

# ROXY-index Analysis of Urbanization and Suburbanization in 1947-95: For the Railway-line Regions of the Three Largest Metropolitan Areas in Japan

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## ABSTRACT

This paper analyzes the intra-metropolitan urbanization and suburbanization processes, during the period between 1947 and 1995, for various railway-line regions in each of the three largest metropolitan areas of Japan (*i.e.*, Tokyo, Osaka and Nagoya). Through this investigation of the spatial redistribution patterns of population by means of the spatial-cycle concept and the ROXY-index method, we have found that the Klaassen spatial-cycle hypothesis seems to be working reasonably well in its description of the intra-metropolitan spatial shifts in the process of urbanization, suburbanization, and possible revived-urbanization within the three largest metropolitan areas in Japan. We have also found that some basic characteristics of the urban demographic dynamism for the three metropolitan areas in Japan are as follows: (1) For the Osaka Metropolitan area, all of the railway-line regions have followed almost the same spatial-cycle paths as all of those in the Tokyo metropolitan area with approximately a ten year delay until the period 1990-95 (with the one exception of the Sanyo-line region), while for the Nagoya Metropolitan area, all of the railway-line regions have followed almost the same spatial-cycle paths as all of those in the Tokyo metropolitan area with approximately a fifteen year delay until the period 1990-95. (2) Since the railway-line regions in the Tokyo metropolitan area seem likely to arrive at the stage of accelerating urbanization before too long, there is a high possibility that the railway-line regions in the Osaka metropolitan area will also reach the stage of accelerating urbanization with approximately a ten year delay, while the Nagoya metropolitan area will also reach the same stage with approximately a fifteen year delay as compared with the railway-line regions in the Tokyo metropolitan area.

## 1 Introduction

This paper analyzes the intra-metropolitan urbanization and suburbanization processes, during the period between 1947 and 1995, for various railway-line regions in each of the three largest metropolitan areas of Japan (Tokyo, Osaka and Nagoya).

In what follows, in Section 2 we first briefly discuss urbanization economies which are closely associated with the phenomena of intra-metropolitan spatial cycles. In Section 3, we explain the basic framework of our analytical approach, while in Section 4 we identify the paths of the spatial cycles for the

railway-line regions by applying the ROXY-index method. In the concluding section, we discuss some of the policy implications that can be derived from the research outcomes obtained in Section 4. We also discuss in the same section the application potential of our analytical approach.

## 2 Urbanization Economies

Agglomeration economies and diseconomies<sup>1)</sup> seem to play substantial roles, especially in the form of urbanization economies<sup>2)</sup>, in the spatial dynamic process of urbanization and suburbanization. Urbanization economies are, concisely speaking, economic benefits emerging from a sizeable urban entity in which a large variety of economic units congregate rather densely, and are usually considered as falling within one of the major categories of the external agglomeration economies<sup>3)</sup>. Namely, as described in Kawashima (1971), "urbanization economies stem from a large-scale spatial juxtaposition of unlike economic units, and are strongly related to the higher level of use of the general apparatuses of urban structure itself", where the general urban features include the transportation and communication infrastructure, public utility systems, and medical, welfare, educational and cultural facilities.

Theoretically, the process of urbanization rather than suburbanization generally continues when the urbanization economy exceeds the urbanization diseconomies, and vice versa<sup>4)</sup>. In the light of this, the population fluctuation in a given metropolitan area recognized through the intra-metropolitan spatial-cycle phenomena would largely correspond to the alternation of the relative dominance in magnitude between the urbanization economies and diseconomies over a reasonably long time-span.

The determinants of the alternation of urbanization and suburbanization are, as a matter of fact, many and intricate<sup>5)</sup>. And consequently, so are those of the spatial cycles. In this connection, we should not discount, under any circumstance, the importance of efforts to find causes for those spatial cycles. It is, however, also necessary for us to illustrate more concretely the spatial-cycle phenomena themselves to provide more proper guidance for finding the basic factors which cause spatial cycles. This is the position of this paper.

## 3 Approach and Data

For our analytical framework we employ (1), as a theoretical scheme, the spatial-cycle hypothesis originally conceived by Klaassen and others<sup>6)</sup>, and (2), as a methodological instrument, the ROXY-index approach originally conceived and empirically applied by Kawashima<sup>7)</sup>.

According to the Klaassen spatial-cycle hypothesis, the intra-metropolitan spatial redistribution process of population traces the recurrently transmuting successive stages. They are four stages<sup>8)</sup> as shown in column B of Table 1: ① accelerating urbanization, ② decelerating urbanization, ③ accelerating suburbanization and ④ decelerating suburbanization.

On the other hand, the ROXY-index is defined as shown by Table 2 based on "the ratio of the weighted average of the growth ratio to the simple average of the growth ratio". For this index which is used to identify the spatial-cycle path<sup>9)</sup>, Table 3 is constructed to show the relationship among ①the sign of the ROXY-index value, ②the pattern of the spatial redistribution process of population ③the direction of the

changes in the ROXY-index value, and ④the speed of the spatial redistribution process of population.

Regarding the spatial units whose data we use in this paper, we examine one hundred and thirty-seven (137) localities in the three largest metropolitan areas. They compose the fifteen (15) major railway-line regions as listed in Table 4. In this table, each locality is accompanied by information saying whether it is located in the core area or suburbs of the metropolitan area<sup>10)</sup>.

Each of the member localities of the above 15 railway-line regions whose geographical locations are represented in Figures 1, satisfy the following two conditions;

- (1) the locality is situated within the boundary of the 1995-version of the Tokyo or Osaka or Nagoya functional urban regions (FURs<sup>11)</sup>) which are considered as metropolitan areas;
- (2) the locality is traversed, however minimally, by one of the 15 railway-lines.

For those localities, we employ the national census figures for the population from 1947 through 1995 for the calculation of the ROXY-index values<sup>12)</sup>.

## 4 Empirical Analysis

Table 5 provides us with the calculated ROXY-index values for the total population for each of the ten five-year periods of 1947-50, 1950-55, 1955-60, 1960-65, 1965-70, 1970-75, 1975-80, 1980-85, 1985-90 and 1990-95. From this table, we can draw Figures 2, 3 and 4, which show the circular-cyclic paths for the fifteen railway-line regions.

We have in these figures the ROXY-index value along the abscissa axis that extends its positive direction to the left, while we have the marginal value<sup>13)</sup> of the ROXY index along the ordinate axis. Note that each quadrant corresponds to the following spatial-cycle stages:

- ⊙ Accelerating urbanization stage ( first-half stage of urbanization): Second quadrant
- ⊙ Decelerating urbanization stage (second-half stage of urbanization): Third quadrant
- ⊙ Accelerating suburbanization stage (first-half stage of suburbanization): Fourth quadrant
- ⊙ Decelerating suburbanization stage (second-half stage of suburbanization): First quadrant

### 4-1 Tokyo Metropolitan Area

Based on Figures 2 and Table 2, which shows diagrammatically all the spatial-cycle paths for the five railway-line regions on the same graph for the 1947-95 period, the following can be summarized about the urbanization and suburbanization process of the five railway-line regions as a bundle in the Tokyo metropolitan area.

- (1) For all of the railway-line regions, before the period 1960-65, the urbanization stages were already complete.
- (2) For all of the railway-line regions, in the middle of the 1970's, the spatial-cycle paths entered the stage of decelerating suburbanization from the stage of accelerating suburbanization.
- (3) For all of the railway-line regions, in the middle of the 1990's, the suburbanization stages seemed gradually to have approached these ends and, in consequence, the revived-urbanization stages appear to have arrived relatively soon.

Meanwhile, on the basis of the same figure, the spatial-cycle stages for the five railway-line regions can be described as follows in terms of the "race along the spatial cycle path (*i.e.*, spatial-cycle race)."

- (1) In the spatial-cycle race of the late 1940s, the Chuo-line region (whose position was then at the second-half stage of decelerating urbanization) was leading the race, followed by a slight margin by the Takasaki-line region (at the second-half stage of decelerating suburbanization), and then by the Joban-line region (at the second-half stage of decelerating suburbanization), the Sobu-line region (at the second-half stage of decelerating suburbanization), the Tokaido-line region (at the first-half stage of decelerating suburbanization), in this order.
- (2) In the spatial-cycle race of the late 1960s, the Chuo-line region (which was then at the first-half stage of decelerating suburbanization) was leading the race, followed by the Tokaido-line region (at the first-half stage of decelerating suburbanization), and then the Takasaki-line region (at the first-half stage of decelerating suburbanization), the Sobu-line region (at the second-half stage of accelerating suburbanization), the Joban-line region (at the second-half stage of accelerating suburbanization), in this order.
- (3) In the spatial-cycle race of the early 1990s, the Sobu-line region (whose position was then at the second-half stage of decelerating suburbanization) was leading the race, followed by the Tokaido-line region (at the second-half stage of decelerating suburbanization), the Joban-line region (at the second-half stage of decelerating suburbanization), the Chuo-line region (at the second-half stage of decelerating suburbanization), the Takasaki-line region (at the first-half stage of decelerating suburbanization), in this order.

These results demonstrate that, among the five railway-line regions, the Chuo-line region was almost continuously at the advanced stage along the spatial-cycle path until the early 1970s, then the relative order in the spatial-cycle race between the Chuo-line region and the Tokaido-line region was reversed in about the middle of the 1970s, and that the Sobu-line region, which was last in the 1947-90 period, reached the most advanced position in the 1990-95 period.

#### 4-2 Osaka Metropolitan Area

Based on Figure 3, the following six points summarize the information from the changes in the value of the ROXY-index as to the urbanization and suburbanization process of the six railway-line regions in the Osaka metropolitan area.

- (1) In all of the railway-line regions, before the period 1960-65, the urbanization stages were already completed.
- (2) In all of the railway-line regions, in the middle of the 1970's, the spatial-cycle paths reached the stages of decelerating suburbanization from the stages of accelerating suburbanization.
- (3) In the middle of the 1990's, the Sanyo-line region entered the revived-urbanization stage.
- (4) In the middle of the 1990, the Tokaido-line and the Kintetsu-line regions were gradually approaching

the process ends and, in consequence of that, the revived-urbanization stages seems likely to arrive relatively soon.

- (5) In the middle of the 1990's, the Kansai-line region was gradually approaching the end of the process and, in consequence of that, the accelerating suburbanization stage seems likely to arrive relatively soon too.
- (6) In the middle of the 1990's, the Keihan-line and the Hanwa-line regions entered the accelerating suburbanization stage too.

In the meantime, on the basis of the same figure, the spatial-cycle races among the six railway-line regions are stated as follows.

- (1) In the spatial-cycle race of the late 1940s, the Sanyo-line region (whose position was then at the first-half stage of decelerating urbanization) was leading the race, followed by a slight margin by the Hanwa-line region (at the first-half stage of decelerating suburbanization), and then by the Keihan-line region (at the first-half stage of decelerating suburbanization), the Tokaido-line region (at the first-half stage of decelerating suburbanization), the Kintetsu-line region (at the first-half stage of decelerating suburbanization) and the Kansai-line region (at the first-half stage of decelerating suburbanization), in this order.
- (2) In the spatial-cycle race of the late 1960s, the Sanyo-line region (whose position was then at the first-half stage of decelerating suburbanization) was leading the race, followed by the Tokaido-line region (at the first-half stage of decelerating suburbanization), and then the Keihan-line region (at the first-half stage of decelerating suburbanization), the Kansai-line region (at the second-half stage of accelerating suburbanization), the Hanwa-line region (at the second-half stage of accelerating suburbanization), the Kintetsu-line region (at the second-half stage of accelerating suburbanization), in this order.
- (3) In the spatial-cycle race of the early 1995s, the Sanyo-line region (whose position was then at the first-half stage of accelerating urbanization (*i.e.*, revived-urbanization) was leading the race, followed by the Tokaido-line region (at the second-half stage of decelerating suburbanization), the Kintetsu-line region (at the second-half stage of decelerating suburbanization), the Keihan-line region (at the second-half stage of accelerating suburbanization), the Kansai-line region (at the first-half stage of decelerating suburbanization), the Hanwa-line region (at the second-half stage of accelerating suburbanization), in this order.

These results demonstrate that, among the six railway-line regions, the Sanyo-line region was almost continuously at the most advanced stage along the spatial-cycle path throughout the whole period.

#### 4-3 Nagoya Metropolitan Area

Based on Figure 4, the following five points summarize the characteristics of the changes in the value of the ROXY-index about the urbanization and suburbanization process of the four railway-line regions in the Nagoya metropolitan area.

- (1) In the period of 1947-50, the Kansai-line region and Chuo-line region still remained at the stages of accelerating urbanization.
- (2) In all of the railway-line regions, before the period 1960-65, the urbanization stages were already complete.
- (3) In all of the railway-line regions, in the middle of the 1970's, all the spatial-cycle paths reached the stage of decelerating suburbanization from the stages of accelerating suburbanization almost simultaneously.
- (4) In the middle of the 1980's, the Tokaido-line region entered the decelerating urbanization stage instead of entering the accelerating urbanization stage.
- (5) In the middle of the 1990's, all of the spatial-cycle paths reached the stage of accelerating suburbanization again.

On the other hand, by referring to Figure 4, progress in the spatial-cycle races among the four railway-line regions can be stated as follows.

- (1) In the spatial-cycle race of the late 1940s, the Tokaido-line region (whose position was then at the first-half stage of decelerating urbanization) was leading the race, followed by the Taketomi-line region (at the first-half stage of decelerating urbanization), and then by the Chuo-line region (at the second-half stage of accelerating urbanization), the Kansai-line region (at the second-half stage of accelerating urbanization), in this order.
- (2) In the spatial-cycle race of the late 1960s, the Chuo-line region (whose position was then at the second-half stage of accelerating suburbanization) was leading the race, followed by the Taketomi-line region (at the first-half stage of accelerating suburbanization), and then the Kansai-line region (at the first-half stage of accelerating suburbanization), the Tokaido-line region (at the first-half stage of accelerating suburbanization), in this order.
- (3) In the spatial-cycle race of the early 1995s, the Taketomi-line region (whose position was then at the second-half stage of accelerating suburbanization) was leading the race, followed by the Chuo-line region (at the second-half stage of accelerating suburbanization), the Kansai-line region (at the second-half stage of accelerating suburbanization), the Tokaido-line region (at the first-half stage of accelerating suburbanization), in this order.

## 5 Conclusion

Through the investigation of the spatial redistribution patterns of population by means of the spatial-cycle concept and the ROXY-index method, we have tried in the present study to find some basic characteristics of the urban demographic dynamics for the three largest metropolitan areas in Japan. We have discovered in some detail the following three characteristics in the ROXY-index path for each of the metropolitan areas.

- (1) For the Tokyo Metropolitan area, all of the railway-line regions in the spatial-cycle path are approaching the end of the decelerating suburbanization stage and are likely to go into the first phase

of accelerating urbanization (which we call "revived-urbanization" as mentioned in Table 2), in fact all at the same rate.

- (2) For the Osaka Metropolitan area, all of the railway-line regions in the spatial-cycle path seem to have followed the paths of all those in the Tokyo metropolitan area but are approximately ten years behind for the period 1990-95 (with the one exception of the Sanyo-line region). Since the regions in the Tokyo metropolitan area will, as mentioned above, presumably go into the stage of accelerating urbanization before too long, there is a high possibility that the regions in the Osaka metropolitan area will also arrive at the stage of accelerating urbanization with about a ten year time-lag after the regions in the Tokyo metropolitan area.
- (3) For the Nagoya metropolitan area, all of the railway-line regions in the spatial-cycle path have re-entered the accelerating suburbanization from the decelerating suburbanization, thus all of them are developing at the same rate. This phenomenon also can be seen in the spatial-cycle path of the Tokaido-line region, the Chuo-line region and the Takasaki-line region in the Tokyo metropolitan area and the Keihan-line region and Hanwa-line region in the Osaka metropolitan area. This may imply that all of the railway-line regions in the spatial-cycle path in the Nagoya metropolitan area seem to have followed the same sort of paths as all those in the Tokyo metropolitan area but are approximately fifteen years behind and the Osaka metropolitan area approximately five years behind for the period 1990-95. Since the railway-line regions in the Tokyo metropolitan area will, as mentioned above, presumably go into the stage of accelerating urbanization before too long, there is a high possibility that the railway-line regions in the Nagoya metropolitan area will also arrive at the stage of accelerating urbanization with about a fifteen year time-lag after the regions in the Tokyo metropolitan area.

The above findings would provide us with policy implications that the necessity for urban investment, for example, the investment for the metropolitan new transportation scheme such as the liner-mortar type Light Rail Transit (LRT)<sup>14)</sup>, and that the substantial ecotones such as improved ditches and waterways to materialize the higher-level of urban amenity, is increasing significantly to support urban agglomeration economies and at the same time to alleviate urban agglomeration diseconomies in the inner area of the Tokyo, Osaka and Nagoya FURs for the forthcoming urbanization stage of the fifteen railway-line regions which will appear in the near future. This implies a priority for urban investment in the railway-line regions that will arrive at the stage of accelerating urbanization relatively sooner.

In conclusion, we have learned that the Klaassen spatial-cycle hypothesis seems to work reasonably well in its description of the intra-metropolitan spatial shifts in the process of urbanization, suburbanization and possible revived-urbanization within the three largest metropolitan areas in Japan.

At the same time, the ROXY-index method appears to be a useful analytical instrument for obtaining a deeper insight into the fundamental characteristics of the urban dynamism of the intra-metropolitan spatial redistribution processes of population.

It should, though, always be borne in mind that the ROXY-index approach is one of many possible methods applicable to spatial redistribution analysis and that there is yet room for future improvement in the ROXY-index approach.

## Notes

- 1) Agglomeration economies are usually categorized into three major groups each with different economics implications: scale economies within a firm, localization economies, and urbanization economies, though these categories are not necessarily mutually exclusive and collectively exhaustive. See, for more detailed discussion on agglomeration economies, Kawashima (1975), Goldstein and Gronberg (1984), Nakamura (1985), Tabuchi (1986), Abdel-Rahman (1990), Mills and Hamilton (1994) and Eberts and McMillan (1999).
- 2) The negative urbanization economies can be regarded as urbanization diseconomies.
- 3) For the concept of comprehensive review of urban external economies, see Kanemoto (1980).
- 4) In the context of optimum urban size, the optimization corresponds to the case when the marginal urbanization economies are equal to the marginal urbanization diseconomies.
- 5) Among probable determinants are business cycles whose representative types are shown in the following table as originally arranged by and reconstructed from Kosaka (1995).

<b>Cycles</b>	<b>Period (years)</b>	<b>Causes</b>	<b>Theories</b>
Kondratief cycle	50	Innovation or War	J.Schumpeter R.M. Goodwin
Kuznets cycle	20	Construction	P.Samuelson
Juglar cycle	7-10	Fixed investment	J.R.Hicks R.M. Goodwin
Kitchin cycle	3-4	Inventory investment	L.A.Metzler A.Medio

- 6) See for the details of the basic original framework of the spatial-cycle hypothesis, Klaassen and Paelinck (1979) and Klaassen *et al.* (1981).
- 7) Kawashima has written about thirty papers on the ROXY index through which he has developed a series of generalized versions of the Klaassen original spatial-cycle hypothesis to facilitate research works, for both intra-metropolitan and inter-metropolitan analyses. For some of them, see the reference to Fukatsu and Kawashima (1999).
- 8) We have two other kinds of spatial-cycle paradigms in Table 1: one with two stages and the other with eight stages, in columns A and C respectively. Meanwhile, as mentioned in the note (1) of this table, the stage of urbanization in its second or further rounds is referred to as *revived-urbanization* to emphasize the re-entry into the stages of urbanization.
- 9) The spatial-cycle path is the locus of the spatial-cycle stages.
- 10) The following localities are classified in the core area: ① localities belonging to the Tokyo special district of the Tokyo metropolitan area, ② Osaka-shi, Moriguchi-shi, Kadoma-shi and Higashiosaka-shi of the Osaka metropolitan area, and ③ Nagoya-shi of the Nagoya metropolitan area. Other locality areas are categorized by suburbs.
- 11) See Fukatsu (1999) and Fukatsu and Kawashima (1999) for the discussion on FURs as well as on the work for defining the FURs of Japan.
- 12) For the period between 1947 and 1995, the population census in Japan was conducted eleven times; in the years 1947, 1950, 1955, 1960, 1965, 1970, 1975, 1980, 1985, 1990 and 1995.
- 13) The marginal value of the ROXY index defined here is calculated following these steps:
  - ① For the periods 1947-50 and 90-95: the difference between " the value of the ROXY index for the associated



period " and " the value of the ROXY index for its adjacent period."

- ② For other periods: the difference between the values of the ROXY index for the two periods, both of which are adjacent to the assigned period.

14) For reference, the counterpart concept of the LRT is the Heavy Rail Transit (HRT).

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Table 1 Recurrently Transmuting Stages in Spatial-cycle Paradigm : for Study of Intra-metropolitan Analysis

A	B		C
Two stages	Four stages		Eight stages
Urbanization	B-1	Accelerating urbanization	First half of accelerating urbanization Second half of accelerating urbanization
	B-2	Decelerating urbanization	First half of decelerating urbanization Second half of decelerating urbanization
Suburbanization	B-3	Accelerating suburbanization	First half of accelerating suburbanization Second half of accelerating suburbanization
	B-4	Decelerating suburbanization	First half of decelerating suburbanization Second half of decelerating suburbanization

[Note]

- (1) The stage of urbanization is called the stage of revived-urbanization when the spatial-cycle path arrives at the stage of urbanization on its second or further round, in order to highlight the phenomena of the re-entry of the spatial-cycle path into the stage of urbanization.
- (2) In the original Klaassen framework, the following terms are used to describe the four major stages represented in the column B; re-urbanization (for B-1), urbanization (for B-2), suburbanization (for B-3) and counter-urbanization (for B-4).

[Source] Fukatsu and Kawashima (1999) from which this table is constructed

Table 2 Definition of ROXY Index for Intra-metropolitan Analysis of Spatial Redistribution Process of Population

$$RI(t, t+1) = (WAGR_{t,t+1} / SAGR_{t,t+1} - 1.0) \times 10^4$$

where

$RI(t, t+1)$  : Value of ROXY index for the period between years  $t$  and  $t+1$   
(calculated on the annual growth-ratio basis)

$WAGR_{t,t+1}$  : Weighted average of the annual growth ratios of population, for the period between years  $t$  and  $t+1$   
over  $n$  subareas composing the metropolitan area being investigated, which is equal to

$$\frac{\sum_{i=1}^n (w_i^t \times r_i^{t,t+1})}{\sum_{i=1}^n w_i^t}$$

$SAGR_{t,t+1}$  : Simple average of the annual growth ratios of population, for the period between years  $t$  and  $t+1$   
over  $n$  subareas composing the metropolitan area being investigated, which is equal to

$$\frac{\sum_{i=1}^n r_i^{t,t+1}}{n}$$

$x_i^t$  : Population of subarea  $i$  of the metropolitan area in year  $t$   
(In our analysis the metropolitan area has two subareas;  $i = 1$  for its core region and  $i = 2$  for its suburbs.)

$n$  : Number of subareas composing the metropolitan area ( $n = 2$  in our analysis)

$r_i^{t,t+1}$  : Annual growth ratio of population of subarea  $i$  for the period between years  $t$  and  $t+1$ ,  
which is defined as the  $k$ -th root of

$$x_i^{t+k} / x_i^t = r_i^{t,t+k}$$

$w_i^t$  : Weighting factor for subarea  $i$  in year  $t$

(We set in our analysis that  $w_1^t = 1$  for  $i = 1$  and  $w_2^t = 0$  for  $i = 2$  regardless of the value of  $t$ .)

[Source] Rearranged based on Fukatsu (1999).

Table 3 Implications of ROXY-index Values for Intra-metropolitan Analysis of Spatial Redistribution Process of Population

A	B	C	D
Sign of ROXY-index value	Pattern of spatial redistribution process of population within a metropolitan area	Direction of changes in ROXY-index values	Speed of spatial redistribution process of population within a metropolitan area
Positive	Urbanization (or Revived-Urbanization)	Increasing	Accelerating
		Levelling-off	Stationary
		Decreasing	Decelerating
Zero	Neutrality from both urbanization and suburbanization	Levelling-off	Continuation of neutrality
Negative	Suburbanization	Decreasing	Accelerating
		Levelling-off	Stationary
		Increasing	Decelerating

[Source] Reconstructed from Kawashima and Hiraoka (1993)

Table 4 Localities for Fifteen Railway-line Regions in the Three Largest Metropolitan Areas in Japan

(a) Tokyo Metropolitan Area

① Tokaido-line	Location	② Chuo-line	Location	③ Takasaki-line	Location	④ Joban-line	Location	⑤ Sobu-line	Location
Chuo-ku	C	Chuo-ku	C	Taito-ku	C	Taito-ku	C	Chiyoda-ku	C
Chiyoda-ku	C	Chiyoda-ku	C	Arakawa-ku	C	Arakawa-ku	C	Sumida-ku	C
Minato-ku	C	Shinjuku-ku	C	Kita-ku	C	Adachi-ku	C	Taito-ku	C
Shinagawa-ku	C	Shibuya-ku	C	Kwaguchi-shi	S	Katsushika-ku	C	Kohtoh-ku	C
Ohta-ku	C	Nakano-ku	C	Warabi-shi	S	Matsudo-shi	S	Edogawa-ku	C
Sarwai-ku	S	Suginami-ku	C	Urawa-shi	S	Nagareyama-shi	S	Katsushika-ku	C
Kawasaki-shi	S	Musashino-shi	S	Yono-shi	S	Kashiwa-shi	S	Ichikawa-shi	S
Turumi-ku	S	Mitaka-shi	S	Omiya-shi	S	Abiko-shi	S	Funabashi-shi	S
Kanagawa-ku	S	Koganei-shi	S	Ageo-shi	S	Toride-shi	S	Narashino-shi	S
Yokohama-shi	S	Fuchu-shi	S	Okegawa-shi	S	Fujisiro-machi	S	Chiba-shi	S
Nishi-ku	S	Kokubunji-shi	S	Kitamoto-shi	S	Ryugasaki-shi	S	Yotsukaido-shi	S
Hodogaya-ku	S	Kunitachi-shi	S	Konosu-shi	S	Ushiku-shi	S	Sakura-shi	S
Totsuka-ku	S	Tachikawa-shi	S	Fukrage-shi	S			Shirui-shi	S
Kamakura-shi	S	Hino-shi	S	Gyohda-shi	S			Yachimata-shi	S
Fujisawa-shi	S	Hachioji-shi	S						
Chigasaki-shi	S	Fujino-machi	S						

(b) Osaka Metropolitan Area

① Sanyo-line	Location	③ Keihan-line	Location	④ Kansai-line	Location	⑤ Hanwa-line	Location	⑥ Kintetsu-line	Location
Osaka-shi	C	Osaka-shi	C	Osaka-shi	C	Osaka-shi	C	Osaka-shi	C
Amagasaki-shi	S	Moriguchi-shi	C	Yao-shi	S	Sakai-shi	S	Higashiosaka-shi	C
Nishinomiya-shi	S	Kadoma-shi	C	Kashiwara-shi	S	Takaishi-shi	S	Ikoma-shi	S
Ashiya-shi	S	Neyagawa-shi	S	Oji-cho	S	Izumi-shi	S	Nara-shi	S
		Hirakata-shi	S	Kashiba-shi	S	Tadaoka-shi	S		
		Yahata-shi	S	Yamatotakada-shi	S	Kishiwada-shi	S		
② Tokaido-line	Location			Shinjo-cho	S	Kaizuka-shi	S		
Osaka-shi	C			Gose-cho	S	Kumatori-cho	S		
Suita-shi	S			Gojo-shi	S	Izumano-shi	S		
Settsu-shi	S			Hashimoto-shi	S	Sennan-shi	S		
Ibaraki-shi	S			Koyaguchi-cho	S	Hannan-shi	S		
Takatsuki-shi	S								

(c) Nagoya Metropolitan Area

① Kansai-line	Location	② Tokaido-line	Location	③ Chuo-line	Location	④ Taketoyo-line	Location
Nagoya-shi	C	Nagoya-shi	C	Nagoya-shi	C	Nagoya-shi	C
Kanai-shi	S	Nishibiwajima-cho	S	Kasugai-shi	S	Obu-shi	S
Jushiyama-mura	S	Shinkawa-cho	S	Tajimi-shi	S	Higashiura-cho	S
Saya-cho	S	Kiyosu-cho	S	Toki-shi	S	Taketoyo-cho	S
Yatomi-cho	S	Inazawa-shi	S	Mizunami-shi	S	Mihama-cho	S
Nagashima-cho	S	Ichinomiya-shi	S	Ena-shi	S	Handa-shi	S
Kuwana-shi	S	Bisai-shi	S				

Core Area : C  
Suburbs : S

Table 5 ROXY Index and its Marginal Changes to the Fifteen Raiway-line Regions

(a) Tokyo Metropolitan

Localities		1947-50	1950-55	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95
①Tokaido-line	ROXY	81.5	54.7	-25.8	-253.3	-261.8	-202.0	-104.0	-64.4	-114.4	-59.9
	$\Delta$ ROXY/ $\Delta$ T	-5.4	-10.7	-30.8	-23.6	5.1	15.8	13.8	-1.0	0.5	10.9
②Chuo-line	ROXY	148.1	36.3	-103.0	-287.5	-222.9	-168.7	-130.4	-73.5	-126.5	-73.6
	$\Delta$ ROXY/ $\Delta$ T	-22.4	-25.1	-32.4	-12.0	11.9	9.3	9.5	0.4	0.0	10.6
③Takasaki-line	ROXY	239.8	106.5	-44.4	-266.9	-333.5	-257.5	-173.9	-106.0	-135.1	-109.7
	$\Delta$ ROXY/ $\Delta$ T	-26.7	-28.4	-37.3	-28.9	0.9	16.0	15.1	3.9	-0.4	5.1
④Joban-line	ROXY	242.4	106.4	-18.5	-315.2	-366.1	-338.6	-229.2	-119.1	-93.6	-50.8
	$\Delta$ ROXY/ $\Delta$ T	-27.2	-26.1	-42.2	-34.8	-2.3	13.7	22.0	13.6	6.8	8.6
⑤Sobu-line	ROXY	256.2	114.0	47.4	-279.8	-359.0	-301.8	-159.5	-60.3	-64.1	-29.0
	$\Delta$ ROXY/ $\Delta$ T	-28.4	-20.9	-39.4	-40.6	-2.2	20.0	24.1	9.5	3.1	7.0

(b) Osaka Metropolitan

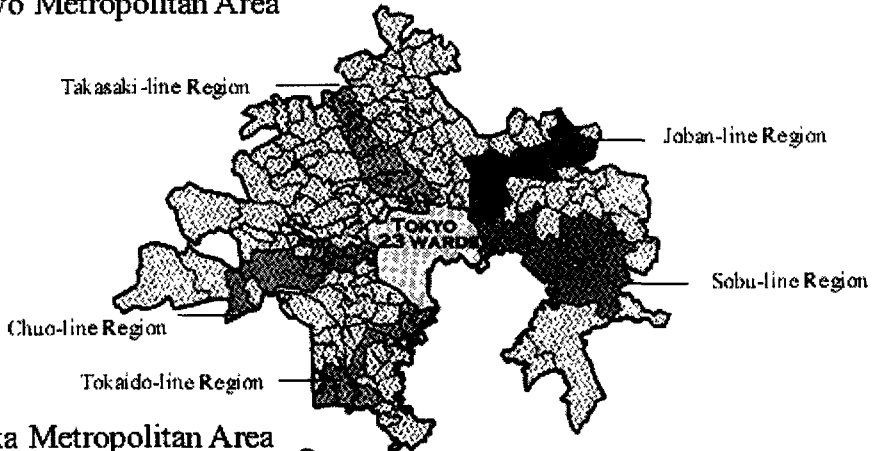
Localities		1947-50	1950-55	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95
①Sanyo-line	ROXY	52.1	38.3	-28.2	-169.6	-163.1	-90.7	-41.5	-6.3	-0.7	52.2
	$\Delta$ ROXY/ $\Delta$ T	-2.8	-8.0	-20.8	-13.5	7.9	12.2	8.4	4.1	5.9	10.6
②Tokaido-line	ROXY	161.9	134.7	-41.1	-462.3	-442.2	-321.2	-121.0	-50.6	-16.3	-12.0
	$\Delta$ ROXY/ $\Delta$ T	-5.4	-20.3	-59.7	-40.1	14.1	32.1	27.1	10.5	3.9	0.9
③Keihan-line	ROXY	165.1	133.3	-81.3	-515.6	-581.0	-364.8	-162.8	-62.4	-19.4	-23.2
	$\Delta$ ROXY/ $\Delta$ T	-6.4	-24.6	-64.9	-50.0	15.1	41.8	30.2	14.3	3.9	-0.8
④Kansai-line	ROXY	202.1	180.5	111.9	-133.7	-237.1	-188.7	-103.4	-51.0	-43.2	-40.5
	$\Delta$ ROXY/ $\Delta$ T	-4.3	-9.0	-31.4	-34.9	-5.5	13.4	13.8	6.0	1.0	0.5
⑤Hanwa-line	ROXY	143.1	119.3	30.9	-150.2	-244.6	-254.2	-115.1	-35.8	-8.6	-24.6
	$\Delta$ ROXY/ $\Delta$ T	-4.8	-11.2	-26.9	-27.5	-10.4	13.0	21.8	10.6	1.1	-3.2
⑥Kintetsu-line	ROXY	242.0	196.9	103.3	-103.9	-287.3	-280.5	-225.7	-120.0	-86.4	-44.3
	$\Delta$ ROXY/ $\Delta$ T	-9.0	-13.9	-30.1	-39.1	-17.7	6.2	16.1	13.9	7.6	8.4

(c) Nagoya Metropolitan

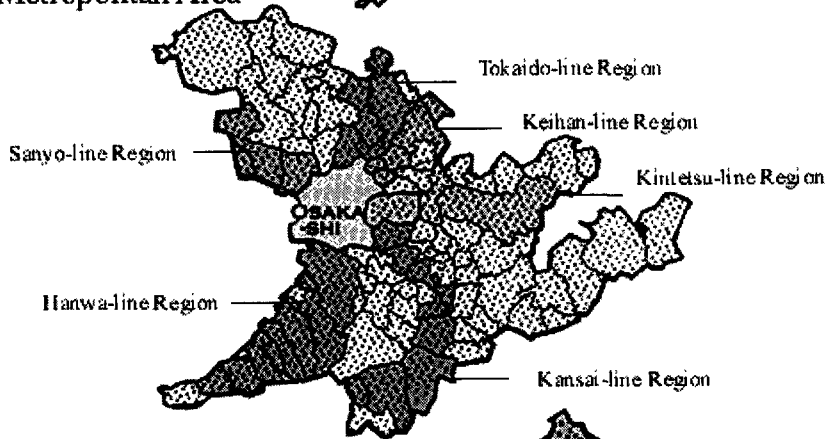
Localities		1947-50	1950-55	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95
①Kansai-line	ROXY	113.2	159.5	135.5	7.6	-64.2	-99.5	-66.3	-49.1	-20.7	-47.1
	$\Delta$ ROXY/ $\Delta$ T	9.3	2.2	-15.2	-20.0	-10.7	-0.2	5.0	4.6	0.2	-5.3
②Tokaido-line	ROXY	105.2	75.4	29.0	11.2	-31.9	-58.3	-33.9	-4.6	3.0	-21.3
	$\Delta$ ROXY/ $\Delta$ T	-6.0	-7.6	-6.4	-6.1	-6.9	-0.2	5.4	3.7	-1.7	-4.9
③Chuo-line	ROXY	143.9	156.0	106.1	-53.8	-101.2	-142.0	-85.6	-38.1	-20.7	-41.4
	$\Delta$ ROXY/ $\Delta$ T	2.4	-3.8	-21.0	-20.7	-8.8	1.6	10.4	6.5	-0.3	-4.1
④Taketomi-line	ROXY	141.0	136.2	99.7	17.3	-89.1	-105.1	-67.1	-49.0	-36.5	-50.3
	$\Delta$ ROXY/ $\Delta$ T	-0.9	-4.1	-11.9	-18.9	-12.2	2.2	5.6	3.1	-0.1	-2.8

**Figure 1 Geographical Locations of the Railway-line Regions in the Three Largest Metropolitan Areas in Japan**

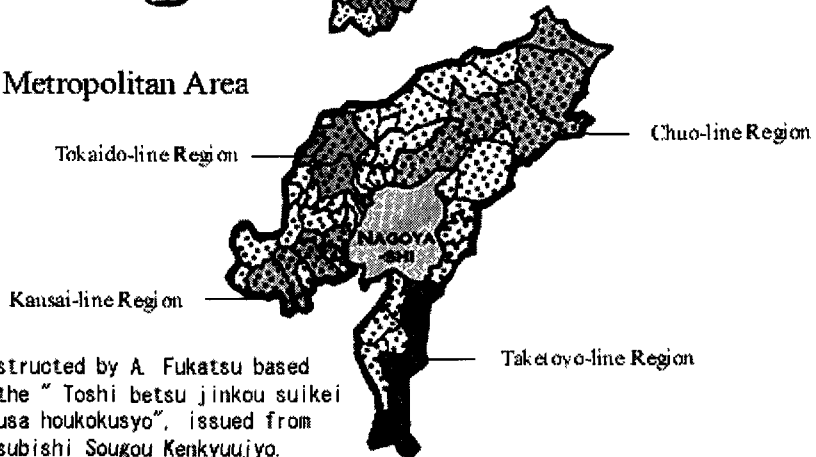
**(a) Tokyo Metropolitan Area**



**(b) Osaka Metropolitan Area**



**(c) Nagoya Metropolitan Area**



[Source] Constructed by A. Fukatsu based on the "Toshi betsu jinkou suikei chousa houkokusyo", issued from Mitsubishi Sougou Kenkyuujo.

Figure 2 Circular-cyclic Path for the Five Railway-line Regions in the Tokyo Metropolitan Area

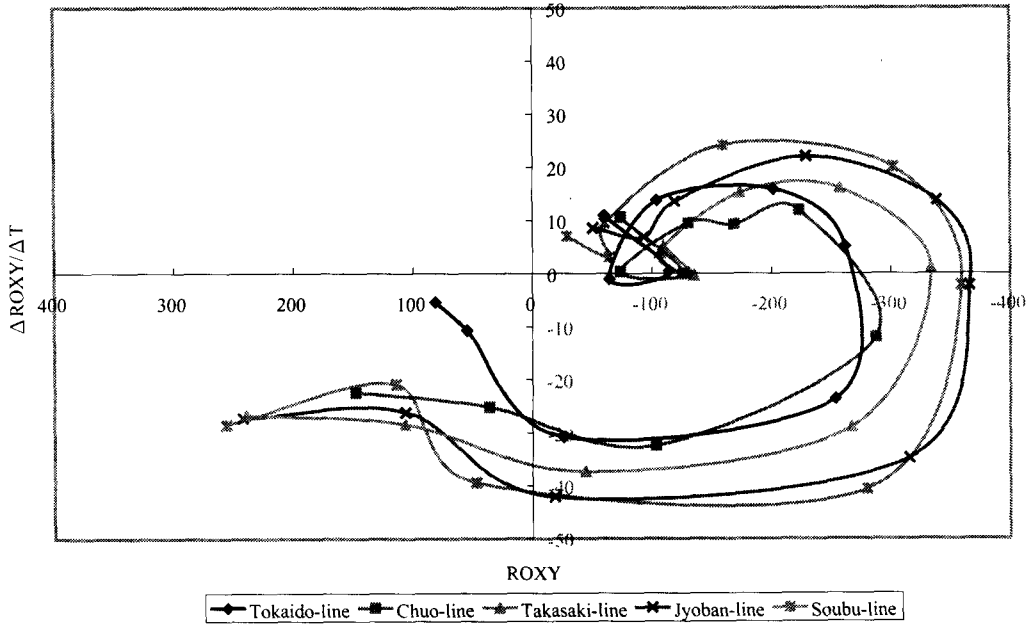


Figure 3 Circular-cyclic Path for the Six Railway-line Regions in the Osaka Metropolitan Area

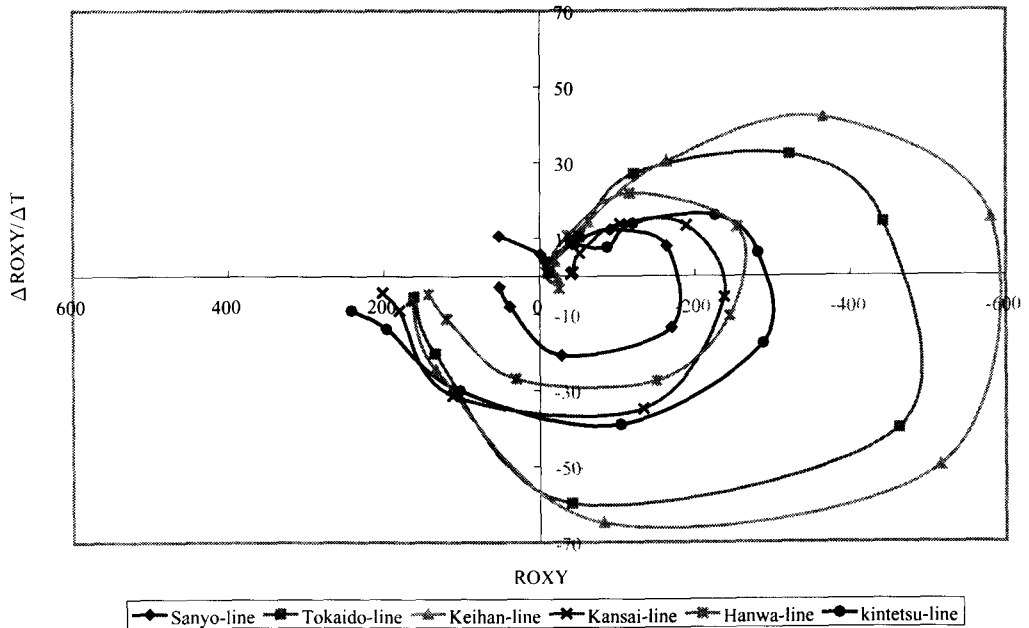


Figure 4 Circular-cyclic Path for the Four Railway-line Regions in the Nagoya Metropolitan Area

