An Urban Growth Modeling Based on The Urban Attraction

Toshiaki AOKI and Hajime INAMURA

Graduate School of Information Sciences
Tohoku University Aoba-ku Sendai 980,JAPAN

ABSTRACT. There are two main current of urban growth modeling. One is a traditional synthetic growth model using System Dynamics(SD). The other is a regional science model which can determine the location of industry and residence based on micro economics. Although this study basically uses the framework of SD, the principles of micro economics and an aggregated behavior model are introduced in some part in order to make the urban growth models more reliable. The model has four traditional sectors ,such as industry sector, population sector, land sector and worker sector. In addition to them ,there is the crucial addition of the migration sector which predicts the migration intended for Sendai, Tokyo and other part of Tohoku. Migration based on urban attraction is determined using real data based on an individual utility concept and an multiple regression analysis. The model is applied to Sendai Metropolitan Area for coming 100 years.

1. Introduction

Major cities in Japan have been growing through the growth of tertiary industries, while Lorwy assumed that secondary industry play a major role to the growth of cities. This fact is proved by two typical examples in Japan. Kitakyusyu city is suffering the decreasing in population where has enough amount of secondary industry. On the other hand, major local metropolises, such as Sapporo and Sendai, are rapidly increasing their population while the cities mainly depended on tertiary industry. Because of sufficient employment opportunity in Japan, a job opportunity, which was one of the major factor of immigration in the past, is getting less important for population growth of a city these days. Since Japanese people today give a priority to the quality and convenience of daily life and affluent environment of living , they are fascinated to a city by such attractiveness rather than an job opportunity or high income level. (KURODA(1990), TABUCHI(1986))

There are two main currents of urban growth modeling. One is a traditional synthetic growth model using System Dynamics(SD). The other is a regional science model which can determine the location of industry and residence based on micro economics. The SD model has an advantage for long term forecasting with complicate problems such as urban growth because of its flexibility. However the SD model has the drawback of being too subjective. The micro economics model is theoretically reliable if its fundamental assumptions, they are the utility maximization principle of human behavior and profit maximization principle of individual firm, are satisfied. Since most of work in this field concentrates on comparative static analysis, it is impossible to apply it directly for a long term dynamic problem. Although this study basically uses the framework of SD, the principle of micro economics and an aggregated behavior model are introduced in some parts in order to make an urban growth model more reliable. The model is applied to forecasting population growth in Sendai Metropolitan Area for coming 100 years.

2. Migration of Sendai Metropolitan Area

Fig-1 indicates the change of immigration and emigration of Sendai Metropolitan Area where includes Sendai city and surrounding twenty small cities and towns. Fig-2 shows the location of the area in discussion.

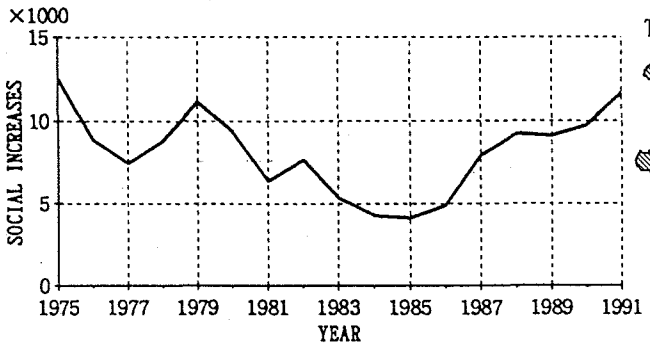

Fig-1 The change of migration in Sendai Metropolitan Area

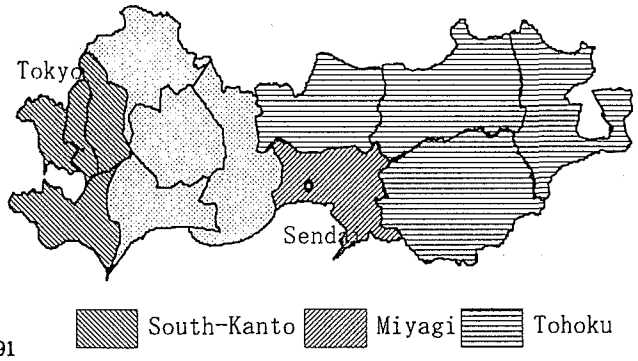

Fig-2 Location of Sendai Metropolitan area

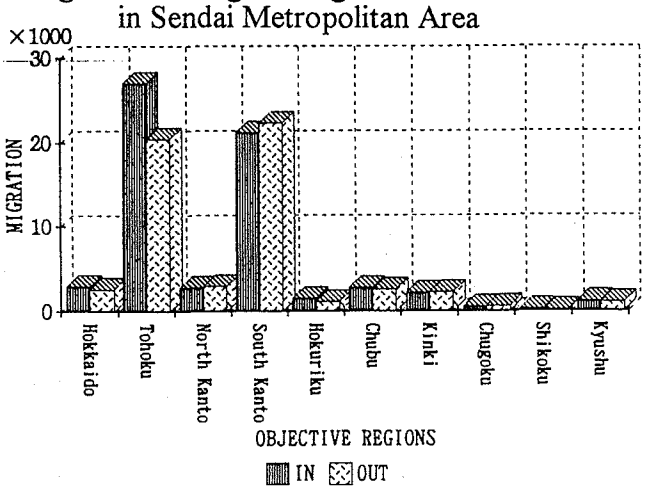

Fig-3 Migration intended for MIYAGI

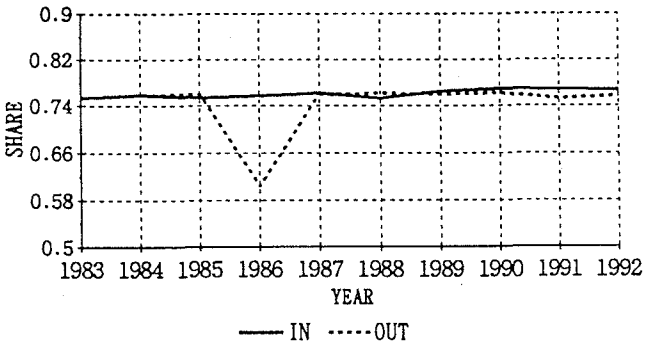

Fig-4 The historical share of migration to/from TMR plus OTR on MIYAGI

Because of limited data set of migration for Sendai Metropolitan Area, some discussion will be made by using prefecture basis data sets. Fig-3 shows the migration statistics from/to Miyagi prefecture by region inside Japan. Remarkable migration origin and destination of Miyagi can be seen with Tokyo metropolitan region (TMR) and Tohoku region (OTR) where TMR is comprised of Tokyo and surrounding three prefectures and OTR includes five prefectures in Tohoku region except Miyagi. Difference of number between immigration and emigration is quite small comparing with total number of migration. It can be understood that great part of migration is consist of university students in/out from other regions and rotation of personnel's by firms in Miyagi. Fig-4 shows the historical share of migration to and from TMR and OTR on Miyagi prefecture in decade. Since migrants of Sendai city dominate in Miyagi and occupy about 80% in that of Miyagi. Therefore, it is assumed that migration of Sendai can also be explained by the same story. In order to estimate the attractiveness of TMR and OTR, the central Tokyo and Ishinomaki city are chosen to represent the TMR and OTR respectively, and socio-economic data/indices, such as number of urban facilities, of these area are used for analytical purposes.

The central Tokyo with twenty three wards covers some 340 square kilometers and includes heart of city. The other hand, the reason why Ishinomaki city was chosen as the representative is the rate of population changes in the past has been almost the same as that of entire Tohoku region.

3. General Feature of Sendai Urban Growth Model

Fig-5 shows the outline of the model. The Sendai metropolitan model used a system dynamics framework, while TMR sector and OTR sector provide the level of variables which is quite important to estimate the immigration and emigration by the Sendai model. An aggregated behavior model and regression equations are used to estimate the number of migration with one year time delay. TMR and OTR sectors deal the variables of three years accumulated number of immigration to the area by which private reasons to go back an original place of living, number of cultural facilities which relates the mental attractiveness, living cost, and total floor area of retail sale which represents the attractiveness for daily life.

Fig-6 illustrates an outline of the Sendai urban growth model. This model consists of five sectors and the migration sector be a heart of it. A social system in Sendai city are expressed in other four sectors. A development policy can be introduced in land sector and industry sector, however, none of the simulation test for it is carried out so far.

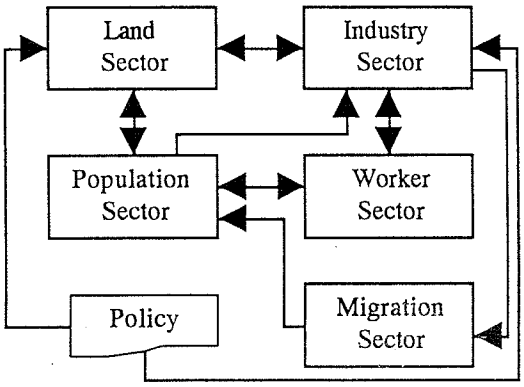

Fig-5 An outline of model

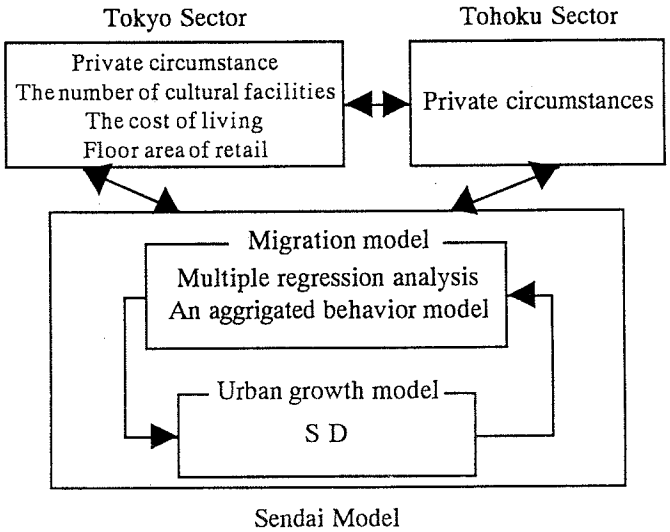

Fig-6 Sectors in urban growth model of Sendai

A) Population Sector

The Cohort model is applied in the population sector in order to estimate the change of population and age group in Sendai.

B) Industry Sector

The industry sector subdivided into five group of industries. They are 1) Primary industry, 2) Construction, 3) other Secondary industry (manufacturing), 4) Retailsale, wholesale, and restaurant, and 5) other Tertiary industry. Value of products from manufacturing industry is given exogenously. This study assumed that the annual growth rate of manufacturing products is at 3.25 % until 2000, 2.75 % from 2001 to 2010, and it is decreased linearly until 2080 at the rate of 2.75% to 1.0%. These figures are determined based on the prediction of GNP growth by central government. Table-1 shows a result of analysis. Shopping population is estimated by the population of Sendai multiplying by a constant. The other tables follow the same expression.

Table-1 Result of The Location Factors of Retail Sale in CBD

Region	Sendai Metropolitan Area
Explanatory variable	Coefficient
Constant	-3.22×10^{5} (-156.34^{*})
Shopping Population	0.26 (154.73^{*})
Workers in tertiary industry	0.02 (2.05)
Office workers in manufacturing	9.18 (82.64^{*})
Land price of CBD	-0.41 (-1.59)
Coefficient of determinant	0.999
The number of samples	10

(t-value), * denotes 1%, and **is 5% level of significance

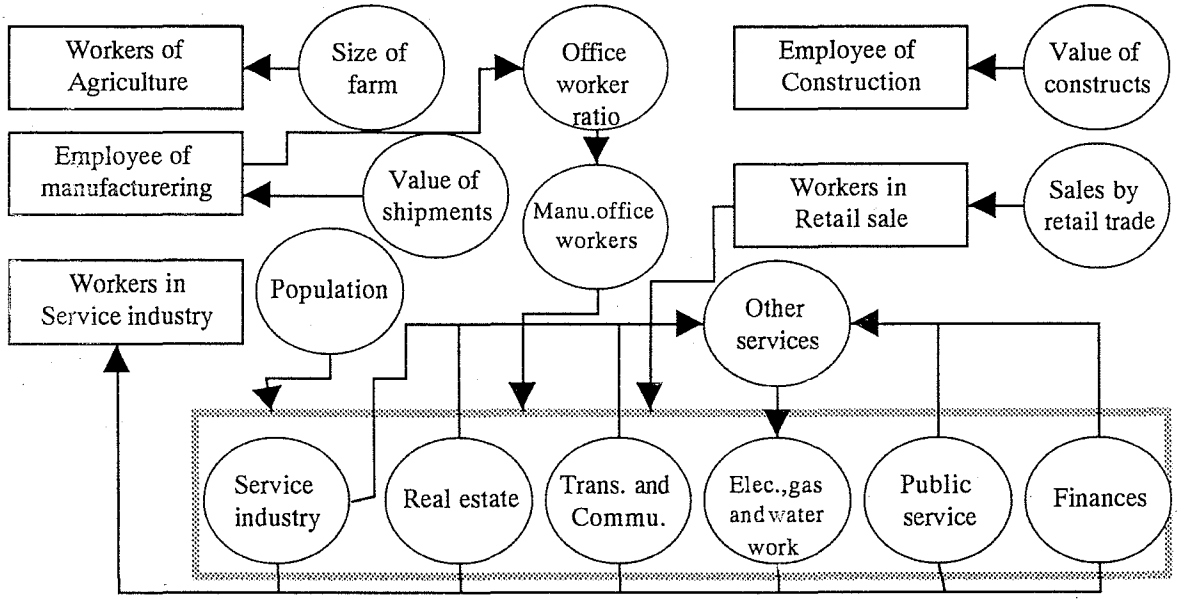

Fig-7 The Outline of Labor Force Sector

C) Labor Force Sector

Number of employee of each industry is estimated in the labor force sector. Fig-7 shows the outline of the sector. Workers of agriculture (primary industry in Sendai) is estimated by a regression equation, and its explanatory variable is cultivated land area. Number of employee of manufacturing is estimated by the value of products. Number of employee including unskilled labor of construction industry is assumed to be proportion to the construction cost. Workers in retail sale is simply determined by sales amount. Other tertiary industries are subdivided six industry groups. They are 1) electricity, gas, water supply, 2) transportation and communication, 3) bank and insurance, 4) real estate, 5) other services, and 6) government services. Number of employee in these industries are estimated each by multiple regression analysis as shown in equation (1).

$$SP_i^t = \alpha_1 POP^{t-1} + \alpha_2 RET^{t-1} + \alpha_3 MEK^{t-1} + \sum_{j \neq i} SP_j^{t-1} \qquad (1)$$

$$SP^t = \sum SP_i^t \qquad (2)$$

SP^t : The number of workers on industry i in term t , α : Parameter, POP : Population

RET : The number of workers engage in retail, MEK : Office workers of construction

As for an example, Table-2 demonstrates a result of analysis for the transportation and communication.

Table-2 The result by multiple regression analysis for transport and communication

Intended Region	Sendai Metropolitan Area	
Kinds of variable	Candidates of variables	Adopted variables
Explanatory variable	Coefficient	Coefficient
Constant	-1.25×10^{4} (-1.13)	1.15×10^{4} (14.31*)
Other service	-0.10 (-2.25)	---
Population	3.22×10^{-2} (3.28**)	1.27×10^{-2} (11.11*)
Workers in retail sale	0.63 (1.88)	---
Office workers of manufacturing	2.06 (4.27*)	1.18 (18.01*)
Coefficient of determination	0.999	0.997
The number of samples	12	

(t-value), * denotes 1%, and **is 5% level of significance

D) Land Use Sector

Landuse is divided into three categories. They are residential area, agriculture field, and park and forest. Additional residential area is determined from the additional number of household, i.e. the net increased migration in Sendai. This means that an immigrated household is assumed to live in a used house as far as a vacant house exist inside Sendai. Additional residential area will be accrued from agriculture field or forest.

E) Migration Sector

The migration sector in one of the heart of the paper and is explained in detail in the following chapter.

4. Interregional Migration Model

4.1. The concept and factors of urban attraction.

Attraction factors of a city which influence migration from area to area is analyzed by using KJ classification system. Six major attraction factors are selected.

A) Attraction of Retail Function

Various choice for shopping is one of the major attraction of a city. It must be affected by the size of retail function in CBD. Total area of retail floor space has selected as an index of the size of retail function. The area of retail floor space in the central Tokyo, Ishinomaki CBD, and Sendai CBD are used for the TMR sector, OTR sector, and Sendai model, respectively.

B) Attraction of Cultural Function

The cultural function here means various education schools, sports facilities, music and art facilities, and playing spots. Because of data availability, number of educational facilities for youth and children, libraries, sports facilities, , museums, welfare facilities for young workers and women, and movie theaters have chosen for this purpose.

C) Job Opportunity

Job opportunity is considered to be one of he most important attraction of a city in the model, while most of previous study dealt it as the direct reason of migration. As mentioned in the introduction, the job opportunity is getting less important factor for migration because of sufficient opportunity in Japan. The level of employment is estimated by the industry sector, and the job opportunity as an attraction is calculated subtracting the number of employee in last year from that of this year.

D) Natural Environment

Affluent natural environment and sufficient green or open space in a city fascinate people to the city. A lot of definition for natural environment exist. Considering data availability, the paper takes the accumulated area of forest, agriculture fields, and park as an index of environment. The area for measuring is the central Tokyo in TMR, old Sendai city (almost half of existing Sendai city in area), and whole Ishinomaki city.

E) Population Density

A degree of congestion is an important factor to move away from a city. Population density is used as an index to measure the degree of congestion. The area for measuring is the same as A).

F) Costs for Daily Life

Income level in Tokyo is the highest in Japan, however, living costs in Tokyo is much higher than those of Sendai and rural area. Degree of burden of the higher living costs depends on the life style or life stage of people. Anyhow, significant number of people escape from Tokyo because of it. A consumption expenditure index from the annual household survey by the Statistics Bureau is used in the model.

4.2. Mathematical Expressions for Migration Forecasting

Since we have three areas in discussion, there are three outflow migration with two direction each. Considering the regional characteristic of three regions, three outflow can be divided into two pattern. If the persons who live in Sendai Metropolitan Area plan to go out from Sendai, they have two choices, i.e., Other Tohoku Area and Tokyo Metropolitan Area. However two areas are quite different in those characteristic. One might be hometown and rural area, and the other is the biggest urbanized area. Their reasons of choice may not come from the attraction of the area but other private reasons. In the case of the person who live in Other Tohoku Area and plan to go out, on the other hand, they also have two choices, i.e. Sendai and Tokyo. Two enough urbanized cities comparing with their hometown are very competitive for them. Sendai city is of course much smaller than Tokyo but still the biggest city in their Tohoku area and have much better natural environment. When someone plan to go back to Tohoku area who live in Tokyo, Sendai and Other Tohoku Area are also very competitive because Sendai might be enough close to their home town. Because the largest portion of the reason of the persons who leave for Tohoku is private reasons such as taking care of old parents according to the statistics of government. Taking these discussions into consideration, a multiple regression analysis is employed for migration from Sendai to Tohoku and from Sendai to Tokyo, and an aggregated behavior model with logit type binary choice is applied for the outflow from Tokyo and Other Tohoku Area.

(Aggregated Logit Model)

It is assumed that peoples decide their destination of migration based on their evaluation of attraction of the regions. The factors taking account of this study are listed the above. The concept of utility (function) of migrants is introduced as a function of attraction factors. Although a private reason for migration has different characteristics from attraction factors of a city, it is also introduced to a utility function as one of the factor in the same manner. The utility function introduced here is defined as equation (3).

$$V_i = \sum_i \beta_{in} Z_{in} \qquad (3)$$

where,

V_i : utility of the region i, Z_{in} : attraction factors of region i , β : parameter

Equation (4) is reduced from the well known process of the aggregated behavior model. Then,

all parameters β are determined by the Maximum Likelihood Estimation.

$$P_{lm} = 1/\{1+exp(V_l - V_m)\} \quad (4)$$

where,

P_{lm}: the percentages of migration from region l to region m against the total number of migration from region 1.

V_l, V_m: each utility in region l,m

In the above model, P is not used for distribution of migrants to the regions, but is used only to estimate the utility function (an attraction of a city), because a migrant has many choices and we have limited data sets for parameters estimation.

Then, the absolute number of migration is estimated by the multi-regression analysis using the utilities of each region which is estimated the above. The amount of migration ΔIP is determined by the equation (5).

$$\Delta IP_{lm} = \gamma_m exp(\delta_m V_m) \quad (5)$$

where,

ΔIP_{lm}:The estimated number of people who moved from region l to region m.

γ_m, δ_m : Parameter

4.3. Parameter Estimation of The Models

A) Emigration from Sendai Metropolis

Emigration from Sendai to Tokyo is estimated by the multiple regression analysis. Floor space of retail sale, number of cultural facilities, job opportunity, natural environment, population density and the cost of living in Tokyo are selected as factors which influence on migration. The result is shown in Table-3.

Regarding the migration from Sendai to Tohoku, natural environment, population density, private reasons, floor space of retail sale and the number of cultural facilities in Sendai are selected. The result of analysis is also shown in Table-3.

Table-3 Estimated Parameters for Emigration from Sendai

Emigration	From Sendai to Tokyo		From Sendai to Tohoku	
Variables	Candidates	Adopted	Candidates	Adopted
Constant	*-1.57 (-0.37)*	*-1.44 (21.85*)*	*-8.27 (-1.43)*	*-0.35 (0.67*)*
Area of retail floor	*1.28 (1.34)*	---	*-0.25 (-1.87)*	*-0.07 (-4.82*)*
Cultural facilities	*0.40 (0.25)*	*1.40 (5.54*)*	*5.66 (1.16)*	---
Job Opportunities	*0.26 (0.83)*	---	---	---
Natural environment	*-5.90 (-1.20)*	---	*-0.025 (-0.04)*	---
Population density	*1.30 (0.64)*	---	*46.31 (1.41)*	---
Cost for daily life	*-0.03 (-0.98)*	---	---	---
Private reasons	---	---	*0.17 (0.82)*	*0.44 (5.24*)*
Coefficient of determinant	*0.749*	*0.686*	*0.809*	*0.737*
The number of samples	*16*		*13*	

Coefficients: Constant×10^4;Natural environment×10^4,(t-value), passed at * is 1%,**is 5% level of significance

B) Emigration from Tokyo Metropolis

A structure of emigration from Tokyo is slightly complicated than the others. Fig-8 shows a structure how to decide to move from Tokyo and to decide a destination. The first, estimating the number of people who emigrate from Tokyo to Sendai and other Tohoku by using multiple regression. The second, analyzing how to decide a destination of migration using an aggregated

behavior model in order to estimate the parameters for utility function. The third, estimating the absolute number of emigrants of each region using multiple regression again.

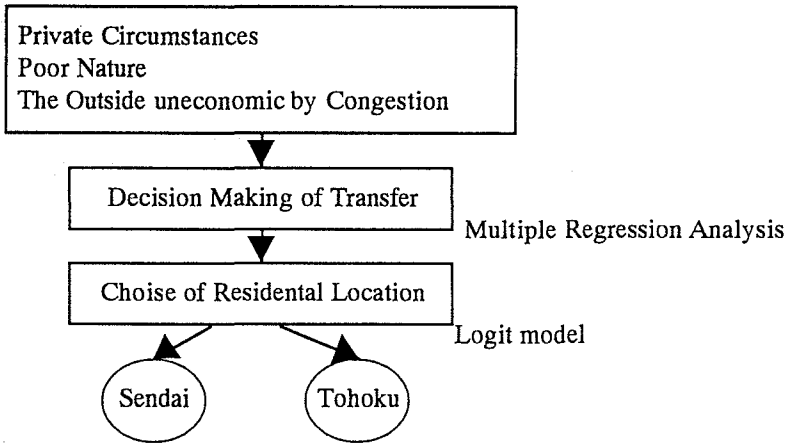

Fig-8 The process of deciding one's will to move away from Tokyo

Number of emigrant from Tokyo is assumed to be explained by natural environment, population density and private reasons. Generally speaking, private reasons will happen at random. Therefore, it is assumed that the accumulated number of people who immigrate from Sendai and other Tohoku can be an index for private reasons. Table-4 shows the result of parameter estimation.

Regarding the destination choice, floor space of retail sale, the number of cultural facilities, job opportunity, and private reasons are used as the explanatory variables. The result is shown in Table-5. Maximum Likelihood estimation is applied to this purpose.

Number of emigrants from Tokyo to Sendai and other Tohoku will be estimated by the equation (5). The explanatory variable is just the estimated utility V by the equation (3). Table-6 shows the result of parameters estimation.

C) Emigration from Tohoku Region

A emigrant from Tohoku region has two choices, they are Sendai and Tokyo. There are many differences between Tokyo and Sendai such as nature and living cost. As for the variables for destination choice, number of cultural facilities ,floor space of retail sale, cost of living, natural environment, population density, and job opportunity are selected. It follows from the result that floor space of retail and cost of living turned out to be significant factors. Other results are obtained by the same procedure as those of Tokyo.

Table-4 Estimated Parameters for Emigration from Tokyo

Migration	Emigration from Tokyo	
Variables	Candidates	Adopted
Constant	-8.81×10^{4} (-3.71^{*})	-8.81×10^{4} (-3.71^{*})
Natural environment	3.19×10^{5} (2.98^{**})	---
Population density	11.12 (2.68^{**})	---
Private reasons	0.67 (2.05)	1.53 (7.35^{*})
Coefficient of determinant	0.913	0.818
The number of samples	14	

(t-value), passed at * is 1%,**is 5% level of significance

Table-5 Estimated Parameters of Utility Function for Destination Choice from Tokyo

Choice	Sendai and Tohoku from Tokyo	
Variables	Candidates	Adopted
Area of retail floor	*0.24 (2.12)*	---
Cultural facilities	$-3.69\times10^{-2}(-9.26^{*})$	---
Job Opportunity	$-2.82\times10^{-2}(-0.72)$	---
Private reasons	$0.70\ (15.22^{*})$	$0.63\ (1.51\times10^{3*})$
Natural environment	$-1.03\ (-10.76^{*})$	---
Likelihood ratio	*0.298*	*0.298*
Correlation coefficient	*0.917*	*0.827*
The number of samples	*13*	

(t-value), passed at * is 1%,**is 5% level of significance

Table-6 Estimated Parameters of Migration Function from Tokyo to The Others

Intended OD	From Tokyo to Sendai and Tohoku
Explanatory variable	Coefficient
$ln(\ \gamma)$	$9.34\ (3.88\times10^{2*})$
δ	$2.07\ (54.51\times10^{*})$
Coefficient of determination	*0.994*
The number of samples	*12*

(t-value), passed at * is 1%,**is 5% level of significance

5. Application of the model

Results of prediction by the model are compared with statistics issued by the government, then, the validity of the model is discussed here. A prediction period of the model is 100 years beginning from year 1980. Fig-9 shows the time series changes of population in Sendai. Both the simulation result and the real statistics are shown during the period of 1980 to 1990. Figure-9 and the followings, horizontal axes between the part of calibration period and that of simulation period were changed. It is found that the simulation result of population growth is slightly smaller than real statistics.

Fig-10 shows the simulation result of migration into Sendai metropolitan region. The net immigration of statistics fluctuates very much, while the simulation result is rather smooth.

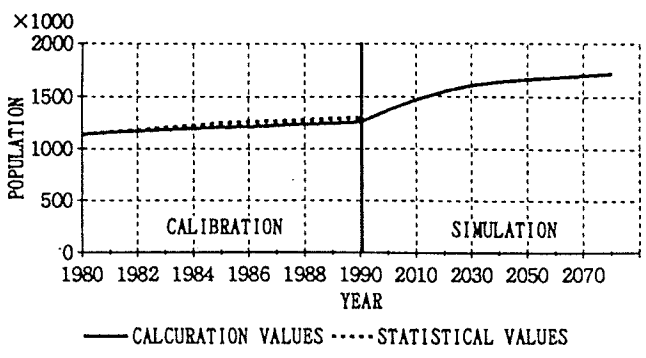

Fig-9 Estimation of population in Sendai

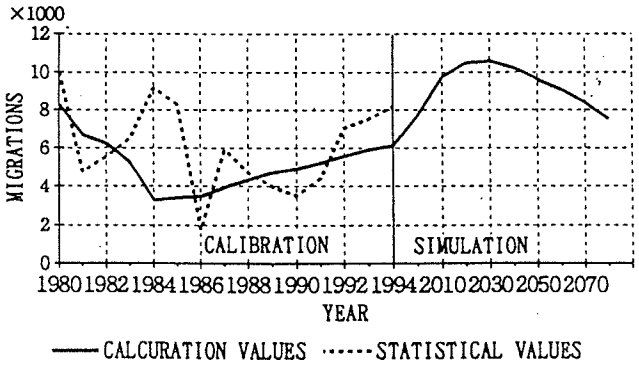

Fig-10 Immigration into Sendai

Fig-11 indicates the migration between Sendai and Tohoku. There is little error at the first half

about migration Tohoku to Sendai. But there is a little error at the latter half. There is a little error generally about the migration from Sendai to Tohoku. These error may influence on population incoming and outgoing from Sendai.

Fig-12 shows the result of migration between Tohoku and Sendai. Although it is observed a little error of it, the model shows very good performance to explain the migration.

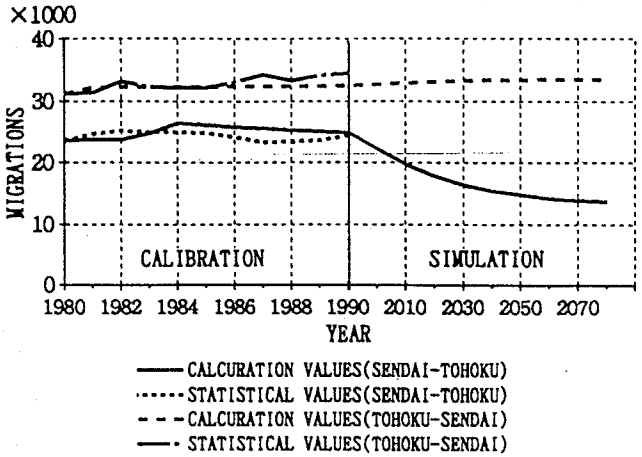

Fig-11 Migration between Sendai and Tohoku

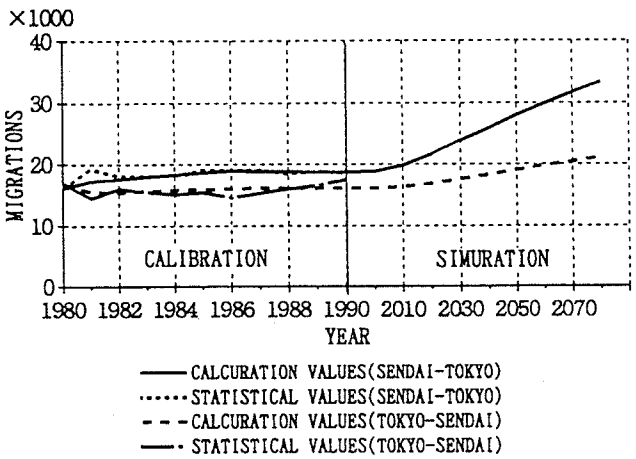

Fig-12 Migration between Sendai and Tokyo

6. Conclusions

This paper analyze the migration in Sendai Metropolitan Area from the point of the urban attraction in order to construct the inter regional migration model around Sendai city and forecast population growth by this model. The results goes as follows.

(1) Emigration from Sendai Area can be explained by comparing Tokyo with Tohoku region.
(2) The interregional migration can be determined by the attraction factors such as opportunity of shopping, cultural facilities, the cost of living.
(3) The factors of migration between Tokyo, Sendai and Tohoku regions was determined and specified by analyzing the real OD statistics.
(4) Validity and applicability of the model were confirmed through a case study.

References

1) Shozo, KURODA.1991. Quantitative Analysis of Urban Population Changes in Japan, *Annual Report of Economic Geography.* 37(3): 66-76
2) Takatoshi TABUCHI.1986. Interregional income gap and interregional migration. *Studies in regional science*. No.17. The Japan section of the USA.: 215-226
3) Yasuo Asakura and Tuna Sasaki.1993. Estimation of the effects on regional industrial activities by the large scale project. *Papers on City Planning,* No.18.: 319-324
4) Hideo N, Yositugu H, Kazuaki M. 1981. A Land Use Model for Suburban Area. *Proceeding of Japan society of civil engineers. No.309*: 103-112
5) Yoshitugu H, Yasuo T. 1988. A Model for Zone Forecast of Like Cycle progress, residential location and population attributes using random utility Models and a Micro-simulation technique, *Proceeding of JSCE. No.395*: 85-90
6) Yasunori S, Kotaro, N, Hironobu, M. Yoshitaka. 1986 A. Simulation Model for Regional Policy Considering Migration Behavior. *Infrastructure planning review, No.4*: 61-68
7) Kazuaki M. 1989. A Land Use Model Based on Random Utility / Rent-bidding Analysis and its Application to The Sapporo Metropolitan Area. *Proceeding of infrastructure planning ,No.12.*:675-680
8) Yoshitaka A. Akio K. 1992. A Migration Model Based on The Difference in Utility Between Regions.