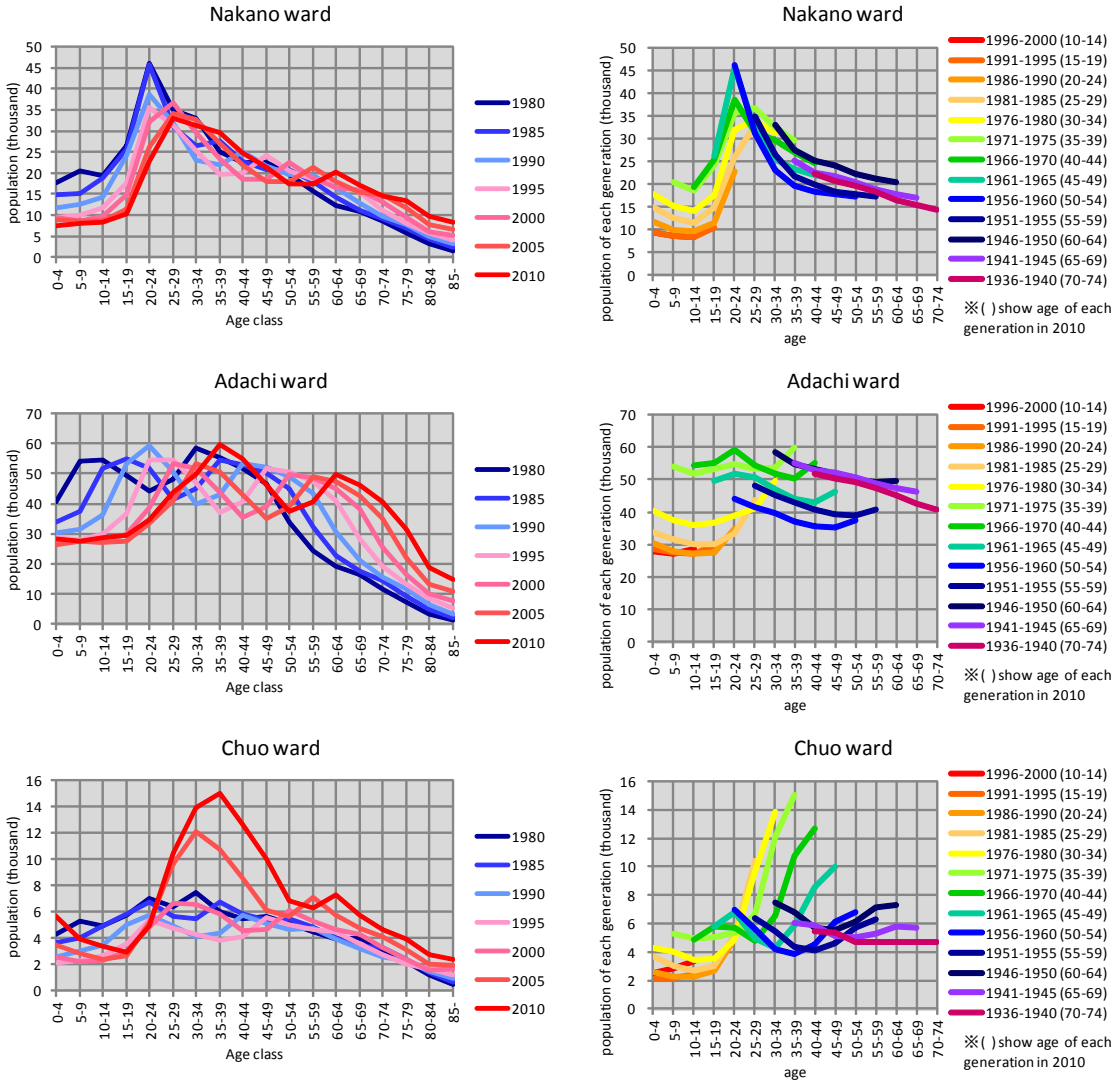

Figure 17 – Comparison of 3 wards with characteristic age structure

Comparison of population fluctuation of each age group

Figure 18 shows the variance and average rate of population fluctuation of each mesh. This indicates that the variance of the population fluctuation rate of residents 45 years old and over is smaller than those 44 and under. This means that migration of under-44-year-old residents has the greatest effect on population age structure.

It is thought that people actively change their residence for reasons shown in Figure 19 when they are at their 10's to 40's. This is consistent with the result of this section.

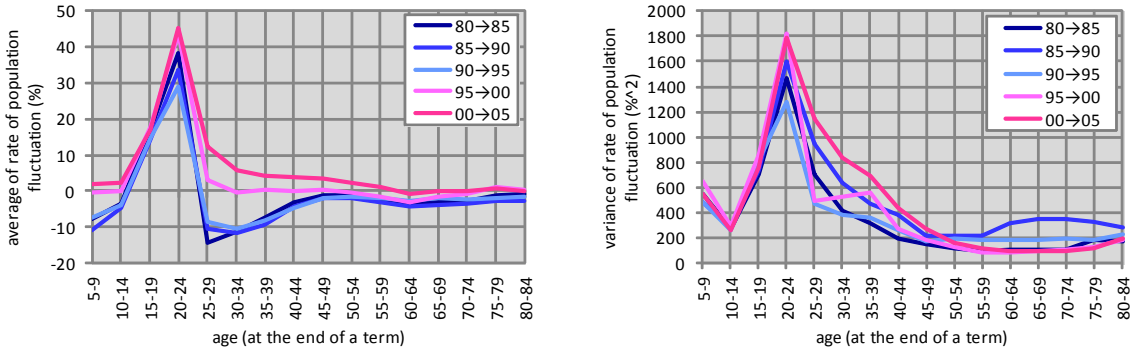

Figure 18 – Average and variance of rate of population fluctuation

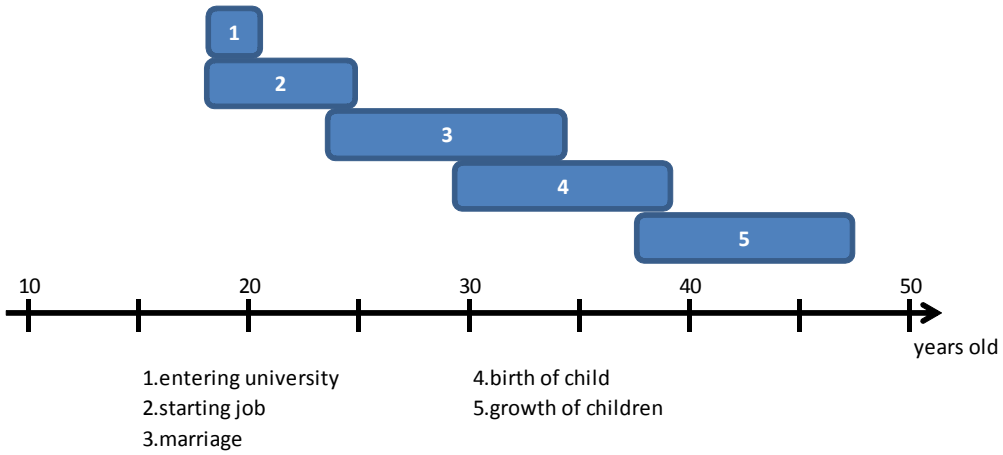

Figure 19 – Reasons and conceivable ages to change one's residence

Categorizing of areas focused on population fluctuation of 15-24 and 25-44

Previous sections show that population migration of 15- to 44-year-old residents is more active than that of other age groups and that inflow of 15-24 year old people and outflow of 25-44 year old people have a significant effect on population age structure. In this section, each mesh is categorized as one of four groups according to its rate of population fluctuation

of 15-24/25-44 year old residents (see Figure 20). This categorizing is based on 1km mesh because it is difficult to grasp the trends of areas when the categorizing is based on 500m mesh. This is because 500m meshes categorized as different groups are intermixed. Figure 21 shows the results (1980 to 1985 / 2000 to 2005). The color of each mesh indicates its category. Age structure tends to be stable in northern areas inside the JR Yamanote Loop Line and northwestern areas outside it because of significant influx of 15-24 year-olds and outflow of 25-44 year-old people. In eastern, northeastern and northwestern areas inflow and outflow are relatively small.

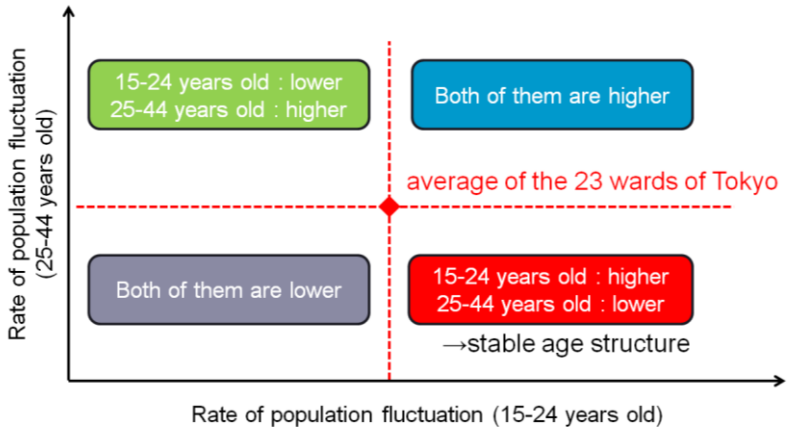

Figure 20 – Categorizing according to population fluctuation of 15-24 and 25-44

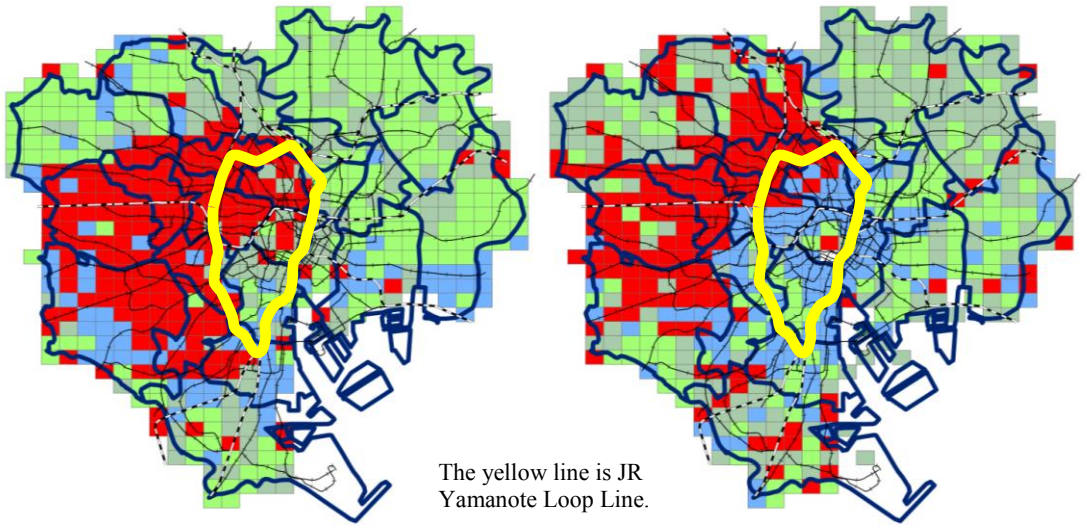

Figure 21 – The results of categorizing of areas

(the left is 1980 to 1985 and the right is 2000 to 2005)

Areas where a particular age group concentrates

The concentration of particular age group tends to result in rapid aging. This section points out the areas where rapid aging is expected because of it. Figure 22 shows population rate of 55-64/45-54 year-olds as of 2005. In northeast areas (e.g. along the Nippori-Toneri Liner, the Tobu Isesaki Line and the Tsukuba Express Line), the rate of 55-64 year-old people is higher than that of other areas. Considering the fact that people of 45 years and over migrate less actively, these areas are in rapid aging and number of passengers using stations on these lines is likely to decline now in the early 2010s. In several new town areas (e.g. Hikarigaoka and Shinagawa-Yashio Park Town), the rate of 45-54 year-old people is higher than that of other areas. These areas will be in rapid aging and number of passengers of lines that is near to these areas (e.g. the Toei Oedo Line) will decline by the early 2020s. Figure 23 shows the age structure of Shinagawa-Yashio Park Town. In this new town, where people started living in 1983, the population of the generation that was in their thirties (most likely to purchase their residence) at that time and their children are large. Decades later, as the grown-up children left home and remaining parents got older, the possibility of rapid aging increased.

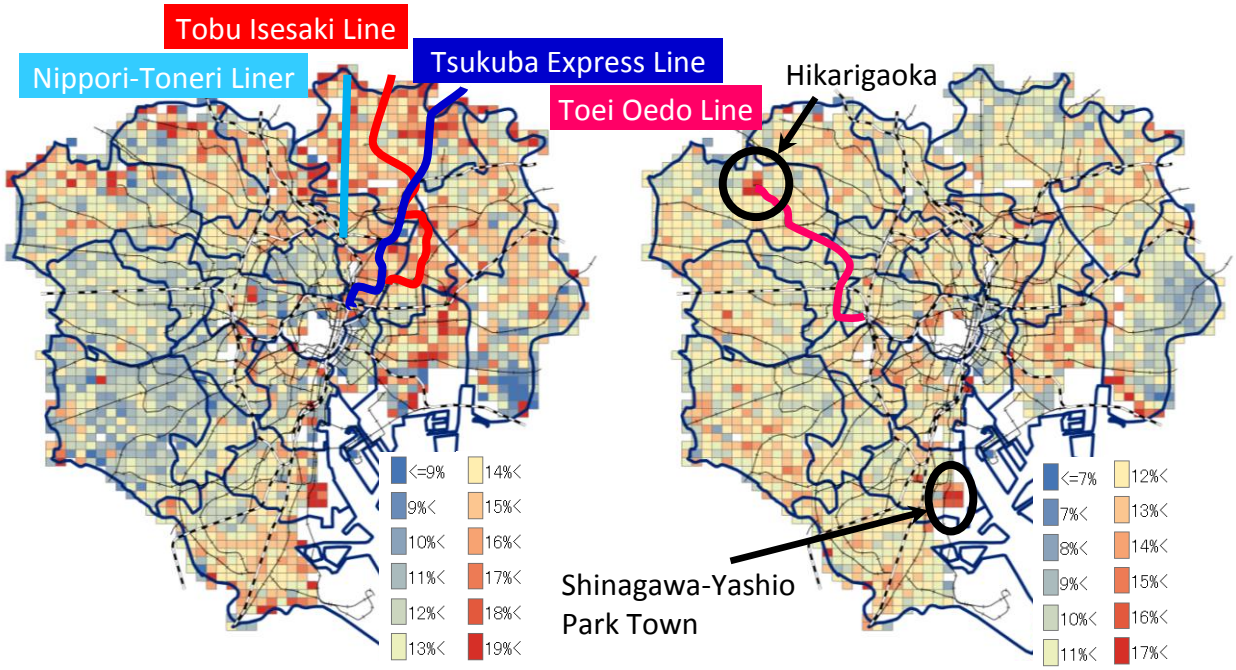

Figure 22 – Population rate of 55-64(left)/45-54(right) years old (2005)

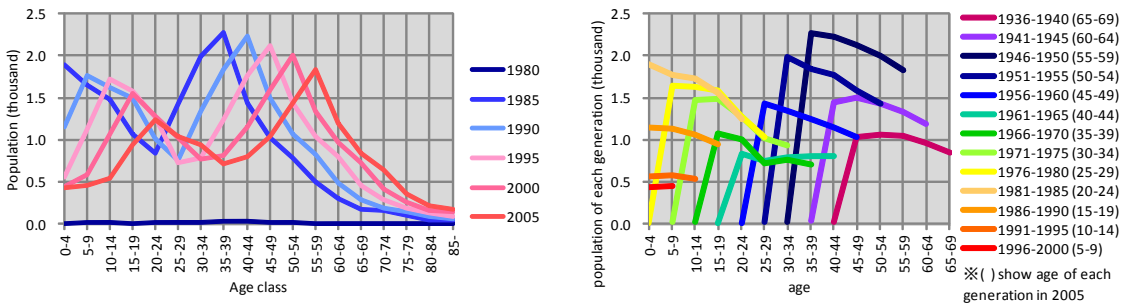

Figure 23 – Age structure of Shinagawa-Yashio Park Town

A suggestion of a perspective considering railway direct operation service

Previous sections dealt with each area along a railway line and the central Tokyo area separately. In the Tokyo metropolitan area, direct operation services are provided on many groups of railway lines. For example, the Tokyu Den-en-toshi Line and the Tobu Isesaki Line are actually connected by a direct operation service. These operations greatly contribute to the convenient railway network of Tokyo. Figure 23 shows trends of age structure around each station for sections on which a direct operation service is provided (Tobu Isesaki Line - Tokyo Metro Hanzomon Line - Tokyu Den-en-toshi Line). In the situation of an aging and depopulating society such as Tokyo, maintaining such convenient railway services is an important issue. When we deal with this issue from the point of view of age structure, it is also useful to regard the areas along all sections of lines on which a direct operation service is provided as a single area.

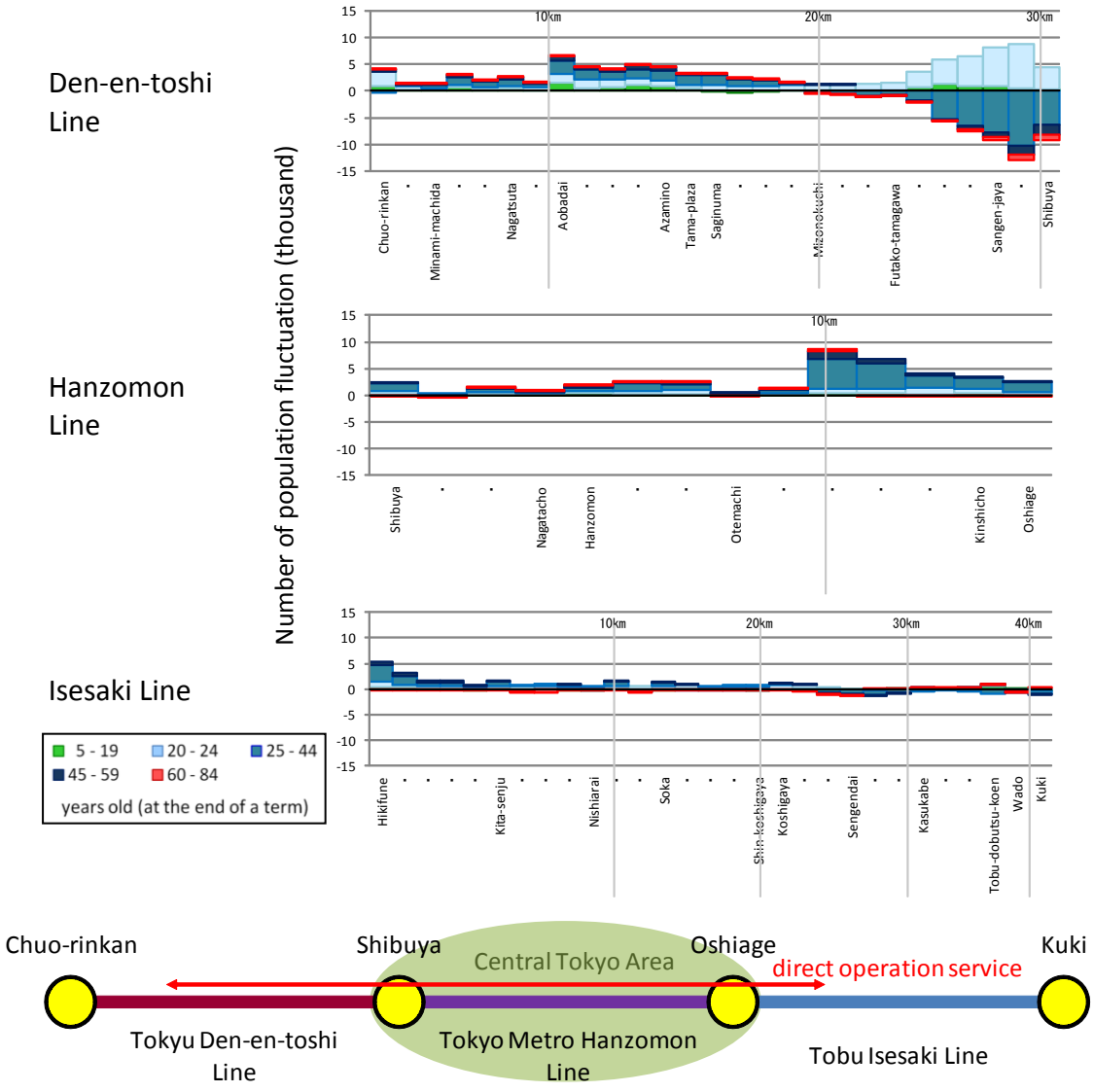

Figure 23 – Population fluctuation around each station on the section of direct operation service

CONCLUSIONS

This study analyzed the difference of trends of age structure inside the Tokyo metropolitan area focusing on railway lines in order to suggest new perspectives for sustainability of various services in depopulating and aging society. It found that the age structure along each line is significantly different. Trends of population migration in the vicinity of stations also differ by distance from the city center even along the same line. In central areas, the variance of the population fluctuation rate of residents 45 years old and over is smaller than that of those 44 and under. The population migration of 44 years old and under primarily affects the population age structure. Age structure tends to be stable in northern areas inside the JR Yamanote Loop Line and northwestern areas outside it because of significant influx of 15-24 year-olds and outflow of 25-44 year-old people.

In planning urban development strategies, it is important to understand the diversity of age structure, as illustrated in this study. Planning a comprehensive residence policy that targets residents who are 44 years of age and under, that is, aiming to develop an attractive area for them on the model of areas into which young people continuously flow, is most effective in avoiding an excessively aging in particular areas. This policy also should mainly target areas where convenient public transportation services are available because it is appropriate for resident areas to be concentrated along public transportation corridors in depopulating society.

For urban planning and railway planning in depopulating and aging society, the results of this study shows the important focus points.

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