POPULATION DISTRIBUTION CHANGE DUE TO THE SHINKANSEN PROJECT IN JAPAN

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Abstract: This paper presents a population distribution model, which can estimate change of the industrial and generational classified population distribution due to the future interregional transport development, and can forecast its effect to the nationwide structure. By applying this model to the Shinkansen project in Japan, this paper analyzes change of the industrial and generational classified population distribution due to it, and looks over its influence to the industrial structure and the generational structure of Japan. As a result, this paper will be able to find that the Shinkansen project in Japan may have some possibilities.

1. INTRODUCTION

The interregional transport development, such as the expressway network project, the high speed railway network project and the airline network project, may make a possibility of interchange of personnel and material better among regions which are connected by such transport systems, and expects a higher growth of all those regions. So, it has been said that the interregional rapid transport modes help deconcentrate the population because it can provide transportation convenience for people living in the rural regions [National Land Agency (1987)]. However, there are some cases that the agglomerate region enjoys the more benefit than the non-agglomerate one, and some analysts point out it as the straw-effect. If some interregional transport facility is constructed between the urban and the rural regions, the urban region might have more concentration of population, where the facility seems to be a straw which absorb population and economy from the rural region. Then, we have to recognize that the interregional transport development has two big problems concerning disequilibrium in the nationwide area; one is disequilibrium of the industrial structure and the other is that of the generational structure.

Ueda and Nakamura (1989) arranged the relationship between the interregional transport development and the growth or the decline of regions through a demonstrative analysis of the Tohoku Shinkansen and the Joetsu Shinkansen project, where analysis was limited to some qualitative evaluation based on statistic data. As for the quantitative analysis, Ueda and Matsuba (1995), Mun (1995), Kobayashi and Okumura (1996), Koike *et al.* (1996), Ohno and Hosomi (1996) and others constructed some socio-economic model and analyzed the impact of the interregional transport development, where analysis was mostly limited to some model analysis or some numerical test.

This paper presents a population distribution model, which can estimate change of the industrial and generational classified population distribution due to the future interregional transport development, and can forecast its effect to the nationwide structure. By applying this model to the Shinkansen project in Japan, this paper analyzes change of the industrial and generational classified population distribution due to it, and looks over its influence to the industrial structure and the generational structure of Japan. As a result, this paper will be able to find that the Shinkansen project in Japan may have some possibilities.

2. THE MODEL

2.1 Framework of the Model

The interregional transport development influence directly the accessibility of each region, and then the productivity of each industry, the labor distribution and the population distribution will change in order. Through the market mechanism, after those changes, the land price and the wage rate will change. And further, the accessibility of each region may change again. In those change flow (see figure 1), this study models the population distribution in each generation in each industry and tries to explain the change of industrial and generational population distribution due to the interregional transport development.

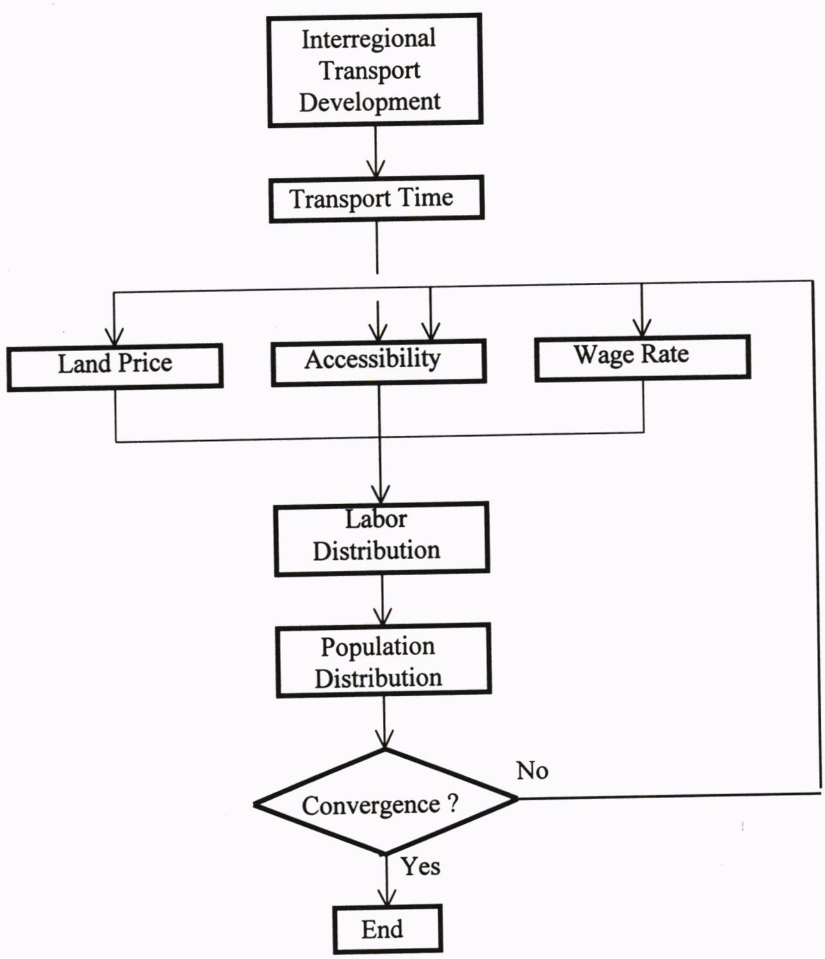

Figure 1. Framework of the Model

2.2 Labor Distribution Model

The labor distribution model is expressed in a logit model:

$$P_i^{nk} = \frac{\exp\left[\omega V_i^{nk}\right]}{\sum_j \exp\left[\omega V_j^{nk}\right]}, \tag{1}$$

where P_i^{nk} : location probability of region i in generation n and industry k,
V_i^{nk} : location utility of region i in generation n and industry k,
ω : distribution parameter of error term added to location utility V_i^{nk}, $\omega \equiv 1$,

and where the generation n is classified into three groups (20-34, 35-49, and 50-64 years-old), and the industry k is done into six groups (construction, manufacture, transport and communication, wholesale and retail, finance and insurance, and service industries).

The location attraction V_i^{nk} means attraction of the region for labors' location, and is formulated as

$$V_i^{nk} = \alpha_1^{nk} + \alpha_2^{nk} \ln\left[r_i\right] + \alpha_3^{nk} \ln\left[w_i^{nk}\right] + \alpha_4^{nk} \ln\left[A_i\right], \tag{2}$$

where r_i : land price of region i, (yen/m^2),
w_i^{nk} : wage rate of region i in generation n and industry k, ($\times 10^4$ yen/person/year),
A_i : accessibility index of region i,
$\alpha_1^{nk}, \alpha_2^{nk}, \alpha_3^{nk}, \alpha_4^{nk}$: unknown parameters.

2.3 Land Price Model

The land price r_i in equation (2) must be decided by the market mechanism, and is formulated as [Morisugi *et al.* (1988)]

$$r_i = \exp\left[\phi_1 + \phi_2 \ln\left[\frac{N_i}{S_i}\right] + \phi_3\left(T - 1900\right) + \phi_4 \chi^B\right], \tag{3}$$

where N_i : population of region i, (persons),
S_i : habitable area of region i, (km^2),
T : year of the Christian Era,
χ^B : dummy variable of the bubble period,
$\phi_1, \phi_2, \phi_3, \phi_4$: unknown parameters.

2.4 Wage Rate Model

The wage rate w_i^{nk} in equation (2) must be also decided by the market mechanism, which is formulated as

$$w_i^{nk} = \exp\left[\varphi_1^k + \varphi_2^k \ln\left[L_i^k\right] + \varphi_3^k \chi^{20-34} + \varphi_4^k \chi^{35-49}\right], \tag{4}$$

where L_i^k : labor number of industry k in region i, (persons),

χ^{20-34} : dummy variable of generation 20-34 years-old,

χ^{35-49} : dummy variable of generation 35-49 years-old,

$\varphi_1, \varphi_2, \varphi_3, \varphi_4$: unknown parameters.

2.5 Accessibility Index

The accessibility index A_i in equation (2) is defined as

$$A_i = \sum_j N_j \exp\left[-\frac{\beta_1 t_{ij}}{\left(N_i \times 10^{-6}\right)^{\beta_2}} \right], \tag{5}$$

where t_{ij} : transport time between region i and j, (hours),

N_i : population of region i, (persons),

β_1, β_2 : unknown parameters.

Equation (5) is based on the idea of the market size of region i. The more the transport time t_{ij} is reduced by the interregional transport development, the more the population of region j must be counted in the market of region i. The more the population of region i is increased by the intraregional development, the more the market size of region i must be increased from the viewpoint of the location concentration.

2.6 Population Model

The population N_i in equations (3) and (5) is defined as

$$N_i = \sum_n N_i^n, \tag{6.1}$$

$$N_i^n = \theta^n L_i^n, \tag{6.2}$$

where N_i^n : population of generation n in region i, (persons),

L_i^n : labor number of generation n in region i, (persons),

θ^n : unknown parameter.

Classification of the generation n in equations (6.1) and (6.2) is same as that in equation (1), which is classified into three groups (20-34, 35-49, and 50-64 years-old). Then the population under 19 years-old and over 65 years-old are assumed to be defined by those generations as

$$N_i^{0-19} = \delta_{11} + \delta_{12} N_i^{20-34} + \delta_{13} N_i^{35-49} + \delta_{14} N_i^{50-64}, \tag{7.1}$$

$$N_i^{65-} = \delta_{21} + \delta_{22} N_i^{20-34} + \delta_{23} N_i^{35-49} + \delta_{24} N_i^{50-64}, \tag{7.2}$$

where $\delta_{11}, \delta_{12}, \delta_{13}, \delta_{14}, \delta_{21}, \delta_{22}, \delta_{23}, \delta_{24}$: unknown parameters.

2.7 Labor Model

The labor number L_i^k in equation (4) and L_i^n in equation (6) are defined as

$$L_i^n = \sum_k L_i^{nk}, \tag{8.1}$$

$$L_i^k = \sum_n L_i^{nk}, \tag{8.2}$$

where L_i^{nk} : labor number of generation n of industry k in region i, which is derived from the following equation.

The labor number L_i^{nk} is

$$L_i^{nk} = P_i^{nk} L^{nk}, \tag{9}$$

where P_i^{nk} : location probability, which is formulated as equation (1),
L^{nk} : labor number of generation n of industry k, which is derived from the following equations.

The labor number L^{nk} is

$$L^{20-34k} = \pi^{20-34k} L^{20-34}, \tag{10.1}$$

$$L^{35-49k} = \lambda^{20-34k} \sum_k L^{20-34k}, \tag{10.2}$$

$$L^{50-64k} = \lambda^{35-49k} \sum_k L^{35-49k}, \tag{10.3}$$

where L^n : labor number of generation n,
π^{20-34k} : ratio of labor number of industry k in generation 20-34 yeas-old, which is fixed by the past data,
λ^{20-34k}, λ^{35-49k} : coefficients, which are fixed by the past data,

and where the formulation is based on the idea of the cohort model.

2.8 Control Total

This population distribution model requires the control total N^n, which is the total population of generation n exogenously. When the future population distribution will be estimated, the future value N^n will be also necessary. This study employs the value N^n of the World Bank's long-term estimates in 1990-2035 [The International Bank for Reconstruction and Development / The World Bank (1994)].

3. ESTIMATED PARAMETERS OF THE MODEL

3.1 Zoning and Data

Zoning of Japan is based on the prefecture, except for Okinawa Prefecture. So Japan is divided into 46 regions (see figure 2). Data set to estimate parameters of the model includes population of each generation, labor number of each generation of each industry, land price, wage rate of each industry and transport time, which is measured by using the fastest railways between each two prefectures in 1975-90 [National Land Agency (1975-90)].

3.2 Estimated Parameters of the Model

Parameters of the labor distribution model, equations (1) and (2), are estimated as shown in table 1.1-1.3. Those of the land price model, equation (3), are estimated as shown in table 2. Those of the wage rate model, equation (4), are estimated as shown in table 3. Those of the accessibility index, equation (5), are set as shown in table 4, so as to get high fitness (the highest R^2) of equation (1). Those of the population models, equations (6) and (7.1)-(7.2), are estimated as shown in tables 5.1 and 5.2, respectively. Finally, those of the labor models, equations (10.1)-(10.3), are fixed by the past data.

3.3 Calibration of the Model

By using those estimated parameters, the population distribution model, which consists of those models mentioned in the previous chapter, can not always reproduce the present pattern. In this case there may be a difficulty to find the population distribution change due to some transport project, so the model is calibrated by introducing the adjustment term to each model so as to do the pattern in 1990.

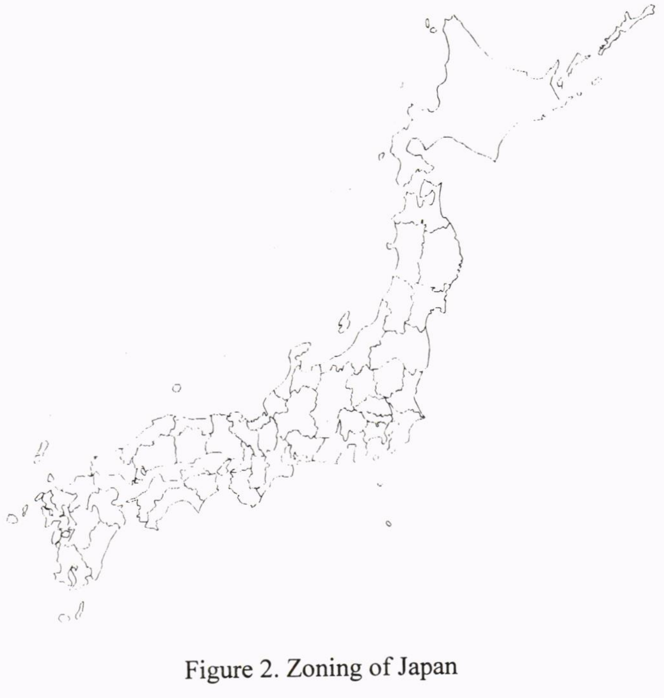

Figure 2. Zoning of Japan

Table 1.1 Estimated Parameters of Labor Distribution Model (20-34 years-old)

Industries	α_1 (Constant)	α_2 (Land Price)	α_3 (Wage Rate)	α_4 (Access.)	R^2
Construction	-0.009 [-0.16]	-0.043 [-1.50]	0.051 [0.25]	1.100 [32.4]	0.98
Manufacture	0.460 [3.00]	-0.120 [-1.40]	1.860 [2.60]	0.460 [9.50]	0.88
Transport and Communication	-0.011 [-0.18]	0.021 [0.69]	0.010 [0.05]	1.180 [30.6]	0.98
Wholesale and Retail	0.690 [5.90]	0.140 [2.00]	-0.480 [-0.78]	0.370 [14.1]	0.93
Finance and Insurance	0.680 [7.40]	0.036 [0.68]	1.140 [2.10]	0.420 [14.4]	0.95
Service	0.880 [8.40]	0.080 [1.30]	-0.006 [-0.01]	0.350 [13.5]	0.93

Note) Values in [ ] mean t-value.

Table 1.2 Estimated Parameters of Labor Distribution Model (35-49 years-old)

Industries	α_1 (Constant)	α_2 (Land Price)	α_3 (Wage Rate)	α_4 (Access.)	R^2
Construction	-0.086 [-1.20]	-0.004 [-0.10]	-0.230 [-1.08]	0.990 [22.1]	0.96
Manufacture	0.160 [1.33]	-0.059 [-0.87]	0.960 [2.10]	0.440 [11.7]	0.91
Transport and Communication	-0.160 [-3.30]	-0.004 [-0.15]	-0.053 [-0.32]	1.100 [33.4]	0.98
Wholesale and Retail	0.560 [5.50]	0.068 [1.10]	0.068 [0.14]	0.360 [14.3]	0.93
Finance and Insurance	0.480 [3.80]	0.067 [0.93]	0.520 [0.81]	0.400 [11.2]	0.91
Service	0.690 [7.20]	-0.008 [-0.14]	0.580 [1.40]	0.330 [13.7]	0.93

Note) Values in [ ] mean t-value.

Table 1.3 Estimated Parameters of Labor Distribution Model (50-64 years-old)

Industries	α_1 (Constant)	α_2 (Land Price)	α_3 (Wage Rate)	α_4 (Access.)	R^2
Construction	0.079 [0.75]	-0.190 [-3.00]	0.460 [1.75]	0.980 [14.7]	0.90
Manufacture	0.240 [1.70]	-0.010 [-0.13]	1.030 [2.03]	0.420 [9.90]	0.90
Transport and Communication	-0.190 [-2.80]	0.018 [0.51]	0.160 [0.74]	0.080 [24.7]	0.97
Wholesale and Retail	0.610 [6.10]	0.041 [0.75]	0.580 [1.60]	0.350 [13.1]	0.93
Finance and Insurance	0.600 [5.20]	0.062 [1.10]	0.420 [0.91]	0.430 [13.8]	0.94
Service	0.730 [6.40]	-0.007 [-0.13]	0.330 [1.10]	0.360 [13.7]	0.92

Note) Values in [ ] mean t-value.

Table 2. Estimated Parameters of Land Price Model

	ϕ_1 (Constant)	ϕ_2 (Density)	ϕ_3 (Year)	ϕ_4 (Dummy) (Bubble)	R^2
(Coefficient)	1.502 [1.40]	0.764 [15.7]	0.063 [4.60]	0.217 [1.40]	0.71

Note) Values in [ ] mean t-value.

Table 3. Estimated Parameters of Wage Rate Model

Industries	φ_1 (Constant)	φ_2 (Labor)	φ_3 (Dummy) (20-34)	φ_4 (Dummy) (35-49)	R^2
Construction	4.010 [21.5]	0.150 [9.10]	-0.230 [-8.20]	0.063 [2.30]	0.61
Manufacture	4.450 [42.7]	0.110 [13.0]	-0.330 [-19.5]	0.027 [1.60]	0.84
Transport and Communication	5.070 [44.8]	0.085 [8.20]	-0.300 [-14.5]	-0.032 [-1.50]	0.71
Wholesale and Retail	4.380 [40.1]	0.120 [13.2]	-0.420 [-24.7]	-0.004 [-0.25]	0.88
Finance and Insurance	5.300 [77.3]	0.081 [12.3]	-0.560 [-41.4]	0.030 [2.20]	0.95
Service	4.460 [36.4]	0.110 [11.1]	-0.400 [-21.8]	0.002 [0.13]	0.85

Note) Values in [ ] mean t-value.

Table 4. Fixed Parameters of Accessibility Index

Industries	20-34 years-old		35-49 years-old		50-64 years-old	
	β_1	β_2	β_1	β_2	β_1	β_2
Construction	$1.1*10^2$	1.0	$7.0*10^2$	1.0	$7.4*10^1$	1.0
Manufacture	7.9	2.0	7.1	2.0	6.6	2.0
Transport and Communication	$7.0*10^2$	1.0	$7.0*10^2$	1.0	$8.5*10^1$	1.0
Wholesale and Retail	$1.1*10^2$	5.0	$1.2*10^2$	5.0	$2.8*10^2$	5.0
Finance and Insurance	$3.3*10^1$	3.0	$2.3*10^1$	3.0	$3.3*10^1$	3.0
Service	$1.2*10^2$	5.0	$1.5*10^2$	5.0	$2.2*10^2$	5.0

Table 5.1 Estimated Parameters of Population Model (20-64 years-old)

Generations	θ	R^2
20-34 years-old	1.486 [175.3]	0.997
35-49 years-old	1.389 [146.6]	0.996
50-64 years-old	1.678 [65.90]	0.976

Note) Values in [ ] mean t-value.

Table 5.2 Estimated Parameters of Population Model (under 19 or over 65 years-old)

Generations	$\delta_{\bullet 1}$ (Constant)	$\delta_{\bullet 2}$ (20-34 Pop)	$\delta_{\bullet 3}$ (35-49 Pop.)	$\delta_{\bullet 4}$ (50-64 Pop.)	R^2
under 19 years-old	-	-0.515 [-10.4]	1.560 [33.9]	-	0.997
over 65 years-old	25,668 [3.40]	-0.135 [-3.00]	-0.370 [-6.60]	1.224 [15.2]	0.991

Note) Values in [ ] mean t-value.

4. THE PROJECT

The project to analyze here is the Chuo Linear Shinkansen project (see figure 3) which is the most notable one of the interregional transport development in Japan [Japan Transport Economic Research Center (1993)]. The Chuo Linear Shinkansen connects Tokyo with Osaka for 1 hour while it takes 2.5 hours at present, and will be finished by 2015.

Now, this study supposes two cases in 2015. One is the case with the Shinkansen project, that is the with-case where the interregional transport time is developed by the project, and the other is the case without the Shinkansen project, that is the without-case where the transport time is assumed to be still in 1995.

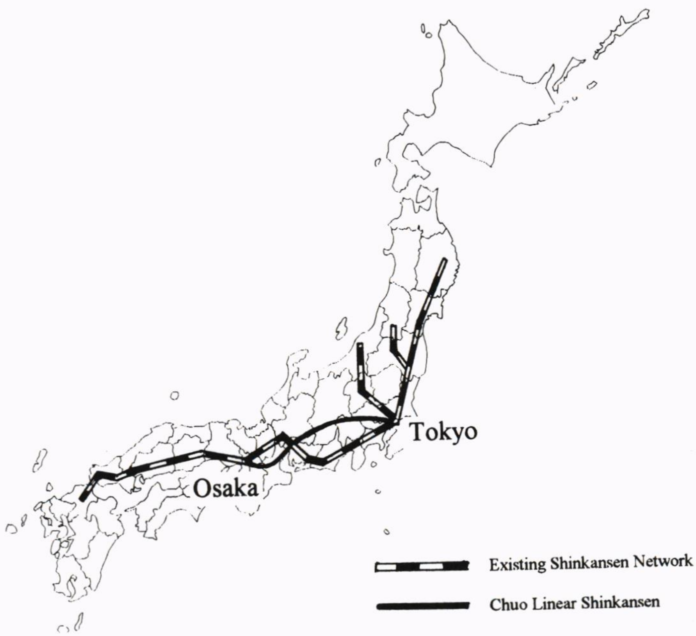

Figure 3. The Chuo Linear Shinkansen in the Shinkansen Network

5. POPULATION DISTRIBUTION CHANGE DUE TO THE PROJECT

By applying this population distribution model to the Chuo Linear Shinkansen project, this paper found some aspects of population distribution change as shown in figures 4, 5.1-5.5 and 6.1-6.6. The values in these figures mean change of ratio (to the whole country) or share (in each region) due to the project. For example, when the ratio of a region changes from 2.0% in the without-case to 2.1% in the with-case, the value of the region is indicated as 0.1(=2.1-2.0) in the figure.

Figure 4 indicates difference between ratio of regional population to national population in the with-case and that in the without-case. It is found that population of some regions along the Tokaido (Tokyo-Osaka) and the Sanyo (Osaka-Fukuoka) Lines, except for a few regions between Tokyo and Nagoya, grows up due to the project. There may be a small possibility of deconcentration, against Tokyo and Osaka, of the total population distribution due to the project. From the viewpoint of nationwide, however, the project may cause concentration of population to the central Japan. Now, this model has not considered the expressway and the airline networks but only the railway network as interregional transport mode. If a long distance transport depends on the airline network mainly and the project cannot make its time reduce, the project effect will be not expected. So this model seems to overestimate its effect in regions far from the Chuo Linear Shinkansen, for example in Fukuoka.

Figures 5.1-5.5 indicate difference between share of each generational classified population in each region in the with-case and that in the without-case. From figures 5.1-5.3, it is found that share of population under 49 years-old increases in almost the same regions as mentioned in figure 4, so it may be understood that this power is a reason why population of those regions grows up. From figures 5.4 and 5.5, on the other hand, share of population over 50 years-old increases in other regions, where the aged society may be accelerated by the project. These figures are caused by phenomena that this project will make young population move to some central regions from other regions but make old population move conversely slightly.

Figures 6.1-6.6 indicate difference between ratio of regional labor number to national labor number in each industry in the with-case and that in the without-case. The construction and the transport and communication industries concentrate to Tokyo, Nagoya and Osaka due to the project (see figures 6.1 and 6.3), while most industry deconcentrate against Tokyo and Osaka (see figures 6.2 and 6.4-6.6). These industries, however, concentrate to regions along the Tokaido and the Sanyo Lines. From the viewpoint of nationwide, as mentioned above, the project may cause concentration of most industry to the central Japan.

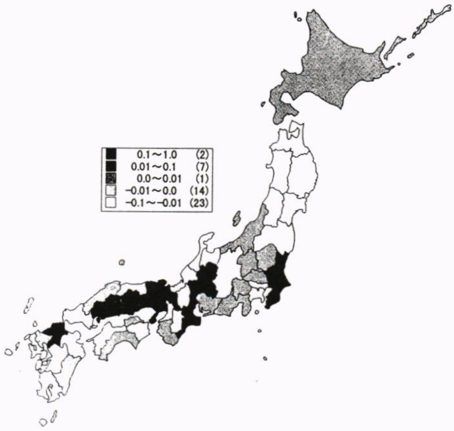

Figure 4. Change of Ratio of Regional Population to National Population

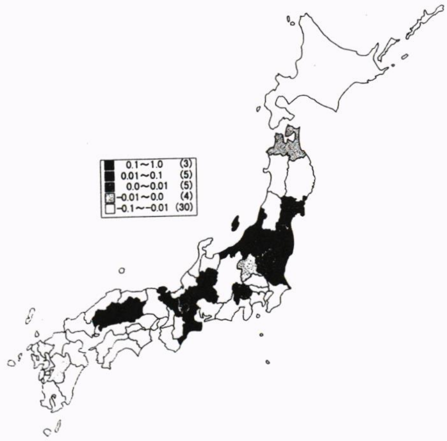

Figure 5.1 Change of Share of Generational Classified Population (under 19 years-old)

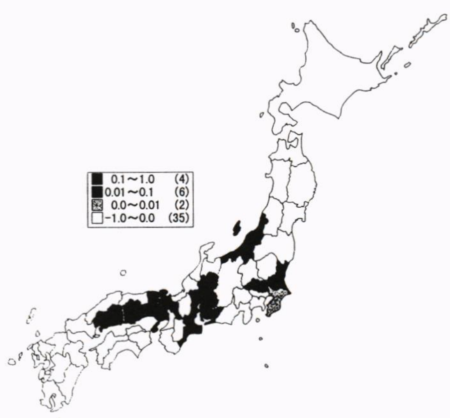

Figure 5.2 Change of Share of Generational Classified Population (20-34 years-old)

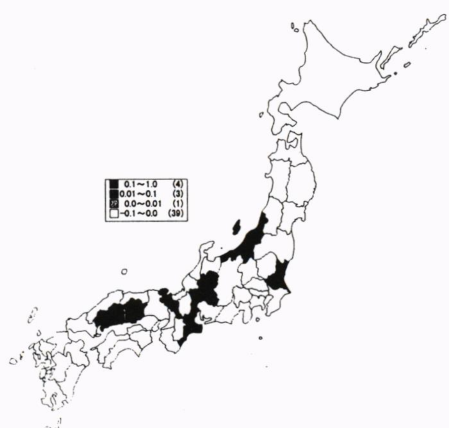

Figure 5.3 Change of Share of Generational Classified Population (35-49 years-old)

Figure 5.4 Change of Share of Generational Classified Population (50-64 years-old)

Figure 5.5 Change of Share of Generational Classified Population (over 65 years-old)

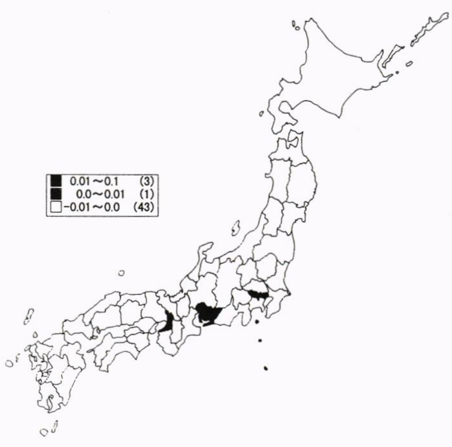

Figure 6.1 Change of Ratio of Regional Labor Number to National Labor Number (Construction Industry)

Figure 6.2 Change of Ratio of Regional Labor Number to National Labor Number (Manufacture Industry)

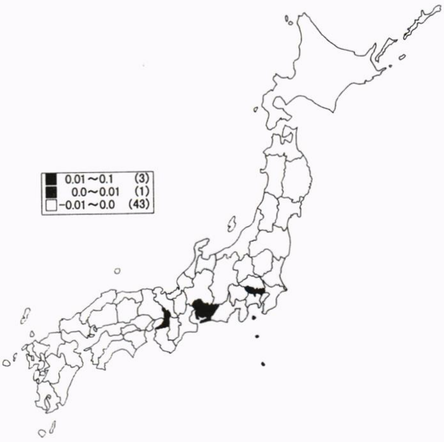

Figure 6.3 Change of Ratio of Regional Labor Number
to National Labor Number
(Transport and Communication Industry)

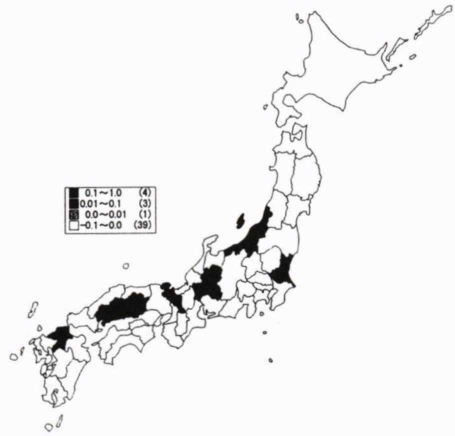

Figure 6.4 Change of Ratio of Regional Labor Number
to National Labor Number
(Wholesale and Retail Industry)

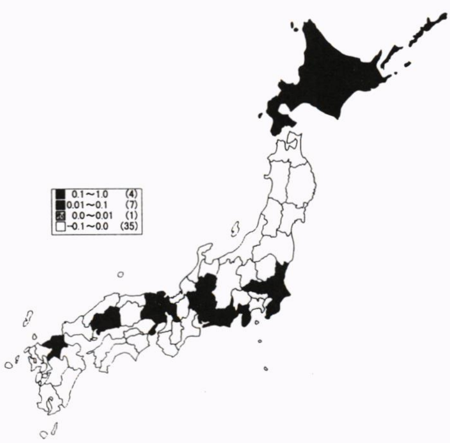

Figure 6.5 Change of Ratio of Regional Labor Number
to National Labor Number
(Finance and Insurance Industry)

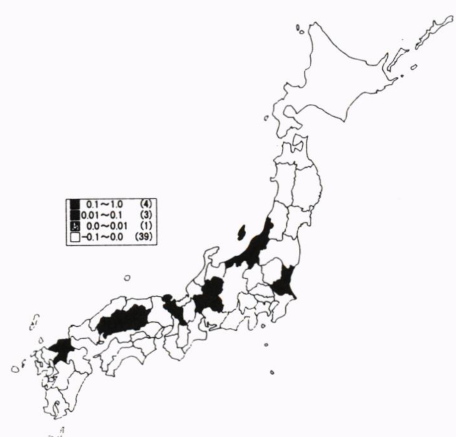

Figure 6.6 Change of Ratio of Regional Labor Number
to National Labor Number
(Service Industry)

6. CONCLUSION

This paper presents a population distribution model, which can estimate change of the industrial and generational classified population distribution due to the future interregional transport development, and can forecast its effect to the nationwide structure. By applying this model to the Shinkansen project in Japan, this paper analyzes change of the industrial and generational classified population distribution due to it, and looks over its influence to the industrial structure and the generational structure of Japan. As a result, this paper has found that the Chuo Linear Shinkansen project may have some possibilities:

(1) Population of some regions along the Tokaido and the Sanyo Lines, except for a few regions between Tokyo and Nagoya, grows up. There may be a small possibility of deconcentration against Tokyo and Osaka. From the viewpoint of nationwide, however, the project may cause concentration of population to the central Japan.

(2) Though share of population under 49 years-old increases in almost the same regions as mentioned above, share of population over 50 years-old increases in other regions, where the aged society may be accelerated by the project.

(3) The construction and the transport and communication industries concentrate to Tokyo, Nagoya and Osaka, while most industry deconcentrate against Tokyo and Osaka. These industries, however, concentrate to regions along the Tokaido and the Sanyo Lines. From the viewpoint of nationwide, the project may cause concentration of most industry to the central Japan.

This population distribution model, on the other hand, has some problems to improve:

(1) Parameter estimation of this model should be improved by choosing variables and/or types of function, because it includes too many parameters, which have low statistical reliability.

(2) This model should consider not only the railway network but also the expressway and the airline networks as interregional transport mode, which depends on the condition of each industry.

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