DEVELOPMENT OF MIGRATION AND INTERACTION MODELS BETWEEN REGIONS IN CONSIDERATION OF THEIR MUTUAL RELATIONSHIP

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INTRODUCTION

Background and aim of study

Recently, many rural regions in Japan have been losing their vitality. This can be attributed to the falling birthrate and aging population. In this situation, it is necessary to promote population inflow and to stimulate interaction between regions in order to revitalise regions. It is considered that people migrate to another residence after they obtain information about the environment and situation of a place to live. Their own experience of visiting the next residence is one of the most affective ways for understanding the situation of the region. The relationship between regions having active interaction is stronger than other regions. In addition, regions with a strong relationship have active migration due to psychological reasons. Thus such "movement of people" is closely related to each other and is influenced by various factors, including convenience of transportation within and between regions. Therefore, it is important to clarify factors which influence interaction and migration between regions and their mechanism. It is also necessary to analyze their mutual relationship for contributing to make regional policies. By using constructed models which can verify regional policies, it is possible to compare and consider several policies.

The aim of this study is to clarify mechanisms of migration and interaction between regions, and their relationship quantitatively. In order to achieve this aim, we develop models of migration and interaction between regions in which their relationship is considered in detail. The method of simulation is verified and suggested by using these models.

Outline

An outline of this paper is presented in Figure 1. First, we review previous migration research and describe its significance as well as the originality of this study.

Next, a migration model is formulated by constructing a consumer behaviour model based on the Utility Maximization Theory in consideration of degree of relationship between regions. An indicator of interaction is explicitly introduced in this model as an independent variable. As a result, relationship between migration and interaction between regions is explained clearly. Concerning interaction, we construct two kinds of differing by purpose of interaction, such as sightseeing and business. An interaction model for sightseeing is constructed based on the Utility Maximization Theory and that for business is based on the Profit Maximization Theory.

Third, these three models, which explain “movement of people”, are applied to Japan in 1990, 1995, 2000 and 2005. By this application, parameters of these models are estimated.

Finally, we suggest simulation methodology using constructed models.

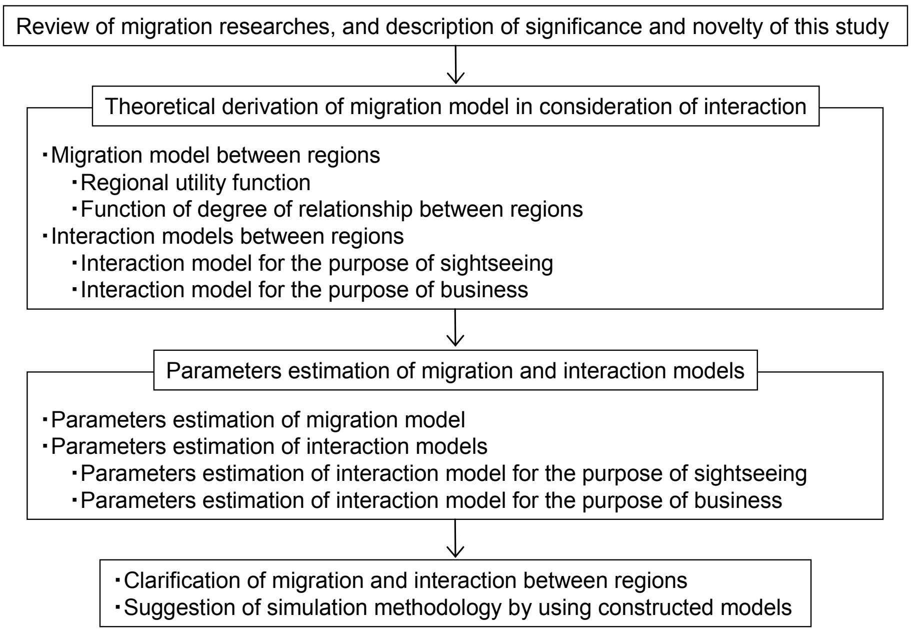

Figure 1 *– Organizational structure of paper*

PREVIOUS STUDIES AND CHARACTERISTICS OF THIS STUDY

Migration has been studied over the years with a significant amount of literature being available. As a result of this, much has been reviewed in previous papers. In the present study, we aim to construct a migration model between regions based on the Utility Maximization Theory. Therefore, we review past migration research which is related to choice of place to live.

First, one of the representative examples of review literature on migration was presented by Greenwood (1975, 1985). He published papers which covered both theoretical and empirical study of migration. According to these papers, migration research related to choice of place to live are composed of: (1) study of migration factor and (2) study of influence of migration. In addition, Greenwood, M. J. (1997, 2003) widely surveyed internal migration studies in developed countries with a focus on the US. Cushing, B. and Poot, J. (2004) showed that migration study extended from internal one to international one. He emphasised that the following are necessary in future migration-related studies: (1) a more unified body of research on internal and international migration, (2) integration of methodologies and perspectives from the different regional science disciplines and (3) connection of migration research to related research areas both inside and outside of the regional science community is required. He also said that successful achievement research could be obtained if these requirements were satisfied.

Next, we review previous migration studies related to choice of destination place. One of the significant economic theories which aim to clarify factors of migration is a theory related to differentiation in wages advocated by Hicks, J. R. (1932). He explained that main factor of migration was due to differentiation in wages. Thus, workers migrated from a region of low wage to a region of high wage. Another theory is about employment opportunity advocated by Schultz, T. W. (1945). He analyzed migration of agricultural populations. Here, the main factor of migration was not related to the price of products but, rather, to opportunities of employment. Robinson, J. (1947) said that workers migrated mainly due to employment opportunity and they were influenced by comparative wages only a little. Wolpert, J. B. (1965) considered that people make a decision whether they migrated or not after deliberation about condition of current habitation and planed habitation after migration such as the situation of their family, quality of habitation, their economic condition and locational situation and so on. Moore, E.G. (1970) considered that negative attitudes towards current living condition were important as a motivational factor for migration. There are many studies based on the Place Utility Theory explained above. Recently, the theory that people decide their destination based on living environment as well as employment opportunities when they move is generally well-known.

Greenwood, M. J. and Hunt, G. L. (1989) analyzed which was more important for migration; employment opportunities and wages or amenities. They concluded that at least the direct effects of jobs and wages are considerably more important than the direct effects of location-specific amenities in metropolitan migration.

Aoyama, Y. and Kondo, A. (1992) and Aoyama, Y. et al. (1995) considered that individual choice of place to live depends on utility. They indicated that flow of migration was even observed from a region having higher in utilities to another region whose utility value was apparently lower in view of actual migration phenomenon. They concluded that this is caused by some kind of regional discrepancy of population such as population density in big cities. This means that there is regional difference in migration opportunities. Thus, they constructed a migration model based on the assumption that migration per capita was dependant on difference in utility in consideration of close relationship between migration and population in a departure region. They applied this model to migration in Japan and analyzed effects by focusing on improvement of transportation facilities in the future. Miyata (1995) constructed urban functions based on the Utility Maximization Theory by regional difference in utility. He assumed that people consume service of each region stochastically. Following this study, Aoki, T. and Inamura, H. (1995) constructed migration models to explain dispersion and concentration migration in a rural region in Japan from the view point of regional attraction. Kondo, A. and Kondo, A. (2005) considered that the degree of relationship between regions affects migration. Then, the function of degree of relationship between regions is incorporated into the model based on the Utility Maximization Theory. In addition, Kondo, A. et al. (2006) incorporated change in perception of life into the model.

We develop a migration model between regions taking into consideration interaction between regions. From the analysis, migration factors are clarified and the relationship between migration and interaction is shown.

In order to clarify mechanisms of migration and interaction between regions, migration and interaction models are constructed in this study with the intention to make use of these models for application to effective analysis of improvement of regional infrastructures. Therefore, models proposed here enable us to apply them to a simulation analysis for measuring effects of improvement of infrastructures. As previously discussed, it is considered that migration and interaction have an intimate relationship. It is also necessary to clarify their mutual relationship theoretically. However, there have been no studies to date where migration and interaction models are constructed which take their relationship into consideration.

A MIGRATION MODEL IN CONSIDERATION OF INTERACTION

A migration model

A migration model is theoretically derived based on the Utility Maximization Theory. This model is founded on regional difference in utility which is the theory that individual choice of place to live depends on utility. In view of actual migration phenomenon, flow of migration is even observed from a region being higher in utilities to another region whose utility value is apparently lower. This is caused by regional discrepancy of population such as population density in big cities. This means that there is regional difference in migration opportunities. The migration model is constructed based on the theory that migration per capita is dependant on difference in utility in consideration of close relationship between migration and population in a departure region (Aoyama, Y. et al., 1995). When migration is explained by regional difference in utility, each person has some motive for migration. Thus, it is assumed that the ratio between migration flow X_{ij} from region i to region j divided by population P_i in region i can be explained by regional difference in utility (U_j-U_i). The degree of relationship between regions can be also considered to affect migration. Then, the function of degree of relationship between regions is incorporated into the model. Moreover, it is assumed that a certain amount of migration flow, which is not related to regional difference in utility and degree of relationship between regions exists, and the amount of such flow is a constant value for population of origin region in migration flow. Finally, a migration model is formulated as shown in equation (1).

$$\frac{X_{ij}}{P_i} = \alpha (U_j - U_i) + \beta R_{ij} + \gamma$$
$$\frac{X_{ji}}{P_j} = \alpha (U_i - U_j) + \beta R_{ji} + \gamma \qquad (1)$$
$$|\alpha(U_j-U_i)| \leqq \beta R_{ij}+\gamma,\ \alpha, \beta, \gamma \geqq 0$$

P_i, P_j: Population in region i, j
X_{ij}, X_{ji}: Migration flow from region i to region j, from region j to region i
U_i, U_j: Utility in region i, j
R_{ij}: Degree of relationship between region i *and* j, $R_{ij} = R_{ji}$
α, β, γ: Parameters

Equation (1) shows amount of migration from region i to region j for population in region i is the summation of the volume of migration due to regional difference in utility $\alpha(U_j-U_i)$, the degree of relationship between regions βR_{ij} and constant value γ. Explanation of this model in case of $U_i>U_j$ is shown in Figure 2.

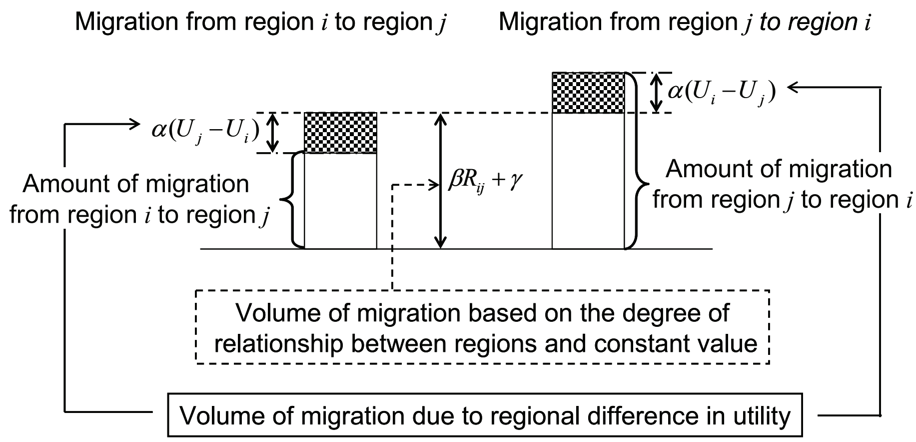

***Figure 2** – Concept of a migration model in this study*

Regional utility function

The regional utility function included in equation (1) is derived as follows. We hypothesize that individual choice of place to live is based on utility. The individual utility function is assumed as shown in equation (2) and the constraint of individual's income is as shown in equation (3).

$$U = A\ln(Z) + B\ln(S) + C\ln(n_H) \quad (2)$$

U: Individual utility, Z: General assets, S: Area of residential land area
n_H: Opportunities for use of community facilities and social interaction
A, B, C: Parameters

$$I = Z + rS + qt_H n_H \quad (3)$$

I: Average income, r: Residential land price, q: Travel cost for unit time per capita
t_H: Travel time

Equation (2) is maximized under equation (3) using Lagrange's method. As a result, an indirect utility function of the living place can be derived. The indirect utility function obtained here is expressed by the equation (4) as follows.

$$U = K\ln(I) - B\ln(r) - C\ln(t_H) + const. \quad (4)$$

$$K=B+C$$

Half-day interchangeable population H is used as a proxy variable for t_H, and employment opportunities W is used as a proxy variable for I .Half-day interchangeable population in a certain region is defined as the total number of population which can be counted in areas located within 1.5 hours one way by train or car from that region. This reflects the reduction of travel time by train or car due to improvement of transportation facilities. This variable is appropriate as a proxy variable for travel time. The variable of employment opportunities is also appropriate as a proxy variable for income because of a strong correlation between these two variables. Equation (5) shows the indirect utility function in which these proxy variables are used.

$$U = a\ln(W) + b\ln(r) + c\ln(H) + const. \quad (5)$$

W: Employment opportunities, H: Half-day interchangeable population

Employment opportunity, W, is an economic attribute. Half-day interchangeable population H implies the condition of development of transportation facilities. Residential land price, r, is a variable reflecting the environmental level. Half-day interchangeable population, which shows the development of transportation facilities, is an indicator having a variety of possible reasons. Regions with a large number of half-day interchangeable population are regarded as those having many cultural and leisure facilities. In addition, employment opportunity is an index which correlates with the income per capita in each region and land productivity. In other words, it can be said that employment opportunity reflects the degree of economic development.

Function of degree of relationship between regions

As discussed above, it is assumed that degree of relationship between regions affects migration. Therefore, the function of degree of relationship between regions is incorporated into the model. This function is assumed as shown as equation (6). When people consider migration, they often go to the region where they contemplate to move, and obtain information about that region. For this reason, it is important to clarify the influence of interaction on migration between regions. In order to ascertain the importance of this influence, an indicator of interaction is explicitly introduced in this function.

$$R_{ij} = k_B \ln\left(\frac{BS_{ij} + BB_{ij}}{P_i} + \frac{BS_{ji} + BB_{ji}}{P_j}\right)$$
$$R_{ji} = k_B \ln\left(\frac{BS_{ji} + BB_{ji}}{P_j} + \frac{BS_{ij} + BB_{ij}}{P_i}\right) \quad (6)$$

BS_{ij}, BS_{ji}: Volume of interaction for the purpose of sightseeing from region i to region j, from region j to region i
BB_{ij}, BB_{ji}: Volume of interaction for the purpose of business from region i to region j, from region j to region i
k_B: Parameter

Rate of interaction for the purpose of sightseeing and business is calculated as a sum of the amount of interaction for the purpose of sightseeing and business divided by the population of departure region. This index is introduced into the function of degree of relationship between regions. This index shows not only preference of moving but also activeness of interaction. In addition, it is influenced by various social indexes including service level of transportation and economic situation. It may be said that this index can describe degree of relationship between regions which is considered to be important due to improvement of traffic condition and stimulation of interaction.

Interaction models by purpose

In this study, we focus upon interaction for the purpose of sightseeing and business, because wide area interaction between regions is an object of analysis. It is considered that interaction factors and behavioural theories differ depending on the purpose of interaction. Thus, interaction models by purpose are constructed.

Interaction model for the purpose of sightseeing

People who live in region i visit region j for the purpose of sightseeing is assumed. When people visit region j by n_{ij} times during a unit period of time, they can to obtain utility u_{ij}. Degree of attraction and traffic convenience are considered to be the variables included in utility. These variables can be interpreted as representing a feeling of strength for people living in region i who are attracted to region j (Mannami, Y. et al., 2007). The utility function of an interaction for the purpose of sightseeing is assumed as shown in equation (7). This equation shows that people who live in region i visit a region having greater attraction, and they can obtain higher utility by staying longer and visiting more times.

$$u_{ij} = z_j \cdot (TC_{ij}) \cdot s_{ij}^A \cdot n_{ij}^B \qquad (7)$$

u_{ij}: Utility of people living in region i obtain by visiting region j
z_j: Degree of attraction in region j
TC_{ij}: Traffic convenience between region i and region j
s_{ij}: Sojourn time for people living in region i and who stay in region j
n_{ij} : Frequency of visits of people living in region i to region j, A, B: Parameters

If the critical utility gradually decreases, both $\partial^2 u_{ij}/\partial s_{ij}^2<0$ and $\partial^2 u_{ij}/\partial n_{ij}^2<0$ are justified, leading to $0<A<1$ and $0<B<1$. U_i which is the total sum of the utility produced when people who live in region i visit all regions. This can be expressed by equation (8). The time constraint is assumed to be as shown in equation (9).

$$U_i = \sum_j u_{ij} = z_j \cdot (TC_{ij}) \cdot s_{ij}^A \cdot n_{ij}^B \qquad (8)$$

U_i: Total utility of people living in region i obtained by visiting region j

$$\sum_j n_{ij}(2t_{ij} + s_{ij}) \le T_i \qquad (9)$$

t_{ij}: One-way travel time between regions i and j
T_i : Free time of people living in region i

It is considered that people try to increase their utility of interaction by increasing the number of times they visit places with a greater attraction and stay longer during their free time.

Equation (8) is maximized under equation (9) by using Lagrange's method. As result, frequency can be derived and is expressed by the following equation (10). By multiplying both sides of equation (10) by population in destination place, equation (11) which expresses the volume of interaction for the purpose of sightseeing from region i to region j, is obtained.

$$n_{ij} = \frac{T_i \left\{ \dfrac{z_j \cdot (TC_{ij})}{(2t_{ij})^{1-A}} \right\}^{1/(1-B)}}{\dfrac{B}{B-A} \sum_j \left\{ \dfrac{z_j \cdot (TC_{ij})}{(2t_{ij})^{B-A}} \right\}^{1/(1-B)}} \qquad (10)$$

$$s_{ij} = \frac{A}{B-A} \cdot 2t_{ij}$$

From $s_{ij}>0$, so, $B>A$. Thus, $0<A<B<1$ is justified.

$$BS_{ij} = \frac{T_i \left\{ \dfrac{z_j \cdot (TC_{ij})}{(2t_{ij})^{1-A}} \right\}^{1/(1-B)}}{\dfrac{B}{B-A} \sum_j \left\{ \dfrac{z_j \cdot (TC_{ij})}{(2t_{ij})^{B-A}} \right\}^{1/(1-B)}} \cdot P_i \qquad (11)$$

Degree of attraction in region j is assumed to be as shown in equation (12), and traffic convenience of transportation between region i and region j is assumed to be as shown in equation (13).

$$z_j = \exp\left(\sum_n \alpha^{(n)} \ln z^{(n)}{}_j\right) \qquad (12)$$

$$TC_{ij} = \exp\left(\sum_m \beta^{(m)} \ln TC^{(m)}{}_{ij} + \sum_l \gamma^{(l)} \delta(TC^{(l)}{}_{ij})\right) \qquad (13)$$

$z^{(n)}{}_j$: Indexes of degree of attractiveness of region j
$\alpha^{(n)}$: Parameters of indexes of degree of attractiveness of region
$TC^{(m)}{}_{ij}$: indexes of convenience of transportation between region i and region j
$\beta^{(m)}$: Parameters of indexes of convenience of transportation between region i and region j
$\delta(TC^{(l)}{}_{ij})$: Dummy variables, if there is a relationship between region i and region j, this parameter is 1, on the contrary to that, this parameter is 0.
$\gamma^{(m)}$: Parameters of dummy variables

Interaction models for the purpose of business

In order to clarify the mechanism of interaction between regions for the purpose of business, first, the profit maximization behaviour model is assumed after consulting existing studies (Ministry of Land Infrastructure and Transport, 2005 and Okumura, M. et al., 1996). In order to achieve this aim, a model is constructed in which volume of interaction for the purpose of business and transport factors related to it is incorporated. In other words, it is assumed that firms operate to maximize profits by investing in land, using money for interaction for the purpose of business and hiring staff. A profit function of firm i is assumed as equation (14).

$$\pi_i = p_i Y_i - r_i S_i - q_i BB_i - w_i L_i \tag{14}$$

π_i: Profit of firms in region i, p_i: Value added per unit of product in region i
Y_i: Value of production of firms in region i, r_i: Land price in region i
S_i: Land area of firms in region i
q_i: The cost of interaction for purpose of business of firms in region i
BB_i : The value of interaction for purpose of business originating in region i
L_i: Number of employees in firms in region i, w_i: Wage ratio in region i

The Cobb-Douglas production function is based on factors of production, the volume of interaction for the purpose of business and the number of employees is assumed as equation (15). This is assumed as a constraint that indicates a technical constraint.

$$Y_i = \eta \cdot H_i^{\mu} \cdot S_i^{\alpha} \cdot BB_i^{\beta} \cdot L_i^{\gamma} \tag{15}$$

H_i: Opportunity of face-to-face communication in region i (Number of employees within a half-day interchangeable area; Half-day interchangeable employees)
$\alpha, \beta, \gamma, \eta, \mu$: Parameters

If the marginal product decreases, $\partial^2 Y_i/\partial H_i^2<0$, $\partial^2 Y_i /\partial BB_i^2<0$ and $\partial^2 u_{ij}/\partial n_{ij}^2<0$ are justified, which leads to $0<\mu<1$, $0<\mu<1$ and $0<\gamma<1$. Equation (14) is maximized under equation (15) using Lagrange's method. In order to grasp influence of people on volume of interaction for the purpose of business on firms, area of land is assumed to be constant. As result, frequency can be derived and is expressed by the following equation (16).

$$Y_i = H_i^{\mu} \cdot S_i^{\alpha} \cdot BB_i^{\beta+\gamma} \cdot \left(\frac{q_i}{w_i}\right)^{\gamma} \cdot \eta \cdot \left(\frac{\gamma}{\beta}\right)^{\gamma} \tag{16}$$

Next, a model to estimate volume of origination on interaction for business is constructed. It is considered that the value of interaction for the purpose of business originating in region i, BB_i, depends on value of production of a firm and accessibility in region i. A model of origination volume and interaction for business is assumed as equation (17).

$$BB_i = a \cdot Y_i^{b} \cdot \sum_k (ACC_i)^{c_k} \tag{17}$$

ACC_i: Accessibility by each transportation mode in region i, a, b, c_k: Parameters

Third, as shown in equation (18), volume of interaction for the purpose of business from region i to region j is expressed by introducing value of interaction for the purpose of business originating in region i. Function of degree of attractiveness and relationship between region i and region j is assumed as equation (19).

$$BB_{ij} = R_{ij} \cdot BB_i \tag{18}$$

$$R_{ij} = \exp\left(\sum_k a^{(k)} \ln V^{(k)}_{ij}\right) \tag{19}$$

R_{ij}: Degree of attractiveness and relationship between region i and region j
$V^{(k)}_{ij}$: Indexes of the degree of attractiveness and relationship between region i and region j
$a^{(k))}$: Parameters of indexes of degree of attractiveness and its relationship

PARAMETER ESTIMATION OF MIGRATION AND INTERACTION MODELS BETWEEN REGIONS

Period of time and areas

In the analysis, data of migration and interaction in 1990, 1995, 2000 and 2005 are used. The migration models and their interaction are applied to Japan. There are 47 prefectures in Japan. These prefectures are divided into 3 groups which are metropolitan areas, urban areas and rural areas based on their socioeconomic situation. In addition, it can be classified like this, according to the tendency of time series variation of migration (Kondo, A. and Kondo, A., 2005). In analyses, population Census (Ministry of Land Infrastructure and Transport) and Annual Report on the Internal Migration in Japan (Ministry of Internal Affairs and Communications) are used as data for migration between prefectures. Passengers Carried Chart between Prefectures (Ministry of Internal Affairs and Communications) for volume of interaction and population is used as interaction data. As data of travel time between regions, we use “TRANET”, “NAVINET” and “NITAS” (Ministry of Land Infrastructure and Transport) in this study, which are measured taking into consideration of airline and railway networks.

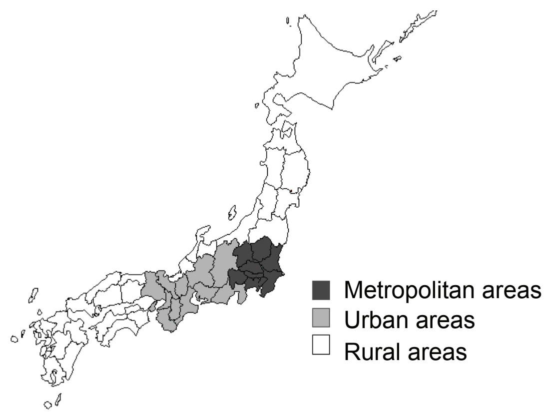

***Figure 3** – 47 prefectures in Japan*

Parameter estimation of interaction models by purpose

Convenience of transportation affects the degree of relationship between regions as well as proximity of regions. In this study, the frequency of airline flights per day between prefectures is introduced as an index to measure transportation convenience. The frequency of airline flights per day is counted from the airline timetables (Japan Travel Bureau). In addition, Half-day interchangeable employees in a certain region is defined as the total number of employees which can be counted in areas located within 1.5 hours one way by train or car from that region. Regions having no interaction are excluded from this study.

Parameter estimation of interaction model for the purpose of sightseeing

Parameters can be estimated using equation (20) which is obtained by taking a proportion of destination j to destination k. Regarding parameters A and B, $0<A<1$ and $0<B<1$ are justified as previously discussed. In order to estimate parameters, equations (12) and (13) are substituted for equation (20), and the logarithm of both sides of equation (20) is taken. Finally, equation (21) is obtained and we can estimate parameters using regression analysis. Tables 1 and 2 show results of parameter estimation for each transportation mode.

$$\frac{n_{ij}}{n_{ik}} = \frac{BB_{ij} / P_i}{BB_{ik} / P_i} = \frac{BB_{ij}}{BB_{ik}} = \left(\frac{z_j}{z_k} \cdot \frac{TC_{ij}}{TC_{ik}} \right)^{\frac{1}{1-B}} \cdot \left(\frac{t_{ik}}{t_{ij}} \right)^{\frac{1-A}{1-B}} \tag{20}$$

$$\ln\left(\frac{BB_{ij}}{BB_{ik}} \right) = \sum\nolimits_n \frac{\alpha^{(n)}}{1-B} \ln \frac{z^{(n)}{}_j}{z^{(n)}{}_k} + \sum\nolimits_m \frac{\beta^{(m)}}{1-B} \ln \frac{TC^{(m)}{}_{ij}}{TC^{(m)}{}_{ik}} + \sum\nolimits_l \frac{\gamma^{(l)}}{1-B} \frac{\delta(TC^{(l)}{}_{ij})}{\delta(TC^{(l)}{}_{ik})} + \frac{1-A}{1-B} \ln\left(\frac{t_{ik}}{t_{ij}} \right) \tag{21}$$

Table 1 *– Result of parameter estimation of interaction model for the purpose of sightseeing -Airline- (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Travel time by airline between regions	1.019	4.545	—	—	1.395	7.821	2.253	13.159
Number of large-scale retail stores	—	—	0.718	12.125	0.974	20.626	0.511	4.902
Number of art and other museums	—	—	0.152	2.115	—	—	0.396	4.247
Accommodation capacity of hot spring resorts	—	—	0.136	4.305	0.173	5.315	0.298	7.557
Frequency of airline flights per day	—	—	0.121	5.507	0.115	4.805	0.089	4.517
Travel time by railway between regions	1.364	10.934	1.299	20.199	1.293	17.347	1.891	20.390
Number of leisure facilities	0.640	10.243	—	—	—	—	0.485	4.783
Histrical trunk roads dummy	2.959	7.023	2.313	6.837	0.791	2.103	1.784	6.879
Coefficient of determination R^2	0.465		0.794		0.812		0.886	
Number of samples	620		1,168		863		1,194	

Table 2 *– Result of parameter estimation of interaction model for the purpose of sightseeing -Railway- (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Travel way time by railway between regions	—	—	1.059	12.522	1.430	15.811	2.009	22.466
Number of large-scale retail stores	—	—	—	—	0.215	2.263	—	—
Number of art and other museums	0.318	3.710	0.567	9.745	0.316	2.638	0.569	6.150
Number of national treasures and important cultural assets	0.317	6.138	0.228	8.274	0.123	2.713	0.306	8.766
Accommodation capacity of hot spring resorts	0.100	2.412	—	—	—	—	—	—
Number of leisure facilities	—	—	0.422	6.734	—	—	0.212	2.657
Rapid railway dummy	0.782	7.370	—	—	—	—	0.383	3.777
Histrical trunk roads dummy	—	—	0.868	9.350	—	—	—	—
Coefficient of determination R^2	0.412		0.632		0.519		0.741	
Number of samples	884		1,090		783		1,229	

As shown in Tables 1 and 2, all of estimated parameters meet the required conditions. Interaction for the purpose of sightseeing by airline is not strongly influenced by travel time by airline between regions in 1990 and 1995. Particularly, this index is excluded as a variable of this model in estimation process in 1995. On the other hand, interaction for airline is strongly influenced by travel time by railway in all years. This means that interaction for the purpose of sightseeing by airline is active between regions where railways are relatively convenient.

Interaction for the purpose of sightseeing of railway is strongly influenced by travel time. Therefore, it follows that it is active between regions where railway is convenient. It can be said that this tendency becomes stronger and stronger as t values of parameters show.

Interaction for the purpose of sightseeing is affected by the number of large-scale retail stores and leisure facilities, which reflect regional scale. Interaction is also affected by the number of art and other museums, national treasures and important cultural assets, which reflect the degree of regional quality. Here, it is clarified that the interaction of the purpose of sightseeing is affected by transportation convenience such as the frequency of airline flights per day. In addition, it is affected by dummy variables, which show whether regions are connected by historical trunk road and express railway. This means that the stronger the relationship between regions, the more active the interaction for the purpose of sightseeing is.

In addition, it can be said that people who emphasize travel time between regions choose airline as the mode of transportation, and who do not it choose railway in 1990. In 1995, people who choose airline as the mode of transportation is not effected by travel time. After the reduction of air fare by relaxation of regulations in 1997, people who travel for the purpose of sightseeing is affected by both travel time of airline and railway between regions. Therefore, interaction for the purpose of sightseeing is strongly influenced by change in condition by development of transportation facilities.

Parameter estimation of interaction model for the purpose of business

First, parameters of profit maximizing behaviour model for the purpose of business are estimated. We obtain equation (22) by taking the logarithm of both sides of equation (20). Parameters by two transportation modes are estimated using this equation. Estimation results for each mode are shown in Tables 3 and 4.

$$\ln Y_i = \mu \ln H_i + \alpha \ln S_i + (\beta + \gamma) \ln BB_i + \gamma \ln \frac{q_i}{w_i} + \ln \left\{ \eta \cdot \left(\frac{\gamma}{\beta} \right)^{\gamma} \right\} \qquad (22)$$

These results show that amount of production is strongly influenced by area of land. This variable correlates with number of employees L_i. Therefore, it can be said that amount of production is strongly affected by indexes presenting business scale. It is indicated that amount of generation of interaction for the purpose of business is affected by transportation facilities, too. However, especially in the results of railway in 1995 and 2000, t-values of half-day interchangeable employees and amount of generation of interaction are low. This means amount of production depends on a fixed scale as typified by area of land.

Table 3 *– Result of parameter estimation of profit maximizing behaviour model -Airline- (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Half-day interchangeable employee	0.119	1.540	0.180	2.041	0.146	2.063	0.370	4.529
Area of land	0.729	8.089	0.651	7.664	0.721	11.673	0.507	7.376
Amount of generation of interaction for the purpose of business	0.262	5.425	0.385	6.634	0.315	7.372	0.319	6.546
(q_i/w_i) index	0.162	0.912	0.362	1.350	-	-	-	-
Constant	-1.722	-0.973	-3.623	-1.772	-2.349	-2.006	-2.528	-2.062
Coefficient of determination R^2	0.914		0.925		0.909		0.859	
Number of samples	47		47		47		47	

***Table 4** – Result of parameter estimation of profit maximizing behaviour model -Railway- (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Half-day interchangeable employee	0.001	0.020	0.067	0.918	0.066	1.027	0.362	4.654
Area of land	0.651	5.465	0.760	5.010	0.725	4.470	0.415	3.843
Amount of generation of interaction for the purpose of business	0.297	3.484	0.063	0.708	0.070	0.800	0.179	3.292
(q_i/w_i) index	0.273	1.224	-	-	-	-	0.030	1.271
Constant	0.320	0.200	1.671	1.192	2.130	1.389	0.563	0.345
Coefficient of determination R^2	0.883		0.821		0.802		0.784	
Number of samples	46		47		47		47	

Next, parameters of model for amount of generation on interaction of business are estimated. It is assumed that amount of generation of airline and railway modes can be described as equations (23) and (24) based on equation (17). In other words, it is assumed that amount of generation on interaction for business travel using airlines is described using the value of production, frequency of airline per day, travel time of railway between regions and number of employees per unit time. The frequency of airline flights per day presents a kind of accessibility of airlines, and also travel time by railway between regions reflects accessibility of railways. It is considered that interaction for business travel using airlines is active between regions where airlines are relatively convenient but railways are not. It is assumed that amount of generation on interaction for business travel by railway can be described using amount of value of production and travel time by railway between regions. Results of estimation of the model for each mode are shown in Tables 5 and 6.

$$BB_i^{(A)} = a_A \cdot Y_i^{b_A} \cdot (A_i)^{c_{A1}} \cdot (\sum_j t_{ij}^{(R)} / 46)^{c_{A2}} \cdot \left\{\sum_j (L_j / t_{ij}^{(A)})\right\}^{c_{A3}} \quad (23)$$

$$BB_i^{(R)} = a_R \cdot Y_i^{b_R} \cdot (\sum_j t_{ij}^{(R)} / 46)^{c_{R1}} \quad (24)$$

$BB_i^{(A)}$: Amount of generation of interaction for the purpose for business travel by airlines in region i
A_i: Number of airline departures and arrivals per day in region i
$t_{ij}^{(R)}$: Travel time by railway between region i and region j
$t_{ij}^{(A)}$: Travel time by airline between region i and region j
L_j: Number of employee in region j
a_A, b_A, c_{A1}, c_{A2}, c_{A3}: Parameters on airline
$BB_i^{(R)}$: Amount of generation of interaction for the purpose for business travel by railway in region i
a_R, b_R, c_{R1}: Railway parameters

***Table 5** – Result of parameter estimation of model of origination volume of interaction for business -Airline- (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Amount of production	1.054	7.487	0.947	9.033	0.922	9.342	0.847	7.870
Frequency of airline flights per day	0.048	2.783	0.033	2.636	0.034	2.337	0.174	4.161
Travel time by railway between regions	1.022	2.702	0.881	3.293	0.834	3.277	0.714	2.071
Number of employee per unit time	-	-	-	-	2.394	4.482	2.661	5.687
Constant	-5.605	-2.224	-3.421	-1.831	-42.196	-4.823	-46.019	-5.920
Coefficient of determination R^2	0.615		0.693		0.793		0.821	
Number of samples	47		47		39		45	

***Table 6** – Result of parameter estimation of model of origination volume of interaction for business -Railway- (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Amount of production	0.854	8.754	1.010	13.682	0.864	9.660	0.859	8.801
Travel time by railway between regions	-2.620	-7.655	-2.404	-13.965	-2.938	-13.383	-2.712	-8.591
Constant	5.801	3.161	2.857	2.202	6.235	3.846	5.534	2.997
Coefficient of determination R^2	0.819		0.925		0.908		0.856	
Number of samples	46		47		47		46	

As Tables 5 and 6 show, amount of generation of interaction for the purpose of business is affected by amount of production of both transportation modes in all time periods. Interaction of airlines is affected by the frequency of airline flights per day and travel time by railway between regions. In 2000 and 2005, amount of generation of interaction is influenced by number of employees, too. Interaction by railway is strongly affected by travel time by railway between regions.

Third, in order to estimate parameters, equation (19) is substituted for equation (18), and the logarithm of both sides of equation (18) are taken. Finally, equation (25) is obtained and we can estimate parameters using regression analysis. Tables 7 and 8 show results of parameter estimation for each transportation mode.

$$\ln \frac{BB_{ij}}{BB_i} = \sum_k a^{(k)} \ln V^{(k)}{}_{ij} \qquad (25)$$

***Table 7** – Result of parameter estimation of allocation model of interaction for business -Airline- (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Travel time by airline between regions	-	-	-	-	-1.769	-5.432	-1.134	-3.524
Number of employee in destination region	0.924	8.122	0.353	2.462	0.518	3.030	0.609	3.340
Employee ratio of managerial position in destination region	1.845	1.812	-	-	1.684	2.988	-	-
Travel time by railway between regions	-	-	-	-	0.473	4.699	0.665	3.551
Shinkansen dummy	-0.543	-2.510	-0.374	-2.694	-0.305	-1.972	-0.603	-3.390
Frequency of airline flights per day	0.485	8.416	0.341	7.499	0.349	6.449	0.251	6.964
Tokyo dummy	0.656	2.361	2.098	4.978	1.757	3.583	1.690	3.268
Government-ordinance-designated city dummy	-	-	0.812	3.322	0.509	1.819	0.743	2.501
Constant	1.668	0.162	-9.300	-4.885	6.648	1.212	-12.835	-5.387
Coefficient of determination R^2	0.628		0.628		0.632		0.657	
Number of samples	202		257		290		249	

***Table 8** – Result of parameter estimation of allocation model of interaction for business -Railway- (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Travel time by railway between regions	-1.455	-22.858	-1.746	-27.771	-1.768	-24.469	-2.179	-30.471
Number of employee in destination region	0.635	10.114	0.966	21.109	0.770	14.605	0.795	17.752
Employee ratio of managerial position in destination region	-	-	0.751	3.280	-	-	-	-
Ratio of main office in overall industry	-	-	-	-	0.948	3.334	1.681	7.236
Shinkansen dummy	0.393	5.218	-	-	-	-	-	-
Tokyo dummy	1.343	5.670	0.806	3.581	0.532	2.006	-	-
Government-ordinance-designated city dummy	0.293	2.827	-	-	-	-	-	-
Constant	0.151	0.145	-8.029	-3.216	-9.516	-6.924	-6.671	-5.446
Coefficient of determination R^2	0.476		0.507		0.471		0.542	
Number of samples	1,399		1,534		1,326		1,506	

As shown in Tables 7 and 8, all of parameters meet the required conditions. It was found that coefficients of determination are not satisfactory. However, some conclusions can be made from the results. Concerning airline use, volume of interaction for the purpose of business between regions is strongly influenced by number of employees in destination region and frequency of airline flights per day. When the regions are connected by Shinkansen (bullet train) there is a tendency that people do not use airlines for interaction for business, because the parameter of Shinkansen dummy variable has a negative sign. Concerning railways, interaction is strongly affected by travel time by railway between regions and number of employees in destination region. In addition, which have a high rate of company offices and industry show a tendency to be chosen as destination of interaction for business.

Amount of production is described using amount of generation on interaction for business in equation (15). On the other hand, these appear in an opposite position in equation (17). In this way, these two indexes have recurrent relationship, so iterative calculation is needed for these two equations. The iterative calculation method is defined as follows. It is assumed that estimation value of amount of production and generation of interaction for business which is regarded as being converged in the nth iterative calculation. These are individually shown as $Y_i(E)^{(n)}$ and $BB_i(E)^{(n)}$, when actual production value is shown as $Y_i(A)$.

Each estimated value is calculated as shown in Table 9. Converged criterion is defined as using estimated value of production and generation of interaction for business which are calculated as the nth and (n-1)th round of iterative calculation with an error rate (%). Thus, it is regarded as beingconverged at the time of meeting both requirements that are equations (26) and (27).

***Table 9** – Iterative calculation method of interaction for the purpose of business*

	Profit Maximazation Model $Y_i=\eta \cdot H_i^{\mu} \cdot S_i^{\alpha} \cdot BB_i^{\beta} \cdot L_i^{\gamma}$ Production Value Y_i	Model of Origination Volume on Interaction for Business $BB_i=a \cdot Y_i^{b} \cdot \Sigma_k(ACC_i)^{c_k}$ Origination Volume on Interaction for Business BB_i
first	$Y_i(E)^{(1)}=\eta \cdot H_i^{\mu} \cdot S_i^{\alpha} \cdot (BB_i(A))^{\beta} \cdot L_i^{\gamma}$	$BB_i(E)^{(1)}=a \cdot (Y_i(E)^{(1)})^{b} \cdot \Sigma_k(ACC_i)^{c_k}$
second	$Y_i(E)^{(2)}=\eta \cdot H_i^{\mu} \cdot S_i^{\alpha} \cdot (BB_i(E)^{(1)})^{\beta} \cdot L_i^{\gamma}$	$BB_i(E)^{(2)}=a \cdot (Y_i(E)^{(2)})^{b} \cdot \Sigma_k(ACC_i)^{c_k}$
third	$Y_i(E)^{(3)}=\eta \cdot H_i^{\mu} \cdot S_i^{\alpha} \cdot (BB_i(E)^{(2)})^{\beta} \cdot L_i^{\gamma}$	$BB_i(E)^{(3)}=a \cdot (Y_i(E)^{(3)})^{b} \cdot \Sigma_k(ACC_i)^{c_k}$
⋮	⋮	⋮
nth	$Y_i(E)^{(n)}=\eta \cdot H_i^{\mu} \cdot S_i^{\alpha} \cdot (BB_i(E)^{(n-1)})^{\beta} \cdot L_i^{\gamma}$	$BB_i(E)^{(n)}=a \cdot (Y_i(E)^{(n)})^{b} \cdot \Sigma_k(ACC_i)^{c_k}$

$$\frac{Y_i(E)^{(n)} - Y_i(E)^{(n-1)}}{Y_i(E)^{(n)}} \times 100 < 0.001\,(\%) \tag{26}$$

$$\frac{BB_i(E)^{(n)} - BB_i(E)^{(n-1)}}{BB_i(E)^{(n)}} \times 100 < 0.001\,(\%) \tag{27}$$

Parameter estimation of migration model in consideration of interaction

Equation (28) is obtained by substituting equations (5) and (6) for equation (1).

$$\frac{X_{ij}}{P_i} = \alpha\left(a\ln\frac{W_j}{W_i} + b\ln\frac{r_j}{r_i} + c\ln\frac{H_j}{H_i}\right) + \beta\left\{ k_B \ln\left(\frac{BS_{ij}+BB_{ij}}{P_i} + \frac{BS_{ji}+BB_{ji}}{P_j}\right)\right\} + \gamma$$
$$\frac{X_{ji}}{P_j} = \alpha\left(a\ln g\frac{W_i}{W_j} + b\ln\frac{r_i}{r_j} + c\ln\frac{H_i}{H_j}\right) + \beta\left\{ k_B \ln\left(\frac{BS_{ij}+BB_{ij}}{P_i} + \frac{BS_{ji}+BB_{ji}}{P_j}\right)\right\} + \gamma \qquad (28)$$

Tokyo prefecture is the centre of politics, economics, culture and so on in Japan. Such things accumulate are more in this area than in other prefectures, accordingly it is expected that in-flow of migration to the area is much greater than other areas. In addition, it is expected that this phenomenon founds in government-ordinance-designated city, too. For this reason, Tokyo dummy and government-ordinance-designated city dummy variables are introduced into the model as equation (29) when migration flow of these prefectures is addressed.

$$\frac{X_{ij}}{P_i} = \alpha\left(a\ln\frac{w_j}{w_i} + b\ln\frac{r_j}{r_i} + c\ln\frac{H_j}{H_i}\right) + \beta\left\{ k_B \ln\left(\frac{BS_{ij}+BB_{ij}}{P_i} + \frac{BS_{ji}+BB_{ji}}{P_j}\right)\right\} + k_T\delta(T_j) + k_C\delta(C_j) + \gamma$$
$$\frac{X_{ji}}{P_j} = \alpha\left(a\ln g\frac{w_i}{w_j} + b\ln\frac{r_i}{r_j} + c\ln\frac{H_i}{H_j}\right) + \beta\left\{ k_B \ln\left(\frac{BS_{ij}+BB_{ij}}{P_i} + \frac{BS_{ji}+BB_{ji}}{P_j}\right)\right\} + k_T\delta(T_i) + k_C\delta(C_i) + \gamma \qquad (29)$$

$\delta(T_j)$, $\delta(T_i)$: Dummy variables, if region i, j is Tokyo, this parameter is 1, on the contrary to that, this parameter is 0.
$\delta(C_j)$, $\delta(C_i)$: Dummy variables, if region i, j is prefecture which is included in government-ordinance-designated city, this parameter is 1, on the contrary to that, this parameter is 0.
k_T, k_C: Parameters

This migration model is estimated by a multiple regression analysis. Results of estimation of the model for each term are shown in Table 10. Rate of interaction for the purpose of sightseeing and business is calculated as the sum of amount of interaction for the purpose of sightseeing and business divided by the population of departure place. This index is calculated using actual interaction data which are used in the analysis of parameter estimation of interaction models. Residential land price and half-day interchangeable population, which are introduced in utility function as dependent variables, show a strong correlation with employment opportunity, therefore these variables are eliminated from the migration model in this study. No multiple collinearity between other dependent variables was observed.

***Table 10** – Result of parameter estimation of migration model (1990-2005)*

Variable	1990		1995		2000		2005	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Employment opportunities	0.0002	13.929	0.0002	16.943	0.0002	19.283	0.0002	18.459
Rate of interaction for the purpose of sightseeing and business	0.0003	30.240	0.0003	38.026	0.0003	38.981	0.0002	26.023
Tokyo dummy	0.0014	13.139	0.0009	10.071	0.0009	11.468	0.0010	11.013
Government-ordinance-designated city dummy	0.0002	4.008	-	-	-	-	-	-
Constant	0.0013	35.497	0.0014	48.062	0.0013	49.613	0.0012	34.286
Coefficient of determination R^2	0.511		0.526		0.556		0.440	
Number of samples	2,002		2,038		2,030		2,040	

As shown in Table 10, rate of interaction for the purpose of sightseeing and business has the greatest effect on migration in all periods of time. Migration is strongly influenced by employment opportunity, too. As previously discussed, interaction for the purpose of sightseeing and business is influenced by various indexes which include improvement of transportation facilities such as travel time and frequency of airline flights per day, regional attractiveness and regional economic situation. This means that migration is influenced by many kinds of indexes as well as indexes shown in table 10. In addition, interaction for the purpose of sightseeing is described using a dummy variable of historical trunk road and express railway. This shows that interaction and migration is influenced by whether regions have historical psychological relationship and geographical relationship.

Government-ordinance-designated city dummy is introduced into the migration model because migration flow to prefectures having been government-ordinance-designated city from other prefectures shows a different tendency when compared with that of other prefectures. However, this variable effects migration only in 1990 and after that, it is not included in the model as a dependent variable. From these results, it can be seen that people tend to favour big cities such as government- ordinance-designated cities as destination place in 1990. After that, it is not considered that migration flow to big cities is special. On the other hand, the Tokyo dummy variable is included in the migration model in all periods. This means that Tokyo is an attractive place to live.

POLITICAL SIMULATION USING THE MIGRATION MODEL

Relationship among migration, interaction and regional condition

As mentioned above, we point out relationship between migration, interaction and regional condition through the migration and interaction models estimated before. How these “movements of people” are related can be described as presented in Figure 4. As shown in this figure, first, improvement of transportation facilities effects change in the traffic condition between regions. Regional accessibility changes with this change, and it directly influences interaction between regions for the purpose of sightseeing and business. Additionally, change in regional condition with change in convenience of transportation effects interaction for the purpose of business. Change in interaction between regions leads to change in migration between regions, because migration is effected by interaction which is clarified by constructing the migration model. Then, migration between regions effects population and the amount of the required conditions and employees with change in population, and this leads a change in interaction. Change in interaction leads a change in migration. In this way, regional condition, interaction between regions and migration between regions influence each other and are intimately related to each other.

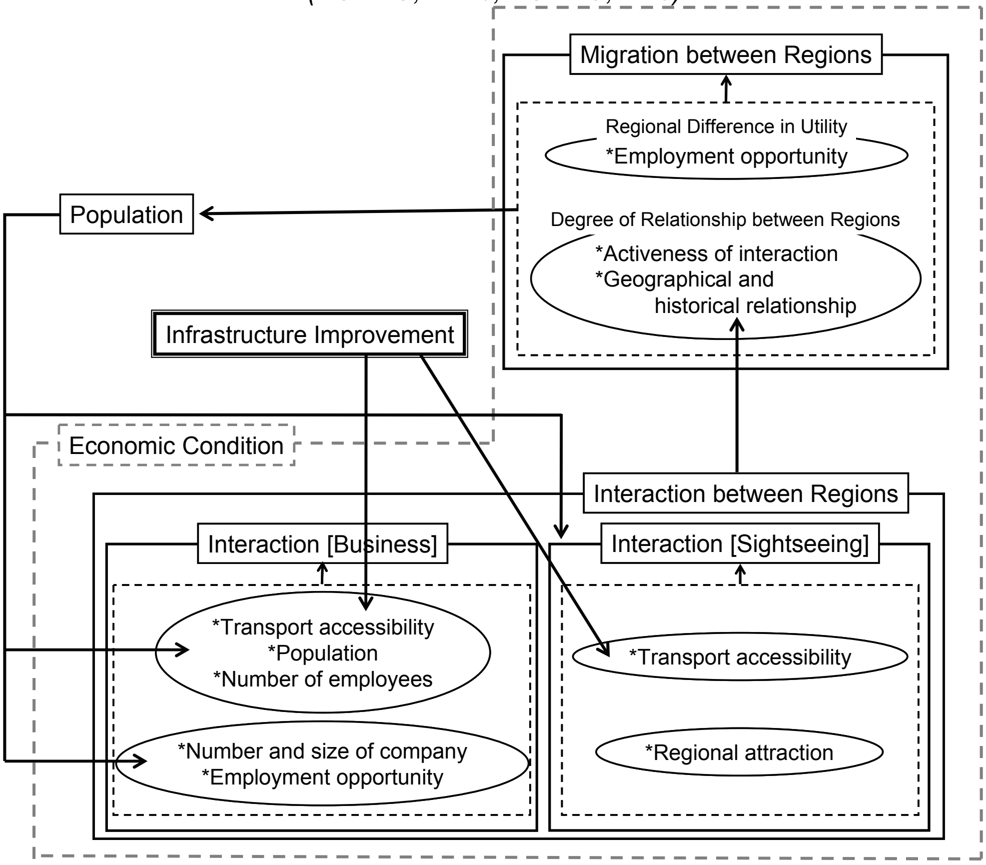

***Figure 4** – Relation of "movement of people"*

As previously discussed, these "movements of people" are strongly related to regional economic condition of departure place. Amount of production is introduced into model of amount of generation of interaction for business. Thus, it can be said that we should consider a direct effect of economic condition on an interaction between regions for the purpose of business. Concerning an interaction between regions for the purpose of sightseeing, we can consider an indirect effect of economic condition by introduction of indexes of regional attractiveness indexes being introduced into the model. Concerning migration between regions, the migration model includes employment opportunity as indirect economic index. It is only considered that difference of economic condition between departure and destination places which is comparative value. It cannot be compared in chronological order. However, the migration model incorporates rate of interaction for the purpose of sightseeing and business as an index which shows the degree of relationship between regions, which reflects regional economic condition.

Method of simulation using migration and interaction models

We suggest a simulation method of migration and interaction models here. A simulation in case that travel time is reduced by improvement of transportation facilities is taken as an example. In this regard, we do not consider ripple effects such as expansion of regional economics and firm's productivity, change of employment opportunity and the amount of employee by improvement of transportation facilities in this study. The method of simulation method is shown in Figure 5, and the simulation process is shown in Figure 6.

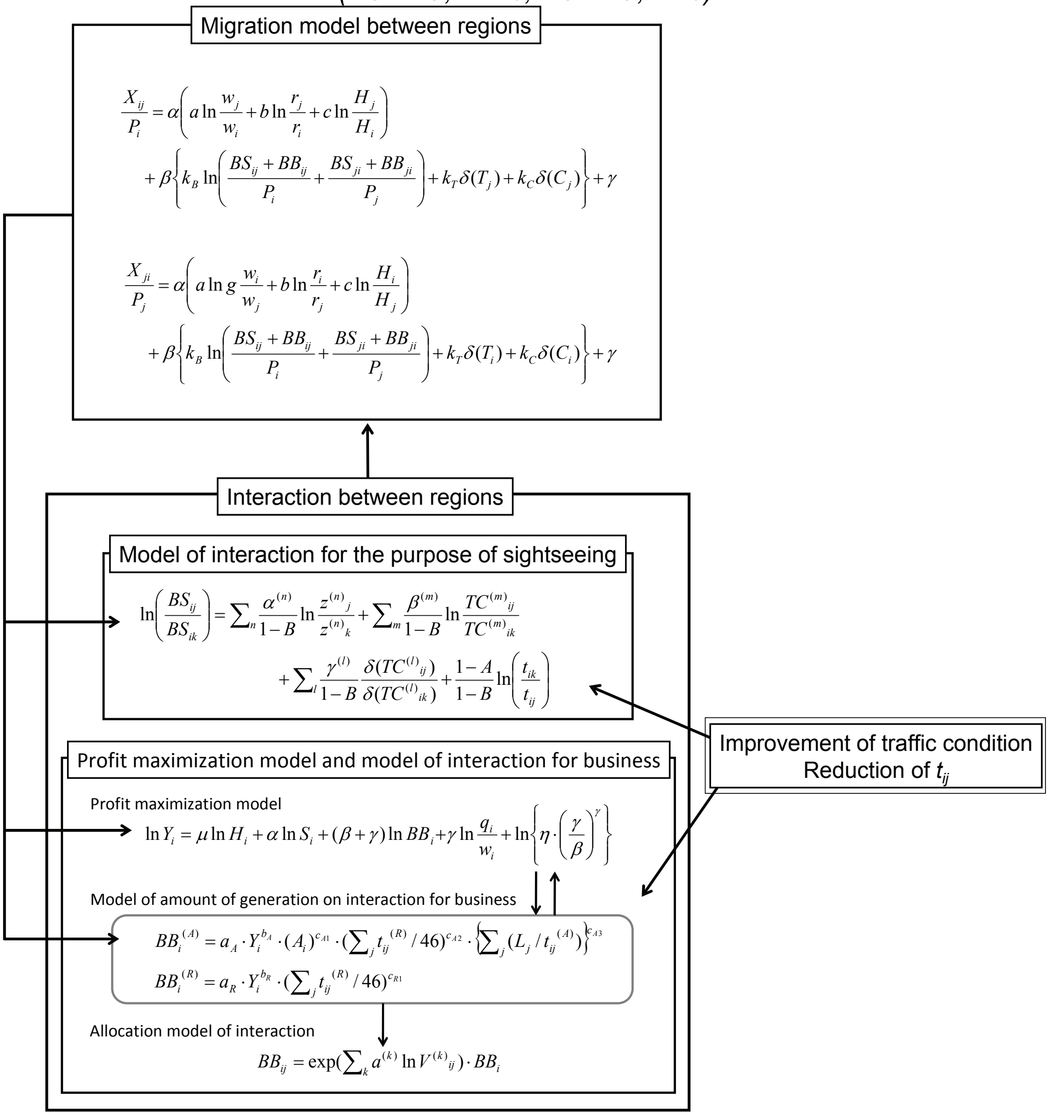

Figure 5 *– Method of simulation using migration and interaction models*

As a first step, change in interaction between regions by reduction of travel time is analyzed. As a second step, change in migration between regions by change in interaction between regions. As a third step, it is analyzed that change in population by change in migration is simulated. As a forth step, change in interaction between regions by change in population is examined. These steps are then repeated.

This simulation enables us to obtain results in which relationship between migration, interaction, population, socioeconomic condition and convenience of transportation can be considered.

Reduction of travel time between regions by improvement of transportation facilities

↓

Kinds of model	Influenced variables	Effect
Interaction model for the purpose of sightseeing	Travel time by airline between regions	Change in interaction between regions
	Travel time by railway between regions	
Profit maximizaing behavior model	Half-day interchangeable employee	
	Amount of generation of interaction for business	
Model of amount of generation of interaction for business	Value of production	
	Travel time of railway between regions	
	Number of employee per unit time	
Allocation model of interaction for business	Travel time by airline between regions	
	Travel time by railway between regions	

↓

Kinds of model	Influenced variables	Effect
Migration model between regions	Rate of Interaction for the purpose of sightseeing and business	Change in migration between regions

↓

Change in population in a region

↓

Kinds of model	Influenced variables	Effect
Interaction model for the purpose of sightseeing	Population in a region	Change in interaction between regions

↓

Kinds of model	Influenced variables	Effect
Migration model between regions	Rate of Interaction for the purpose of sightseeing and business	Change in migration between regions

↓

Change in population in a region

Figure 6 *– Simulation process in case of reduction of travel time*

CONCLUSION

In this study, we focussed upon the “movement of people” which is one of the most fundamental and important factors to revitalize regions. In order to clarify mechanisms of migration and interaction between regions, migration and interaction models were constructed with the intention to use them for application to effective analysis of improvement of infrastructure. The migration model was theoretically constructed based on the Utility Maximization Theory. This is founded on regional difference in utility which is the theory that individual choice of place to live depends on the utility. Degree of relationship between regions was incorporated into the model. In addition, we developed models of migration and interaction between regions in which their relationship were incorporated explicitly.

From the results, was clarified that migration between regions is strongly influenced by interaction between regions as well as employment opportunity. In addition, interaction models for the purpose were constructed using various variables which show the socioeconomic condition and convenience of transportation and so on. As a result, it was shown that migration is strongly related to regional difference in utility and degree of relationship between regions. The regional relationship is explained by activeness of interaction between regions as well as the geographical and historical relationship between regions. In addition, it was clarified that interaction between regions is closely related to convenience of transportation by two kinds of models. The relationship between migration, interaction, infrastructure improvement and economic condition was clarified.

It is clarified that "movement of people" such as migration and interaction between regions is huge influenced by change in condition by development of transportation facilities and the degree of relationship between regions such as the existence of historical trunk roads. Recently in Japan, we have been facing serious concerns related to rapid aging and a very low birthrate, and it is widely known that the population will start to decrease rapidly after its peak in 2004. In such a situation, many rural regions have difficulty to sustain their communities. Thus, it is important to increase population by increasing of in-flow of migration into rural regions. The result of this study is expected to contribute to further revitalization of regions as well as to help sustain regions. Interaction between regions was focused upon as factors of regional revitalization. In other words, we show that appropriate improvement of transportation facilities can make rural regions maintain and promote the vitality in Japan.

The models and method of simulation in this study are useful when effectiveness of infrastructure development is analyzed regional policies are simulated. It can be said that results obtained in this study contribute to advance national and regional policy in the future.

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