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A Study on Evolution of Regional Population Distribution Based on the Dynamic Self-Organization Theory

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Abstract

This study aims to investigate the evolution of regional population distribution in Hokkaido brought about by regional infrastructure provision. For this objective we employ the dynamic self-organization model to simulate changes of the regional population. First, a simple explanation of the principle of dynamic self-organization is presented in this paper. Secondly, construction of highways is regarded as " fluctuation", then the evolutions of the regional population distribution are simulated under the principle of dynamic self-organization.

Key Words : Self-organization, dissipative structure, population distribution, migration, highway

1. Introduction

An interregional imbalance has been highly remarkable in Hokkaido prefecture. That is to say, the main industries such as agriculture, forestry and fishery, iron and steel, coal mining, shipbuilding have been deteriorating in Hokkaido prefecture because of the depression of the domestic demand and appreciation of the yen against other foreign currencies. As a result, the opportunity for the employment has decreased markedly in the local areas in Hokkaido prefecture, and the inhabitants are migrating to Sapporo city, the capital of Hokkaido prefecture, or out of the prefecture to seek jobs.

Under this problem orientation, this paper aims at investigating the possibility of the regional redistribution of population of Hokkaido prefecture based upon the theory of dynamic self-organization of population distribution, which was originated by I.D. Prigogine.

2. Recent Development of Hokkaido Prefecture

As mentioned in the introductory section, Hokkaido prefecture has encountered a serious socio-economic situation. Therefore, we quantatively analyze the socio-economic situation of Hokkaido prefecture in this section centering on the population, income and industrial structure.

2-1 Population

Tables 1 and 2 show the trends of populations of Hokkaido prefecture and Japan, respectively. Let us examine the trend of population of Hokkaido by means of the annual

Table 1 Population of Hokkaido

(unit : thousand persons)

		1965	1970	1975	1980	1985	annual average growth rate (%) '70/'65	'75/'70	'80/'75	'85/'80
Total		5172	5184	5333	5558	5665	0.05	0.57	0.83	0.38
age	0−14	1462	1309	1311	1295	1215	−2.19	0.03	−0.25	−1.27
	15−64	3460	3576	3564	3812	3902	0.66	−0.07	1.35	0.47
	65−	249	299	368	451	548	3.73	4.24	4.15	3.97
Male		2583	2553	2619	2728	2759	−0.23	0.51	0.82	0.23
age	0−14	746	669	671	663	621	−2.16	0.06	−0.24	− 1.3
	15−64	1721	1746	1779	1863	1901	0.29	0.38	0.93	0.4
	65−	116	139	169	202	237	3.68	3.99	3.63	3.25
Female		2589	2631	2714	2830	2906	0.32	0.62	0.84	0.53
age	0−14	716	641	640	632	594	−2.19	−0.03	−0.25	−1.23
	15−64	1740	1830	1875	1949	2001	1.01	0.49	0.78	0.53
	65−	133	160	199	249	311	3.77	4.46	4.58	4.55
0−14(%)		28.3	25.3	24.6	23.3	21.4				
15−64(%)		66.9	6969	66.8	68.6	68.9				
65− (%)		4.8	5.8	6.9	8.1	9.7				

Table 2 Population of Japan

(unit : thousand persons)

		1965	1970	1975	1980	1985	annual average growth rate (%) '70/'65	'75/'70	'80/'75	'85/'80
Total		99209	104665	111890	117150	121049	1.08	1.34	0.92	0.66
age	0−14	25529	25153	27221	27507	26033	−0.3	1.59	0.21	−1.1
	15−64	67444	72119	75717	78835	82509	1.35	0.98	0.81	0.92
	65−	6236	7393	8865	10647	12468	3.46	3.7	3.73	3.21
Male		48692	51369	55091	57594	59497	1.08	1.41	0.89	0.65
age	0−14	12999	12857	13943	14103	13339	−0.22	1.64	0.23	−1.11
	15−64	32952	35266	37274	38942	41031	1.37	1.11	0.88	1.05
	65−	2741	3246	3838	4500	5100	3.44	3.41	3.23	2.53
Female		50517	53296	56849	59467	61552	1.08	1.3	0.9	0.69
age	0−14	12530	12295	13273	13404	14694	−0.38	1.54	0.2	1.85
	15−64	34493	36854	38533	39893	41475	1.33	0.89	0.7	0 0.78
	65−	3495	4147	5028	6148	7368	3.48	3.93	4.1	3.69
0−14(%)		25.7	24	24.3	23.5	21.5				
15−64(%)		68	68.9	67.7	67.3	68.2				
65− (%)		6.3	7.1	7.9	9.1	10.3				

average growth rate during each five-year interval from 1965 to 1985. The annual average growth rates are 0.05% from 1965 to 1970, 0.57% from 1970 to 1975, 0.83% from 1975 to 1980 and 0.38% from 1980 to 1985. Comparing these figures with those of Japan, the annual growth rate in Hokkaido is smaller than that of Japan in every period. Thus it may be concluded that the outmigration from Hokkaido prefecture has been far exceeded that of inmigration. However, the annual average growth rate was nearly equal to that of Japan in the period from 1975 to 1980. This phenomenon is interpreted as that the settlement of

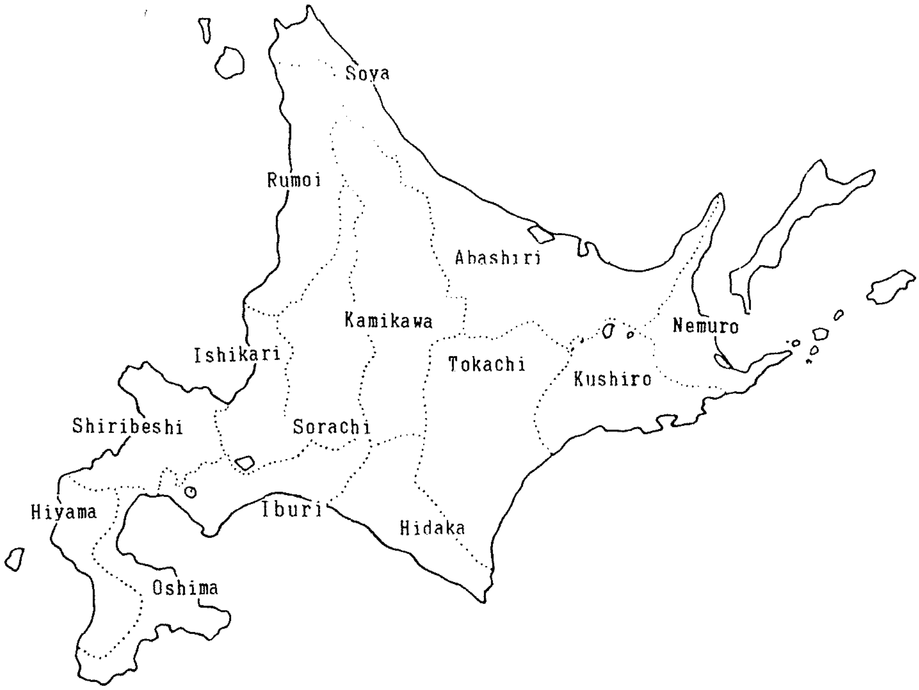

Figure. 1 Classification of Hokkaido into Fourteen Blocks

the population was promoted in Hokkaido because of the increasing of per capita income in Hokkaido prefecture.

Looking at the change of population by age groups in Table 2, it is observed that the share rate of the young age group from 0 to 14 years old decreased from 1965 to 1985. However, this trend is also observed in the change of the national population. Thus this phenomenon is considered to be due to the decrease of the birth rate. The share rate of the class from 15 to 64 years old slightly increased from 1965 to 1985, but it was more than that of the national population after 1980. This trend is considered to reflect the concentration of young people in Sapporo city. The population of people more than 65 years old has increased since 1965, but its share rate has been smaller than that of the national population. Thus, Hokkaido stands out as the region where the advancing of age is the slowest among the local regions in Japan.

Now, let us divide Hokkaido prefecture into fourteen blocks and examine the change of population in more detail. The division of Hokkaido is depicted in Figure 1, and cities, towns and villages in each block are illustrated in Table 3. Table 4 and Figure 2 show the trend of the population of each block from 1975 to 1985. It is observed in the table or the figure that the population increased only in Ishikari block, which has Sapporo city, and the populations of the other blocks leveled off or decreased. Because the natural growth rate of the population is positive, this trend is interpreted as the number of emigrants out of Hokkaido was larger than the emigrants in each block except Ishikari block.

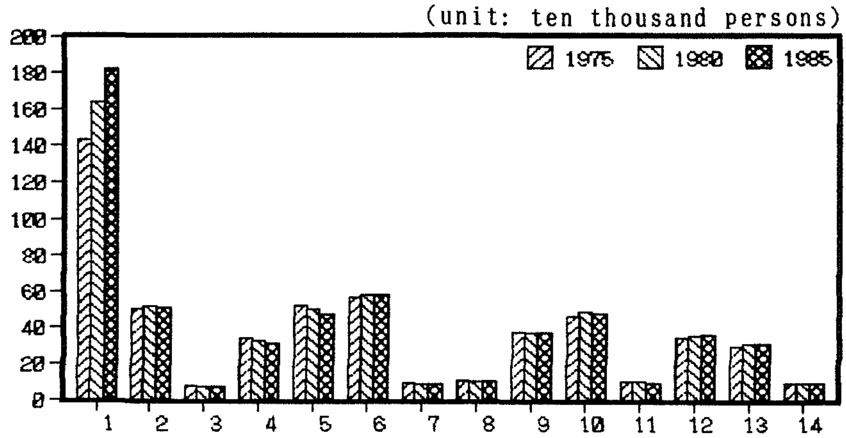

Figure. 2 Actual Population of Each Block

2-2 Income

We consider the income of Hokkaido prefecture in this subsection. Table 5 shows the trend of the regional incomes of Japan and Table 6 denotes the per capita incomes of the nine regions. The annual average growth rate of the income of Hokkaido prefecture were 8.94% from 1965 to 1970, 6.9% from 1970 to 1975, 5.93% from 1975 to 1980 and 1.52% from 1980 to 1985. Comparing these figures with those of the national income, Hokkaido's growth rates exceeded the national rates from 1970 to 1980. Therefore it is considered that the oil shock in 1974 did not markedly affect Hokkaido's economy. However, the annual average growth rate from 1980 to 1985 was smallest among those of the nine regions, thus it can be said that present Hokkaido prefecture is in a serious socio-economic situation.

Now, normalizing the regional per capita incomes by taking the national average as a hundred, Hokkaido's per capita incomes were 92.2 in 1965, 86.0 in 1970, 94.2 in 1975, 99.8 in 1980 and 91.5 in 1985. Despite the fact that the per capita income of Hokkaido prefecture was growing larger after 1965 and reached nearly the national average level in 1980, it has been decreasing recently because of another interregional imbalance due to the one-pole concentration of socio-economic activities in the Tokyo metropolitan area.

2-3 Industrial Structure

In this subsection, we examine the change of Hokkaido's industrial structure. Tables 7 and 8 denote the trend of Hokkaido's and national gross product by kind of economic activity from 1965 to 1985. In these tables the economic activities are classified into nine activities, which are Agri. (agriculture, forestry and fisheries), Mining, Manufac. (manufacturing), Construct. (construction), Commerce (retail and wholesale), Fin. (financial, insurance and real estate), Pub. Ser. (electricity, gas, water, transportation and telecommunication), Service and Public Ad. (public administrative service). However, it becomes difficult to perceive the trend of the regional industries because of the massiveness of the data. So we shall introduce location coefficient and relative growth rate, which are defined as

Table 3 Cities, Towns, and Villages in Each Blocks ; Centers of Hokkaido

i	BLOCK	RANGE	C O N T E N T S	CENTER
1	Ishikari	city town village	Sappro, Ebetsu, Chitose, Eniwa Hirosima, Ishikari, Tobetsu Shinshinotsu, Atsuta, Hamamasu	Sapporo
2	Oshima	city town village	Hakodate Matsumae, Hukushima, Shiriuchi, Kikonai, Kamiiso, Oono, Nanae, Toi, Esan, Minamikayabe, Shikabe, Sawara, Mori, Yakumo, Oshamambe Todohokke	Hakodate
3	Hiyama	town	Esashi, Kaminokuni, Atsusabu, Otobe, Kumaishi, Taisei, Okushiri, Setana, Kitahiyama, Imakane	Esashi
4	Shiribeshi	city town village	Otaru Sutsutsu, Kuromatsunai, Rankoshi, Niseko, Kimobetsu, Kyogoku, Kutchan, Kyowa, Iwanai, Shakotan, Furubira, Niki, Yoichi Shimamaki, Makkari, Rusutsu, Tomari, Kamoenai, Akaigawa	Otaru
5	Sorachi	city town village	Yubari, Iwamizawa, Bibai, Ashibetsu, Akabira, Mikasa, Takikawa, Sunagawa, Utashinai, Fukagawa Kurisawa, Namporo, Naie, Kamisuuagawa, Yuni, Naganuma, Kuriyama, Tukigata, Uraisu, Shintotsukawa, Moseushi, Chippubetsu, Uryu, Hokuryu, Numata, Horokanai Kita	Iwamizawa
6	Kamikawa	city town village	Asahikawa, Shibetsu, Nayoro, Furano Takasu, Higashikagura, Toma, Pippu, Aibetsu, Kamikawa, Higashikawa, Biei, Kamifurano, Nakafurano, Minamifurano, Wassamu, Kembuchi, Asahi, Furen, Bifuka, Nakagawa Shimukappu, Otoineppu	Asahikawa
7	Rumoi	city town village	Rumoi Mashike, Obira, Tomamae, Haboro, Embetsu, Teshio, Horonobe Shosambetsu	Rumoi
8	Soya	city town village	Wakkanai Hamatombetsu, Nakatombetsu, Esashi, Utanobori, Toyomori, Rebun, Rishiri, Higashirishiri Sarufutsu	wakkanai
9	Abashiri	city town village	Kitami, Abashiri, Mombetsu Memambetsu, Bihoro, Tsubetsu, Shari, Kiyosato, Koshimizu, Tannno, Kunneppu, Oketo, Rubeshibe, Saroma, Tokoro, Ikutahara, Engaru, Maruseppu, Kamiyubetsu, Yubetsu, Takinoue, Okoppe, Oumu Higashimokoto, Shirataki, Nishiokoppe	Kitami
10	Iburi	city town village	Muroran, Tomakomai, Noboribetsu, Date Toyoura, Abuta, Sobetsu, Shiraoi, Hayakita, Abuta, Mukawa,Hobetsu Toya, Ootaki	Tomakomai
11	Hidaka	town	Hidaka, Biratori, Niikappu, Shizunai, Mitsuishi, Urakawa, Samani, Erimo	Shizunai
12	Tokachi	city town village	Obihiro, Otofuke, Shihoro, Kamishihoro, Shikaoi, Shintoku, Shimizu, Memuro, Taiki, Hiroo, Makubetsu, Ikeda, Toyokoro, Hombetsu, Ashoro, Rikubetsu, Urahoro Nakasatsunai, Sarabetsu, Churui	Obihiro
13	Kushiro	city town village	Kushiro Kushoro, Akkeshi, Hamanaka, Shibecha, Teshikaga, Akan, Shiranuka, Ombetsu Tsurui	Kushiro
14	Nemuro	city town	Nemuro Bekkai, Nakashibetsu, Shidetsu, Rausu	Nemuro
0	others	village	Shikotan, Tomari, Ruyobetsu, Rubetsu, Shana, Shibetoro	——

Table 4 Actual Population of Each Block

i	BLOCK	CENTER	1975	1980	1985	'80/'75	'85/'80
1	Ishikari	Sapporo	142.9 (26.80)	164.1 (29.53)	182.1 (32.14)	2.81	2.1
2	Oshima	Hakodate	49.9 (9.36)	51.3 ((9.23)	50.9 (8.98)	0.55	0.16
3	Hiyama	Esashi	8.1 (1.52)	7.6 (1.37)	7.1 (1.25)	−1.27	−1.35
4	Shiribeshi	Otaru	33.7 (6.32)	32.7 (5.88)	31.1 (5.49)	−0.6	−1
5	Sorachi	Iwamizawa	52.4 (6.83)	50.1 (9.01)	47.4 (8.37)	−0.89	−1.1
6	Kamikawa	Asahikawa	56.5 (10.59)	58.2 (10.47)	58.3 (10.29)	0.59	0.03
7	Rumoi	Rumoi	9.7 (1.82)	9.1 (1.64)	8.5 (1.50)	−1.27	−1.35
8	Soya	Wakkanai	11.3 (2.12)	10.7 (1.93)	10.2 (1.80)	−1.09	−0.95
9	Abashiri	Kitami	37.4 (7.01)	37.1 (6.68)	36.6 (6.46)	−0.16	−0.27
10	Iburi	Tomakomai	46.7 (8.76)	48.5 (8.73)	47.7 (8.42)	0.76	−0.33
11	Hidaka	Shizunai	10.6 (1.99)	10.3 (1.85)	9.9 (1.45)	−0.57	−0.79
12	Tokachi	Obihiro	34.7 (6.51)	35.5 (6.39)	36.2 (6.39)	0.46	0.39
13	Kushiro	Kushiro	29.7 (5.57)	30.7 (5.52)	30.8 (5.44)	0.66	0.07
14	Nemuro	Nemuro	9.7 (1.82)	9.9 (1.78)	9.7 (1.71)	0.41	−0.41
TOTAL			533.3 (100.00)	555.8 (100.00)	566.5 (100.00)	0.83	0.38

Note 1: (unite) population in ten thousand persons, share and growth rates in %.
Note 2: share rates are in parentheses.

follows;

$$lc_i^r = \frac{R_i^r}{R_i^N} \tag{1}$$

$$rg_i^r = \frac{X_i^r(1985)/X_i^r(1975)}{X_i^N(1985)/X_i^N(1975)} \tag{2}$$

where, lc_i^r :location coefficient of industry i in region r
R_i^r : share rate of industry i in region r
R_i^N : share rate of industry i in the national
rg_i^r : relative growth rate of industry i in region r
$X_i^r(t)$: gross product of industry i in region r in year t
$X_i^N(t)$: gross domestic product of industry i in year t

That is to say, the location coefficient represents how much of industry i in region r specializes as compared with the domestic average. The relative growth rate shows a comparison of the growth rate of industry i in region r with that of the domestic one.

Now, let the horizontal and vertical lines be a location coefficient and a relative

Table 5 Regional Income

(unit : billion yen at market price of 1980)

region	1965	1970	1975	1980	1985	annual average growth rate (%) '70／'65	'75／'70	'80／'75	'85／'80
Hokkaido	3374	5176	7226	9640	10394	8.94	6.9	5.93	1.52
	(4.81)	(4.26)	(4.49)	(4.75)	(4.29)				
Tohoku	6219	9671	14085	17467	20016	9.23	7.81	4 4	2.76
	(8.87)	(7.96)	(8.76)	(8.61)	(8.26)				
Kanto	23886	42529	57164	72667	91206	12.23	6.09	4.92	4.65
	(34.06)	(35.02)	(35.54)	(35.82)	(37.65)				
Tokai	7798	14237	18040	22948	28444	12.79	4.85	4.93	4.39
	(11.12)	(11.72)	(11.22)	(11.31)	(11.74)				
Hokuriku	1767	2857	3982	4988	5664	10.09	6.87	4.61	2.57
	(2.52)	(2.35)	(2.48)	(2.46)	(2.34)				
Kinki	13314	24948	28805	35932	41816	13.38	2.92	4.52	3.08
	(18.99)	(20.54)	(17.91)	(17.71)	(17.26)				
Chugoku	4455	7492	10155	12276	14026	10.96	6.27	3.87	2.7
	(6.35)	(6.17)	(6.31)	(6.05)	(5.79)				
Shikoku	2303	3800	5018	6128	6803	10.53	5.72	4.08	2.11
	(3.28)	(3.13)	(3.12)	(3.02)	(2.81)				
Kyushu	7010	10726	16365	20800	23891	8.88	8.82	4.91	2.81
	(10)	(8.83)	(10.17)	(10.25)	(9.86)				
Total	70126	121436	160840	202846	242260	11.61	5.78	4.75	3.62
	(100)	(100)	(100)	(100)	(100)				

Note : share rates are in parentheses

Table 6 Regional per Capita Income

(unit : thousand yen/person, at market price of 1980)

region	1965	1970	1975	1980	1985	annual average growth rate (%) '70／'65	'75／'70	'80／'75	'85／'80
Hokkaido	652	998	1354	1729	1830	8.89	6.29	5.01	1.14
	(92.22)	(86.03)	(94.22)	(99.83)	(91.45)				
Tohoku	540	849	1212	1453	1639	9.47	7.38	3.69	2.44
	(76.38)	(73.19)	(84.34)	(83.89)	(81.91)				
Kanto	826	1320	1604	1923	2294	9.83	3.97	3.69	3.59
	(116.83)	(113.79)	(111.62)	(111.03)	(114.64)				
Tokai	714	1209	1418	1723	2060	11.11	3.24	3.97	3.64
	(100.99)	(104.22)	(98.68)	(99.48)	(102.95)				
Hokuriku	641	1029	1367	1653	1834	9.93	5.85	3.87	2.1
	(90.66)	(88.71)	(95.13)	(95.44)	(91.65)				
Kinki	844	1434	1534	1832	2082	11.18	1.36	3.61	2.59
	(119.38)	(123.62)	(106.75)	(105.77)	(104.05)				
Chugoku	648	1071	1379	1618	1810	10.57	5.19	3.25	2.27
	(91.65)	(92.33)	(95.96)	(93.42)	(90.45)				
Shikoku	579	973	1242	1472	1609	10.94	5	3.46	1.8
	(81.9)	(83.88)	(86.43)	(84.99)	(80.41)				
Kyushu	527	824	1216	1478	1653	9.35	8.09	3.98	2.26
	(74.54)	(71.03)	(84.62)	(85.33)	(82.61)				
Total	707	1160	1437	1732	2001	10.41	4.38	3.8	2.93
	(100)	(100)	(100)	(100)	(100)				

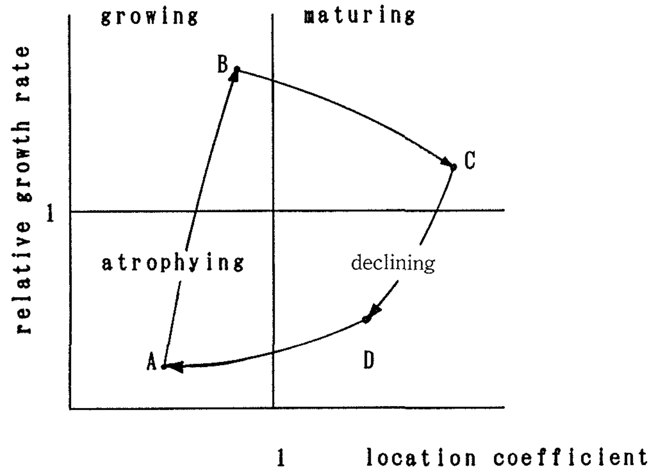

Figure. 3 Life Cycle of Industry

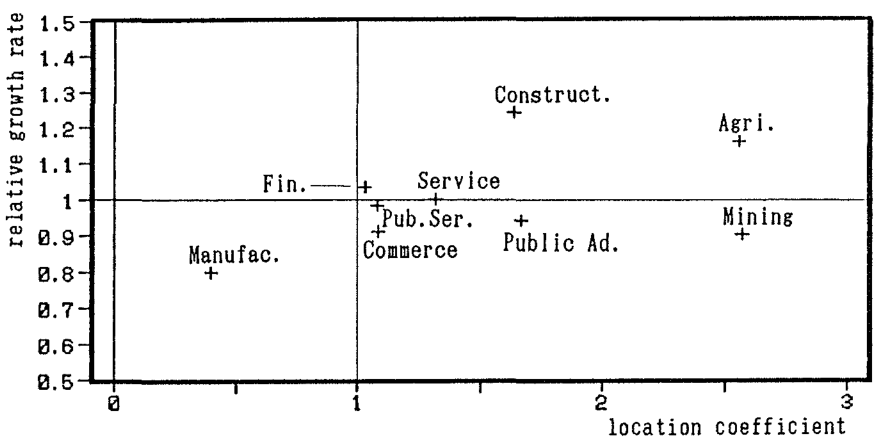

Figure. 4 Location Coefficient and Relative Growth Rate of Each Industry (Hokkaido)

growth rate, respectively, in a Cartesian coordinate. We then obtain a figure as shown in Figure 3. Point A represents an industry with a low location coefficient and a low relative growth rate. Such an industry is called an atrophying industry. Point B denotes an industry with a high relative growth rate and a low location coefficient. This industry is said to be a growing industry. At point C, both location coefficient and relative growth rate of the industry are high, thus the industry is termed a maturing industry. Point D indicates an industry whose location coefficient is high but relative growth rate is low. Therefore, this industry is called a declining industry. The life cycle of industry is recognized to shift through A→B→C→D→A.

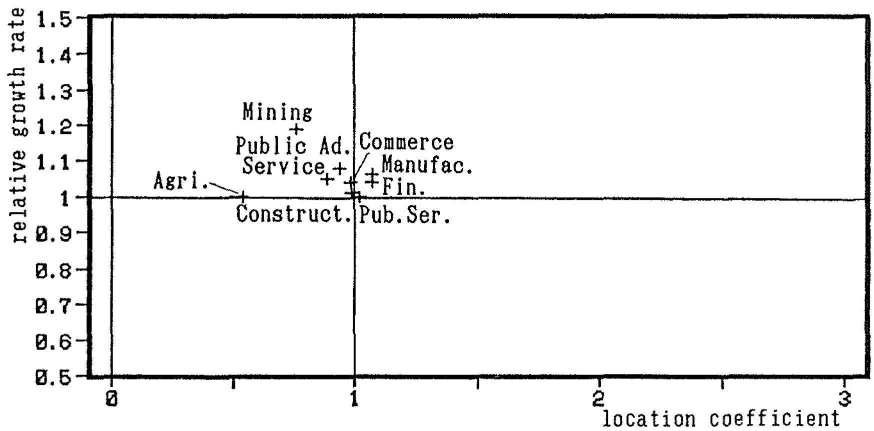

Figure. 5 Location Coefficient and Relative Growth Rate of Each Industry (Kanto)

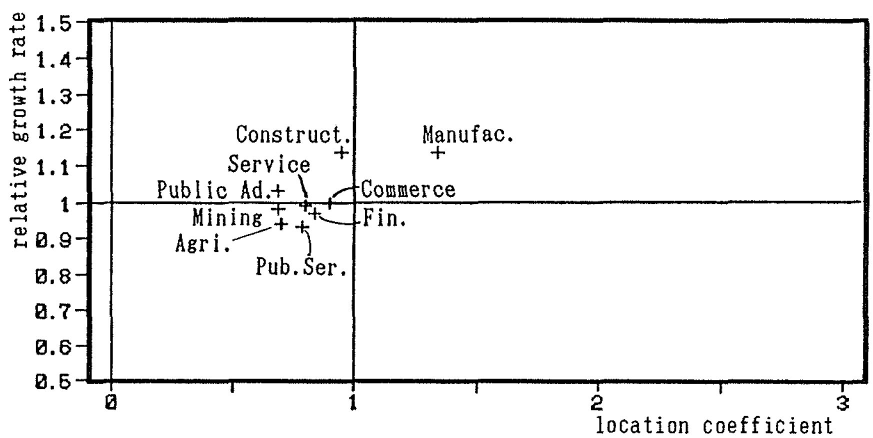

Figure. 6 Location Coefficient and Relative Growth Rate of Each Industry (Tokai)

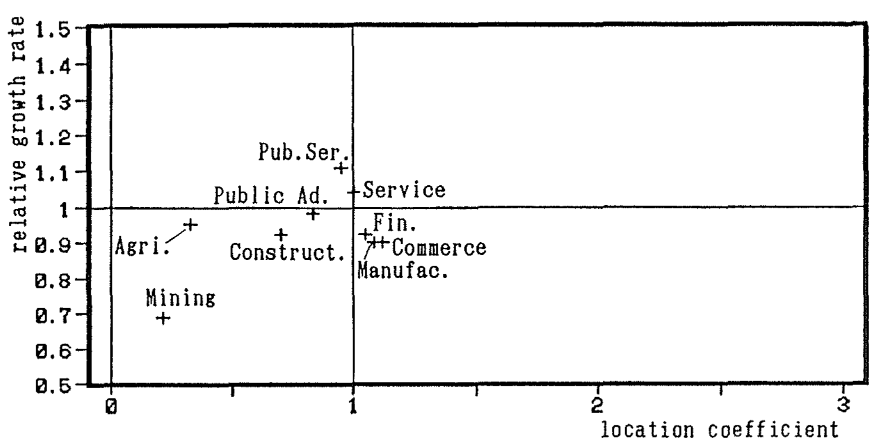

Figure. 7 Location Coefficient and Relative Growth Rate of Each Industry (Kinki)

Table 7 Gross Product by kind of Economic Activity (Hokkaido)

						annual average growth rate (%)			
industry	1965	1970	1975	1980	1085	'70/'65	'75/'70	'80/'75	'85/'80
Total	4417	6507	8331	12344	11550	8.06	5.07	6.18	0.54
	(100)	(100)	(100)	(100)	(100)				
Agri.	618	721	853	826	855	3.13	3.42	−0.64	0.69
	(13.99)	(11.08)	(10.24)	(7.35)	(7.4)				
Mining	105	109	107	125	125	0.75	−0.37	3.16	0
	(2.38)	(1.68)	(1.28)	(1.11)	(1.08)				
Manufac.	420	664	922	1480	1535	9.59	6.79	9.93	0.73
	(9.51)	(10.2)	(11.07)	(13.16)	(13.29)				
Construct.	558	799	1092	1420	1278	7.44	6.45	5.39	−2.09
	(12.63)	(12.28)	(13.11)	(12.63)	(11.06)				
Commerce	412	805	1319	2201	2041	14.34	10.38	10.78	−1.5
	(9.33)	(12.37)	(15.33)	(19.57)	(17.67)				
Fin.	433	672	993	1306	1405	9.19	8.12	5.63	1.47
	(9.8)	(10.33)	(11.92)	(11.62)	(12.16)				
Pub.Ser.	544	874	814	1058	1242	9.95	−1.41	5.38	3.26
	(12.32)	(13.43)	(9.77)	(9.41)	(10.75)				
Service	943	1331	1584	2066	2259	7.14	3.54	5.46	1.8
	(21.35)	(20.45)	(19.01)	(18.37)	(19.56)				
Public Ad.	384	532	647	762	810	6.74	3.99	3.33	1.23
	(8.69)	(8.18)	(7.77)	(6.78)	(7.01)				

Note 1: (unit) gross products in billion yen at market prices of 1980, share and growth rates in %.
Note 2: share rates are in parentheses.

Table 8 Gross Product by kind of Economic Activity (Japan)

						annual average growth rate (%)			
	1965	1970	1975	1980	1985	'70/'65	'75/'70	'80/'75	'85/'80
Total	86599	144610	194316	253084	300650	10.8	6.09	5.48	3.5
	(100)	(100)	(100)	(100)	(100)				
Agri.	9076	9016	10021	8561	8691	−0.13	2.14	−3.1	0.3
	(10.48)	(6.23)	(5.16)	(3.38)	(2.89)				
Mining	766	825	963	1292	1251	1.5	3.14	6.05	−0.64
	(0.88)	(0.57)	(0.5)	(0.51)	(0.42)				
Manufac.	16424	35574	47482	70884	99377	16.72	5.94	8.34	6.99
	(18.97)	(24.6)	(24.44)	(28.01)	(33.05)				
Construct.	11670	20312	21482	22400	20227	11.72	1.13	0.84	−2.02
	(13.48)	(14.05)	(11.06)	(8.85)	(6.73)				
Commerce	8488	17141	28663	42269	48583	15.09	10.83	8.08	2.82
	(9.8)	(11.85)	(14.75)	(16.7)	(16.16)				
Fin.	9468	14080	25870	31609	35447	8.26	12.94	4.09	2.32
	(10.93)	(9.74)	(13.31)	(12.49)	(11.79)				
Pub. Ser	7778	14473	19253	24853	29893	13.22	5.87	5.24	3.76
	(8.98)	(10.01)	(9.91)	(9.82)	(9.94)				
Service	17027	25338	31117	39781	44574	8.27	4.19	5.04	2.3
	(19.66)	(17.52)	(16.01)	(15.72)	(14.83)				
Public Ad.	5901	7851	9465	11435	12607	5.88	3.81	3.85	1.97
	(6.81)	(5.43)	(4.87)	(4.52)	(4.19)				

Note 1: (unit) gross products in billion yen at market prices of 1980, share and growth rates in %.
Note 2: share rates are in parentheses.

Figures 4～7 show the location coefficient in 1985 and the relative growth rate from 1975 to 1985 of each industry in Hokkaido prefecture, and the three greatest metropolitan areas, that is, Kanto, Tokai and Kinki regions.

In Hokkaido prefecture, financial, service, construction and agriculture are indicated as maturing industries, but there is no growing industry. Mining, public administrative service, commerce and public service industries are observed as declining industries, whereas manufacturing industry is noted as a unique atrophying industry. Comparing the industrial structure of Hokkaido prefecture with those of the three greatest metropolitan regions, the fact that there is no growing industry means that the industrial activities in Hokkaido prefecture are declining. Agriculture and mining industries in Japan can be regarded as matured ones. Therefore considering the future trend of Japan's economy, these industries will shift to declining ones in the future. Thus, if this trend should continue, it could be expected that Hokkaido's industrial structure would become weaker than what it is at present. The fact that construction industry is matured indicates that Hokkaido's economy is susceptible to the influences from a domestic business fluctuation. Therefore, it suggests that stable growth of Hokkaido's economy may be difficult. The reason why manufacturing is antrophying industry is that heavy industries such as iron and shipbulding constitute the bulk. Thus, it suggests that manufacturing industry could not easily help improve Hokkaido's economy if assembling and processing industries with a high value added are established in Hokkaido prefecture.

3. Dynamic Self-Organization Theory of Regional Population Distribution

In the previous section, we described the trend of population, income and industrial structure in Hokkaido prefecture. From the analyses the seriousness of the present socio-economic situation of Hokkaido prefecture is pointed out. Especially, it is noted that the population has increased only in Ishikari block with Sapporo city but those of the other blocks are stable or decreasing. Improvement of the above-mentioned interregional imbalance is considered as one of the most important problems in actualization of a balanced development of Hokkaido prefecture.

In this section, therefore, we propose to apply Dynamic Self-Organization Theory (DSOT) to grasp the change of regional population distribution in Hokkaido prefecture. The reason for the application of the theory is its ability to indicate explicit interdependent relationship between factors of a complicated regional system and to clarify new ordering derived from a fluctuation in the regional system. As a prelude to its application, we describe the essence of DSOT in this section.

3-1 Development of Dynamic Self-Organization Theory

The dynamic self-organization is defined as the shift of the initial state of a system to another ordered state through fluctuation. This definition was originally introduced by Nicolis and Prigogine (1977)[27]. We recognize immediately from the definition that self-organization would not occur if the concerned system was in the stationary state. Thus, the system should be in another state to be organized autonomously. Prigogine has called that state the dissipative structure. The dissipative structure is definied as the macro structure which appears in a non-equilibrium and open system. As this definition indicates, the DSOT and dissipative structure were originally devised in the field of thermodynamics. At present, the DSOT has been applied in the fields such as chemical reaction (Nicolis and Prigogine;1977)[27], ecosystem (Allen; 1976)[4], urban development (Allen et. al. : 1978, 1978, 1978, 1979, 1981a, 1981b)[5)-10)] and economics (Silverberg : 1984)[32] etc. Especially the progress of the theory has been remarkable in the natural sciences, but the application in the regional science has been hardly found.

3-2 Theoretical Background of Dynamic Self-Organization

Because the definition of DSOT is quite general, the subjects of this theory are of a very wide range. Thus, we take a simple example and describe the essence of DSOT hereafter.

Now let us consider a two regional population growth model. The model is represented as follows :

$$\frac{dx_1}{dt}=k_1x_1(N_1-x_1-\beta x_2)-d_1x_1 \tag{3}$$

$$\frac{dx_2}{dt}=k_2x_2(N_2-x_2-\beta x_1)-d_2x_2 \tag{4}$$

where, x_i : population of region i

N_i : carrying capacity

k_i : birth and inmigration rate in region i

β : parameter of interdependence between the regions i and j

d_i : death and outmigration rate in region i

If Equations (3) and (4) are assumed to be stable at $t=0$, then the following equations must hold.

$$\frac{dx_1}{dt}=0 \rightarrow k_1x_1(N_1-x_1-\beta x_2)-d_1x_1=0$$

$$\frac{dt_2}{dt}=0 \rightarrow k_2x_2(N_2-x_2-\beta x_1)-d_2x_2=0$$

$$\therefore\ k_1x_1^2+k_1\beta x_1x_2+(d_1-k_1N_1)x_1=0 \tag{5}$$

$$k_2x_2^2+k_2\beta x_1x_2+(d_2-k_2N_2)x_2=0 \tag{6}$$

Therefore, $x_1=x_2=0$ is a trivial solution of Equations (5) and (6). If we assume $x_1\neq0$ and $x_2=0$, then Equation (5) is reduced as;

$$k_1x_1+(d_1-k_1N_1)=0$$

$$\therefore\ x_1=N_1-d_1/k_1$$

Accordingly, $(N_1-d_1/k_1,\ 0)$ is a stationary solution of Equations (3) and (4). Similarly assuming $x_1=0$ and $x_2\neq0$, we obtain another stationary point $(0,\ N_2-d_2/k_2)$. Finally, when we assume $x_1\neq0$ and $x_2\neq0$, Equations (5) and (6) can be transformed into ;

$$k_1x_1+k_1\beta x_2=k_1N_1-d_1 \tag{7}$$

$$k_2\beta x_1+k_2x_2=k_2N_2-d_2 \tag{8}$$

$$\therefore\ x_1=\{N_1-d_1/k_1-\beta(N_2-d_2/k_2)\}/(1-\beta^2) \tag{9}$$

$$x_2=\{N_2-d_2/k_2-\beta(N_1-d_1/k_1)\}/(1-\beta^2) \tag{10}$$

Summarizing the above-mentioned solutions, we obtain the four stationary points of Equations (3) and (4) as follows;

$(x_1^*, x_2^*)=(0, 0)$, $(N_1-d_1/k_1, 0)$, $(0, N_2-d_2/k_2)$, and

$$(\{N_1-d_1/k_1-\beta(N_2-d_2/k_2)\}/(1-\beta_2), \{N_2-d_2/k_2-\beta(N_1-d_1/k_1)\}/(1-\beta^2))$$

Now let us consider the behaviour of the solution near the stationary points. We take the Taylor expansion of the right hand side of Equations (3) and (4) around center (x_1^*, x_2^*).

$$\begin{aligned}
\therefore \frac{d}{dt}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} &= \frac{\partial}{\partial x}\begin{bmatrix} k_1x_1(N_1-x_1-\beta x_2)-d_1x_1 \\ k_2x_2(N_2-x_2-\beta x_1)-d_2x_2 \end{bmatrix}_{x=x^*}\begin{bmatrix} x_1-x_1^* \\ x_2-x_2^* \end{bmatrix} \\
&+ O\begin{bmatrix} (x_1-x_1^*)^2 \\ (x_2-x_2^*)^2 \end{bmatrix} \\
&= \begin{bmatrix} -2k_1x_1^*-k_1\beta x_2^*+k_1-d_1, & -k_1\beta x_1^* \\ -k_2\beta x_2^* & ,-k_2\beta x_1^*-2k_2x_2^*+k_2N_2-d_2 \end{bmatrix}\begin{bmatrix} x_1-x_1^* \\ x_2-x_2^* \end{bmatrix} \\
&+O\begin{bmatrix} (x_1-x_1^*)^2 \\ (x_2-x_2^*)^2 \end{bmatrix} \qquad (11)
\end{aligned}$$

We investigate the bifurcation of the solution of Equations (3) and (4) from a stationary point by employing linearized system of equation (11).

● *Self-Organization from the stationary point* $(N_1-d_1/k_1, 0)$

At the stationary point $(N_1-d_1/k_1, 0)$, Equation (11) is transformed as ;

$$\begin{aligned}
\frac{d}{dt}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} &= \begin{bmatrix} d_1-k_1N_1, & \beta(d_1-k_1N_1) \\ 0 & , k_2N_2-d_2-k_2\beta(N_1-d_1/k_1) \end{bmatrix}\begin{bmatrix} x_1-N_1+d_1/k_1 \\ x_2 \end{bmatrix} \\
&+O\begin{bmatrix} (x_1-N_1+d_1/k_1)^2 \\ x_2^2 \end{bmatrix} \qquad (12)
\end{aligned}$$

The eigen values of the above-stated 2×2 matrix are calculated as $\lambda_1=d_1-k_1N_1$ and $\lambda_2=k_2N_2-d_2-k_2\beta(N_1-d_1/k_1)$. Because the stationary value of x_1, which is N_1-d_1/k_1, is positive, λ_1 is negative. As for λ_2, the following two cases are possible.

$\lambda_2>0 \rightarrow N_2-d_2/k_2>\beta(N_1-d_1/k_1)$ (13)

$\lambda_2<0 \rightarrow N_2-d_2/k_2<\beta(N_1-d_1/k_1)$ (14)

Now let us assume that a very small "fluctuation" $\varepsilon>0$ is given to the point $x_2=0$. If Equation (13) holds, x_2 will increase up to some upper bound. Furthermore, when x_1 and x_2 consume completely common resources, β must be unity. Then Equation (13) becomes

$N_2-d_2/k_2>N_1-d_1/k_1$ (15)

In this case, x_1 decreases from the stationary value $x_1^*=N_1-d_1/k_1$, while x_2 increases from the point $x_2=\varepsilon>0$. And x_1 and x_2 shift asymptotically to another stationary point $(0, N_2-d_2/k_2)$. The behaviour of $x_1(t)$, $x_2(t)$ and $x_1(t)+x_2(t)$ is illustrated in Figure 8.

When each regional population consumes completely separate resources, β should be zero. In this case, $x_1(t)$ stays at N_1-d_1/k_1 while $x_2(t)$ converges to $x_2^*=N_2-d_2/k_2$. The behaviour of $x_1(t)$, $x_2(t)$ and $x_1(t)+x_2(t)$ is also depicted in Figure 9.

Finally, let us investigate the case in which two regional populations consume some common resources. Then $0<\beta<1$ must be realized. This case is divided into the two sub-cases corresponding to the below-stated conditions.

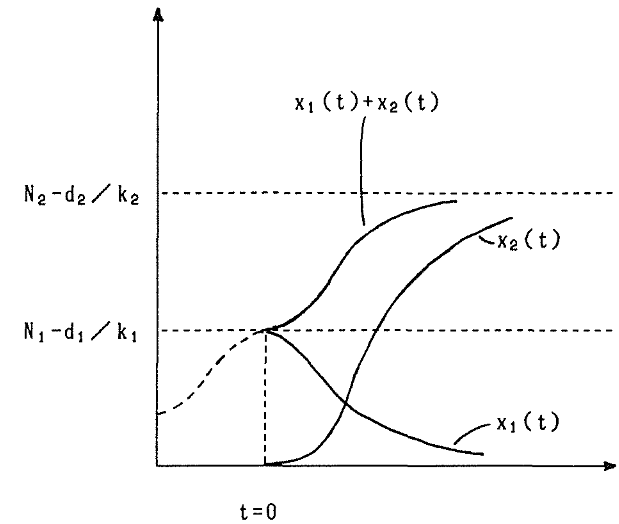

Figure. 8 Regional Population ($\beta=1$)

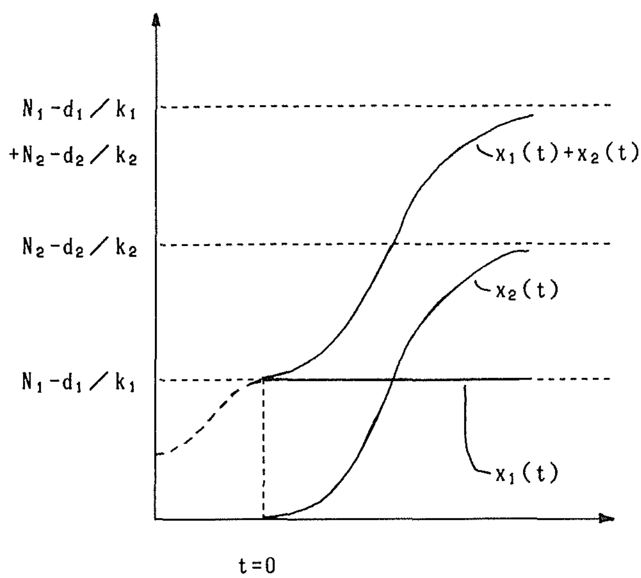

Figure. 9 Regional Population ($\beta=0$)

$$\begin{cases} N_2-d_2/k_2>\beta(N_1-d_1/k_1) & (16)\\ \beta(N_2-d_2/k_2)>N_1-d_1/k_1 & (17)\end{cases}$$

or

$$\begin{cases} N_2-d_2/k_2>\beta(N_1-d_1k_1) & (18)\\ \beta(N_2-d_2/k_2)<N_1-d_1/k_1 & (19)\end{cases}$$

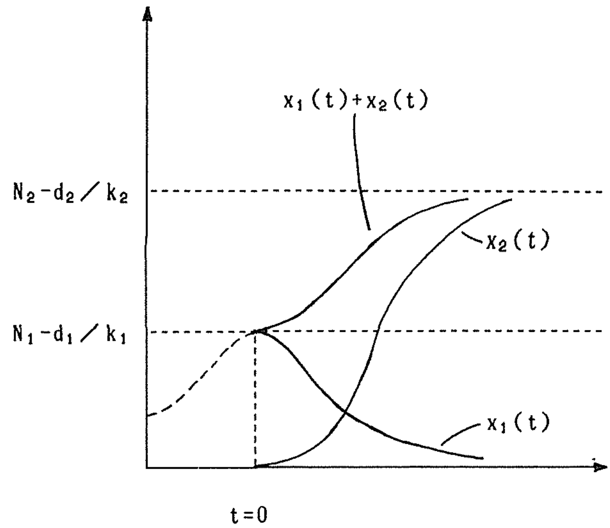

Figure. 10 Regional Population $(0<\beta<1)$

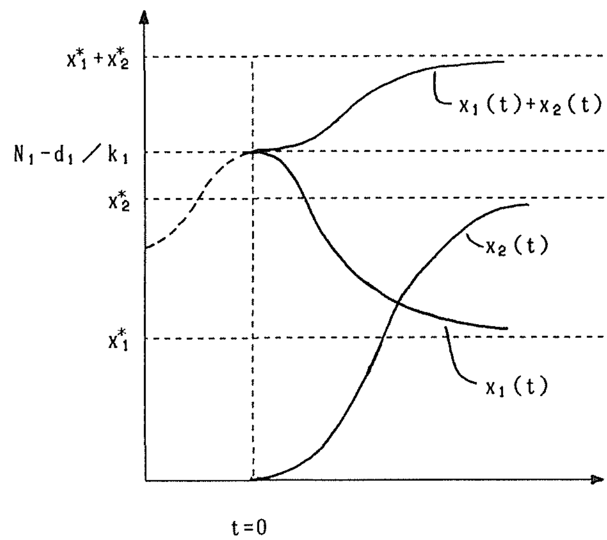

Figure. 11 Regional Population $(0<\beta<1)$
Note : $x_1^*=\}N_1-d_1/k_1-\beta(N_2-d_2/k_2)\}/(1-\beta^2)$
$x_2^*=\{N_2-d_2/k_2-\beta(N_1-d_1/k_1)\}/(1-\beta^2)$

When both Equations (16) and (17) hold, $\lambda_1=d_1-k_1N_1<0$ and $\lambda_2=k_2N_2-d_2-k_2\beta(N_1-d_1/k_1)>0$ are realized. Thus $x_1(t)$ decreases while $x_2(t)$ increases. The new stationary value of x_1 is represented as max $(0, \{N_1-d_1/k_1-\beta(N_2-d_2/k_2)\}/(1-\beta))$, however, this figure becomes zero due to Equation (17).
Therefore $x_1(t)$ and $x_2(t)$ will converge to $x_1^*=0$ and $x_2^*=N_2-d_2/k_2$, respectively. Also, the

total population in the stationary phase is N_2-d_2/k_2, and which is larger than the initial population N_1-d_1/k_1. (see Figure 10)

In the case of Equations (18) and (19), $\lambda_1<0$ and $\lambda_2>0$ also hold, but the new stationary value of x_1 is max $(0, \{N_1-d_1/k_1-\beta(N_2-d_2/k_2)\}/(1-\beta^2))=\{N_1-d_1/k_1-\beta(N_2-d_2/k_2)\}/(1-\beta^2)$. Thus the point $(x_1(t), x_2(t))$ converges to another stationary point $(\{N_1-d_1/k_1-\beta(N_2-d_2/k_2)\}/(1-\beta^2), \{N_2-d_2/k_2-\beta(N_1-d_1/k_1)\}/(1-\beta^2))$. Furthermore we observe that the final total population will be larger than the initial one, because the total population in the new stationary phase is $x_1^*+x_2^*=\{N_1-d_1/k_1+N_2-d_2/k_2\}/(1+\beta)>N_1-d_1/k_1$. (see Figure 11)

As stated above, it has been shown that the initial stationary phase of population $(N_1-d_1/k_1, 0)$ is disturbed by the exogenously derived fluctuation $\varepsilon>0$ for x_2, then another stationary state is organized autonomously corresponding to the figure of β. This phenomenon is an inherent nature of the non-equilibrium state, and I.D. Prigogine has called the phenomena mentioned above in this section "self-organization in the dissipative structure through a fluctuation". The development of this model and analysis will be presented in the next section as a multi-regional model.

4. Evolutionary Process of Population Distribution of Hokkaido

In Section 3, we discussed the theoretical background of the theory of evolution of regional population distribution and the two-regional population growth model based on it. However, this model seems to be too simple to describe the actual regional population dynamics. Also it may not be so appropriate to grasp the effect on regional population distribution caused by regional development projects. In this section, therefore, we develop our model into a more practical one, then we investigate the improvement of the imbalance of regional population distribution of Hokkaido through some policy simulations.

4-1 Evolution of Population Distribution Model

(1) Skeleton of the Model

Allen and his coworkers have developed the modelling of the evolution of central places based on the theory initiated by Pligogine. They have not only taken some thoughts of the dynamics into the logistic equation of the population but also constituted the new terms with the thoughts of economics of individuals who had lived and would live in the regions. It is important that they have analyzed individual behaviours and put them together with reference to the attractivities of the regions.

Now, let us refer to the following model.

$$\frac{dx_i}{dt}=b_i x_i(J_i^0+\sum_{k=1}^{4} J_i^k-x_i)-m_i x_i \qquad (20)$$

$$+\tau\{\sum_{j\neq i} x_j^2\exp(-\beta d_{ij})-x_i^2\sum_{j\neq i}\exp(-\beta d_{ij})\} \qquad (21)$$

$$\frac{dJ_i^k}{dt}=\alpha J_i^k(M_i^k-J_i^k)$$
$$M_i^k=\lambda_i^k D_i^k \tag{22}$$

$$D_i^k=\sum_j \frac{x_i \varepsilon^k}{(P_i^k+\phi^k d_{ij})^e}\frac{A_{ij}^k}{\sum_n A_{nj}^k} \tag{23}$$

$$A_{ij}^k=\eta_i^k\frac{\left[\gamma-\dfrac{1}{\delta+\rho^k(x_i-x_k^{th})}\right]^I}{(P_i^k+\phi^k d_{ij})^I} \tag{24}$$

where, t : time
x_i : population of block i
b_i : birth rate with an inflow from outside
m_i : mortality rate with an outflow to outside
J_i^0 : basic carrying capacity of block i
d_{ij} : distance between blocks i and j
x_k^{th} : threshold population by urban function k in block i
J_i^k : increment of J_i^0 by jobs offered as employment k in block i
M_i^k : potential demand for employment by function k in block i
D_i^k : potential demand by function k in block i
A_{ij}^k : attractivity of block i as perceived by the inhabitants in block j
P_i^k : price practised in block i
α, β, γ, δ, ε^k, ϕ^k, λ^k, ρ^k, η_i^k, e, I : parameters as ;

α is a measure of the rate at which firms react to changes in the market. β reflects the ease or difficulty of commuting a distance d_{ij}. γ, δ, η^k and ρ describe the manner in which its attractivity grows up. ε^k is the quantity of k demanded per individual at unit price. ϕ^k is the transformator for a distance d_{ij} into some prices. Also, λ_i^k is one for potential demand D_i^k into the number of employees in i. Moreover, e and I are some elasticities for demands and attractivities.

(2) Explanation of the Model

Now, let us consider the structure of this model. Looking at the differential Equation (20), we can find a traditional logistic equation $\frac{dx_i}{dt}=b_i x_i(J_i^0-x_i)-m_i x_i$, which draws the natural curve of the population increase or decrease. And the second term shows the inflow and the outflow with the competition of i to all j's (In fact, it prevents us from getting its general solutions.) Then, from now on, we are to be occupied with constructing $\sum_{k=1}^{4} J_i^k$ in the first term which increase the basic carrying capacity J_i^0, while the attractivity derived from the function k generates more opportunities of employment.

J_i^k is given in the form of a differential equation exactly like the logistics with limitation M_i^k. This limitation corresponds to potential demand D_i^k with constant η_i^k, which also owes an efficiency to link the demand with the number of the population. D_i^k is given in the form of product between total demand by all the people in j's and the proportion to the attractivity from j to i. Then, attractivity A_{ij}^k is constructed as follows ; When x_i approaches x_k^{th}, $\gamma=1$ and $\delta=1$ then A_{ij}^k approaches near to zero. And when $x_i-x_k^{th}$ diverges

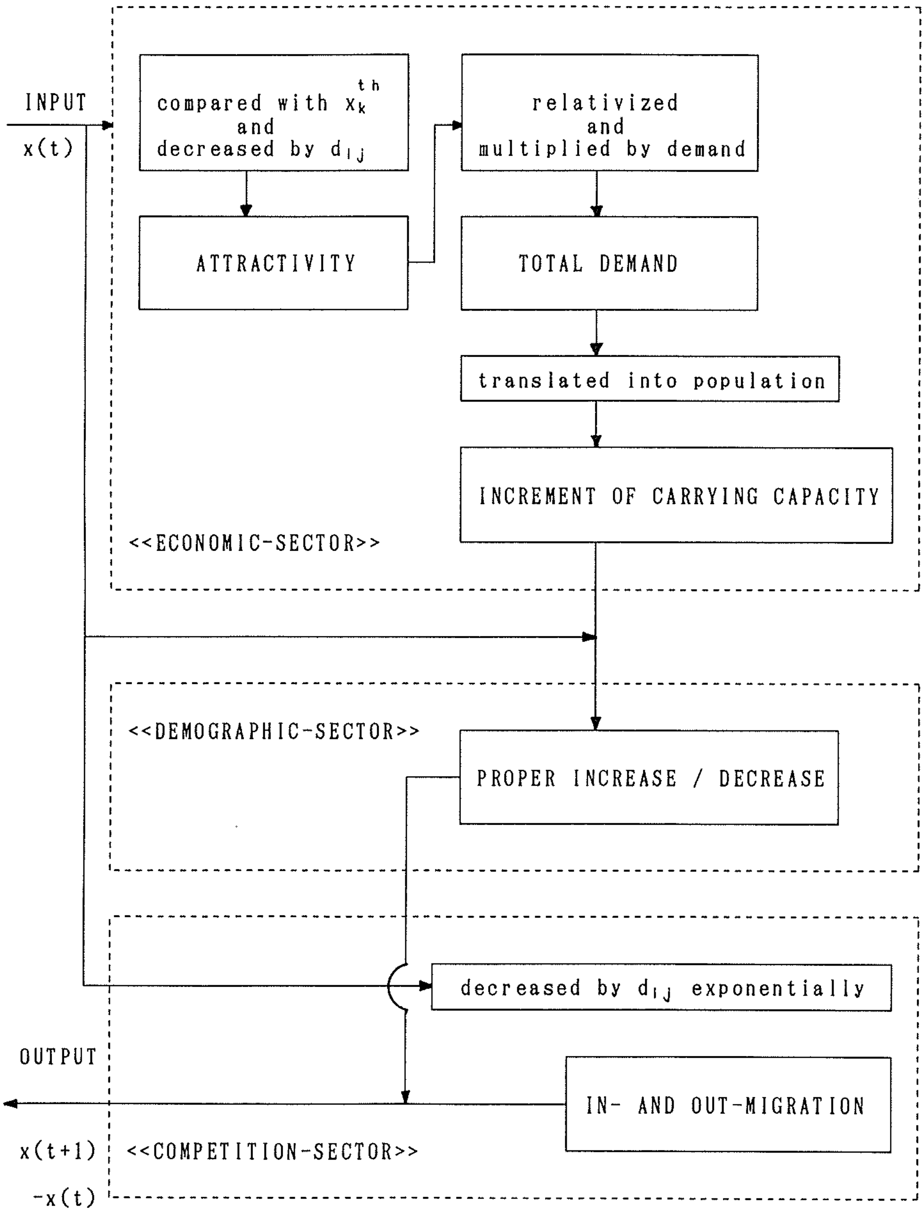

Figure. 12 Flowchart of the Model

and $\gamma=1$ then the numerator of A_{ij}^k draws close to one, while the denominator increases as the price there and the distance cost grow. Thus the larger the x_i is and the smaller these types of costs are, the more the attractivity increases. In other words, such attractivities actually reflect the increment of the population of the block.

The above-mentioned process is presented in the following flowchart; Figure 12.

Table 9 The Time-Shortest Distances Between Every Two Cities [1975−80]

(unit : hour)

i	BLOCK	CENTER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Ishikari	Sapporo	0.1	6.8	5.1	1.2	1.2	3.7	3.0	6.4	7.2	1.7	3.4	6.2	8.2	10.5
2	Oshima	Hakodate	6.8	0.0	1.6	5.3	6.8	9.2	8.6	12.0	12.8	5.6	7.3	9.6	12.1	14.4
3	Hiyama	Esashi	5.1	1.6	0.0	4.9	6.3	8.7	8.1	11.5	12.3	5.0	6.7	8.9	11.4	13.7
4	Shiribeshi	Otaru	1.2	5.3	4.9	0.0	2.4	4.8	3.1	6.5	8.3	2.9	4.6	7.4	9.3	11.6
5	Sorachi	Iwamizawa	1.2	6.8	6.3	2.4	0.0	2.4	2.9	6.4	6.0	1.6	3.1	5.0	7.9	9.5
6	Kamikawa	Asahikawa	3.7	9.2	8.7	4.8	2.4	0.0	1.8	5.1	3.6	4.0	4.3	4.2	6.0	7.0
7	Rumoi	Rumoi	3.0	8.6	8.1	3.1	2.9	1.8	0.0	3.4	5.4	4.1	5.8	5.1	7.9	8.9
8	Soya	Wakkanai	6.4	12.0	11.5	6.5	6.4	5.1	3.4	0.0	6.8	8.1	9.4	9.0	9.5	9.5
9	Abashiri	Kitami	7.2	12.8	12.3	8.3	6.0	3.6	5.4	6.8	0.0	7.4	7.0	3.5	3.2	3.2
10	Iburi	Tomakomai	1.7	5.6	5.0	2.9	1.6	4.0	4.1	8.1	7.4	0.0	1.7	3.9	6.4	8.7
11	Hidaka	Shizunai	3.4	7.3	6.7	4.6	3.1	4.3	5.8	9.4	7.0	1.7	0.0	3.1	5.6	7.9
12	Tokachi	Obihiro	6.2	9.6	8.9	7.4	5.0	4.2	5.1	9.0	3.5	3.9	3.1	0.0	2.5	4.8
13	Kushiro	Kushiro	8.2	12.1	11.4	9.3	7.9	6.0	7.9	9.5	3.2	6.4	5.6	2.5	0.0	2.3
14	Nemuro	Nemuro	10.5	14.4	13.7	11.6	9.5	7.0	8.9	9.5	3.2	8.7	7.9	4.8	2.3	0.0

Table 10 The Time-Shortest Distances Between Every Two Cities for Standard Case [1980−85]

(unit : hour)

i	BLOCK	CENTER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Ishikari	Sapporo	0.0	6.8	5.1	1.1	1.2	3.7	3.0	6.4	7.2	1.6	3.3	6.1	8.1	10.5
2	Oshima	Hakodate	6.8	0.0	1.6	5.3	6.8	9.2	8.6	12.0	12.8	5.6	7.3	9.6	12.1	14.4
3	Hiyama	Esashi	5.1	1.6	0.0	4.9	6.3	8.7	8.1	11.5	12.3	5.0	6.7	8.9	11.4	13.7
4	Shiribeshi	Otaru	1.1	5.3	4.9	0.0	2.3	4.7	3.1	6.5	8.2	2.8	4.6	7.3	9.2	11.5
5	Sorachi	Iwamizawa	1.2	6.8	6.3	2.3	0.0	2.4	2.9	6.4	6.0	1.6	3.1	5.0	7.9	9.5
6	Kamikawa	Asahikawa	3.7	9.2	8.7	4.7	2.4	0.0	1.8	5.1	3.6	4.0	4.3	5.2	6.0	7.0
7	Rumoi	Rumoi	3.0	8.6	8.1	3.1	2.9	1.8	0.0	3.4	5.4	4.1	5.8	5.1	7.9	8.9
8	Soya	Wakkanai	6.4	12.0	11.5	6.5	6.4	5.1	3.4	0.0	6.8	8.1	9.4	9.0	9.5	9.5
9	Abashiri	Kitami	7.2	12.8	12.3	8.2	6.0	3.6	5.4	6.8	0.0	7.4	7.0	3.5	3.2	3.2
10	Iburi	Tomakomai	1.6	5.6	5.0	2.8	1.6	4.0	4.1	8.1	7.4	0.0	1.7	3.9	6.4	8.7
11	Hidaka	Shizunai	3.3	7.3	6.7	4.6	3.1	4.3	5.8	9.4	7.0	1.7	0.0	3.1	5.6	7.9
12	Tokachi	Obihiro	6.1	9.6	8.9	7.3	5.0	4.2	5.1	9.0	3.5	3.9	3.1	0.0	2.5	4.8
13	Kushiro	Kushiro	8.1	12.1	11.4	9.2	7.9	6.0	7.9	9.5	3.2	6.4	5.6	2.5	0.0	2.3
14	Nemuro	Nemuro	10.5	14.4	13.7	11.5	9.5	7.0	8.9	9.5	3.2	8.7	7.9	4.8	2.3	0.0

4-2 Evolutionary Process of Population Distribution of Hokkaido

We choose Hokkaido as a study area, because it can be regarded as an almost closed area, an island, and it has a proper number of proper- width-areas with a central city or two. We divided Hokkaido into fourteen blocks, which are the same as those in Section 2.

(1) The Data

We need some data to start our simulation, which are the populaion of each city and the time-shortest distances between every two cities with a highway route as much as possible. The former has been already shown in Table 4, and the later is illustrated in Tables 9 and 10.

We simulate for these ten years, from 1975 to 1985, because ten years are sufficient to change numerous aspects in our society which are presented as constants in the differential equations. Moreover, non-linearity and discontinuity of the differential equation prevent us from finding out the proper values of parameters for the longer term. This simulation is so theory-oriented and attractivity-based that we have made more than a hundred trials to estimate the parameters which will ensure that the gap between the estimated and the actual number of populations is minimized through the calibrations.

In order to define the urban functions, application of the share rates of the industries in each block is employed, because the industrial structure reflects the urban functions well. So we regard the share rates of industries as the urban functions, and define four functions as follows ;

$k=4$: {#2 no−marked,#3≧70%} $\rightarrow x_4^{th}=100$
$k=3$: {#2 <25% and #3≧62%} $\rightarrow x_3^{th}=50$
$k=2$: {#2 no−marked,#3≧53%} $\rightarrow x_2^{th}=30$
$k=1$: {#2 >20% and #3≧44%} $\rightarrow x_1^{th}=10$
$k=0$: {#2 <20% or #3<44%}

It should be noted here that a higher degree function must always contain lower ones, for example, the city which has the function $k=4$ should have the functions $k=3$, $k=2$, and $k=1$, likewise. Needless to say, $k=0$ means that there is no higher urban function except the primary one. The primary industry #1 is not taken into account. Moreover, it is necessary for all the functions not to be against the number of the people which the cities have, in order to choose proper levels of four thresholds x_k^{th}. Thus, the higher the degree function a city has, the more people it should have. Once considered this way, the urban function level of each city is decided almost uniquely as shown in Table 11.

(2) Estimation of the Parameters and Fittness of the Model

In order to analyze and assess the impacts driven by the projects planned for Hokkaido, we must verify the reliability of this model and discover the proper standard parameters for each block. Now we calculate the parameters through more than a hundred times of calibrations as;

$b_i=0.14$ (for all i's), $m_i=0.06$ (for all i's), $\alpha=0.01$, $\beta=1.5$
$\gamma=1.1$, $\delta=1$, $\lambda=1$, $\tau=1$, $P_i^k=1$ (for all k's and all i's)
$\varepsilon^1=0.25$, $\varepsilon^2=0.15$, $\varepsilon^3=0.1$, $\rho^4=0.01$
$\rho^1=1$, $\rho^2=0.2$, $\rho^3=0.1$, $\rho^4=0.01$
$\phi^1=1$, $\phi^2=0.15$, $\phi^3=0.1$, $\phi^4=0.01$, $I=10$, $e=1$

Now we should decide only fourteen proper values of η_i^k for all k's, so we will get x_i's at 1980($t=1$) and 1985($t=2$) as in Table 12 and Figure 13. Looking at the mean absolute percentage of error (MAPE) values ;

$$\mathrm{MAPE}_i=\frac{1}{n+1}\sum_{t=0}^{2}\left|\frac{x_i(t)-x_i(t)}{x_i(t)}\right|\times 100(\%) \tag{25}$$

in Table 13 and Figure 14, we will find that the estimated populations in the blocks are quite acceptable because MAPE shows small enough figures to be ignored as zero. We call this simulation as a standard case hereafter.

(3) The Simulations

In this subsection, based on the above-mentioned model we set and simulate some cases in order to observe what happens to the population distribution under other conditions.

Table 11 Share Rates of Industries and Level of Regional Function
(unit : %)

i	BLOCK	CENTER	# 1	# 2	# 3	k
1	Ishikari	Sapporo	2	22	75	4
2	Oshima	Hakodate	12	24	64	3
3	Hiyama	Esashi	30	25	44	0
4	Shiribeshi	Otaru	14	24	61	2
5	Sorachi	Iwamizawa	21	26	53	2
6	Kamikawa	Asahikawa	17	21	62	3
7	Rumoi	Rumoi	21	26	52	0
8	Soya	Wakkanai	26	25	49	1
9	Abashiri	Kitami	21	24	55	2
10	Iburi	Tomakomai	7	29	64	2
11	Hidaka	Shizunai	33	21	46	0
12	Tokachi	Obihiro	22	22	56	2
13	Kushiro	Kushiro	12	25	63	2
14	Nemuro	Nemuro	32	20	48	0
T O T A L			13	23	63	3

Note : # 1 , # 2 , # 3 represent primary, secondary and tertiary industries, respectively

Table 12 Estimated Population of Each Block (Standard Case)
(unit : thousand persons)

i	BLOCK	CENTER	1975	1980	1985
1	Ishikari	Sapporo	1429	1642	1816
2	Oshima	Hakodate	499	514	508
3	Hiyama	Esashi	81	74	71
4	Shiribeshi	Otaru	337	323	312
5	Sorachi	Iwamizawa	524	502	471
6	Kamikawa	Asahikawa	565	583	583
7	Rumoi	Rumoi	97	90	84
8	Soya	Wakkanai	113	107	103
9	Abashiri	Kitami	374	371	366
10	Iburi	Tomakomai	467	484	478
11	Hidaka	Shizunai	106	103	99
12	Tokachi	Obihiro	347	358	361
13	Kushiro	Kushiro	297	305	308
14	Nemuro	Nemuro	97	98	97
T O T A L			5333	5554	5659

There could be various causes of the regional population increase (decrease), such as living environment, traffic condition, income level, and so on. Then we adopt the improvement of the traffic condition, time distance between regions d_{ij} as the most realistic policy of all the parameters. We assume six cases with two highways that will be constructed in the near future ; Hokkaido Vertical Highway and Hokkaido Traverse Highway (See Table 14 and Figure 15). One decade between 1975 and 1985 is considered and the first half between 1975 and 1980 would have permitted us to satisfy the highway conditions.

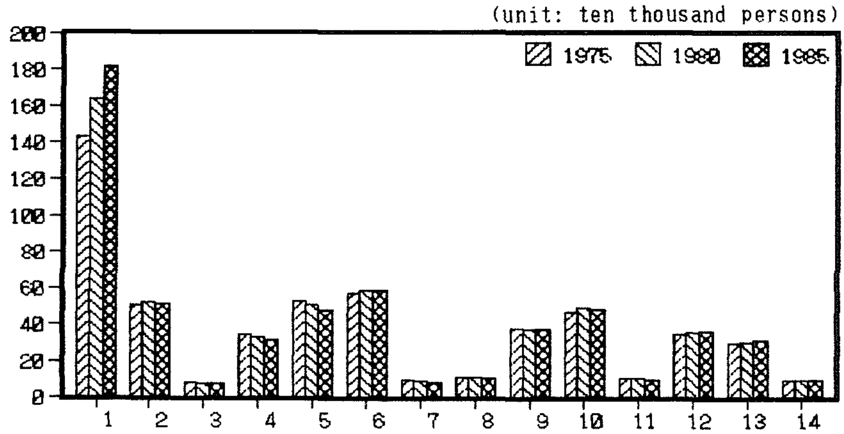

Figure. 13 Estimated Population of Each Block

Table 13 MAPE between Actual and Estimated Populations (unit : %)

i	BLOCK	CENTER	MAPE
1	Ishikari	Sapporo	0.15
2	Oshima	Hakodate	0.12
3	Hiyama	Esashi	1.12
4	Shiribeshi	Otaru	0.74
5	Sorachi	Iwamizawa	0.42
6	Kamikawa	Asahikawa	0.12
7	Rumoi	Rumoi	1.03
8	Soya	Wakkanai	0.49
9	Abashiri	Kitami	0.07
10	Iburi	Tomakomai	0.23
11	Hidaka	Shizunai	0.24
12	Tokachi	Obihiro	0.43
13	Kushiro	Kushiro	0.29
14	Nemuro	Nemuro	0.77
TOTAL			0.09

Table 14 Case Setting

DIREC.	ROUTE /CASE	STD	1	2	3	4	5	6
EAST	Sapporo ~ Shimizu					○	○	○
	Shimizu ~ Kitami						○	○
	Shimizu ~ Kushiro						○	○
WEST	Sapporo ~ Otaru	○	○	○	○	○	○	○
SOUTH	Sapporo ~ Tomakomai	○	○	○	○	○	○	○
	Tomakomai ~ Hakodate			○	○			○
NORTH	Sapporo ~ Asahikawa		○		○			○

Note : ○ means the improvement of the highways.

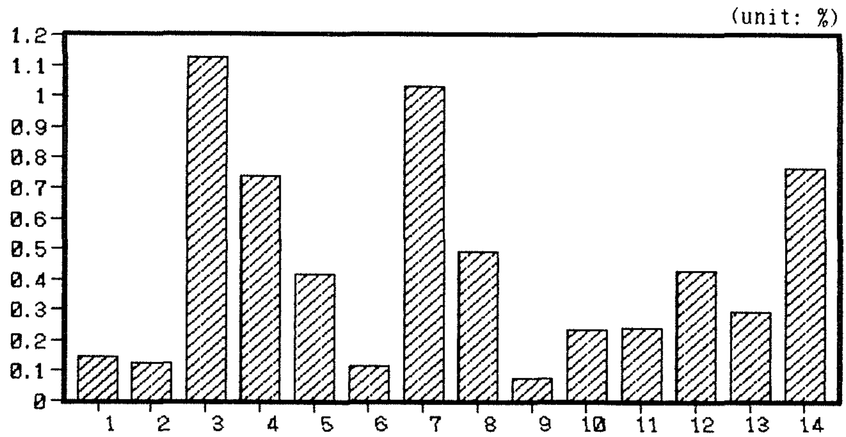

Figure. 14 MAPE between Actual and Estimated Populations

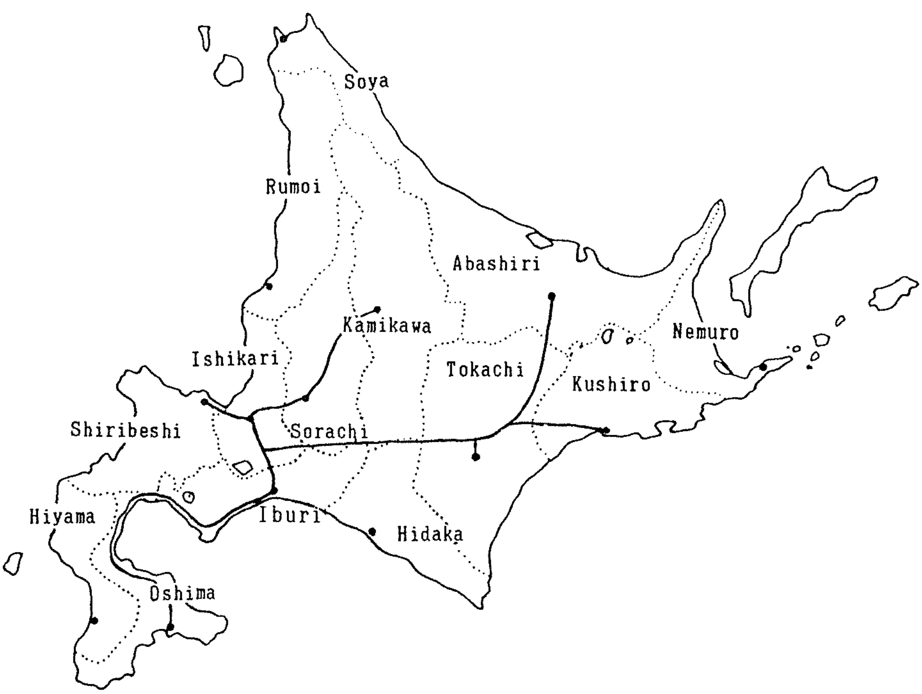

Figure. 15 Highway Plan in Hokkaido

① *Case 1*

Case 1 is the situation whereby Hokkaido Vertical Highway extended northward from Sapporo city, and Sapporo and Asahikawa cities had been linked with the highway by 1980. It decreased the time distances as in Table 15, and the simulation results are shown in Table 16 and Figure 16. There is a remarkable positive effect in Sorachi and Kamikawa blocks, but negative effect in Ishikari block, and a small increment in Shiribeshi block.

Table 15 The Time-Shortest Ditances Between Every Two Cities for Case 1 [1980−85]

(unit : hour)

i	BLOCK	CENTER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Ishikari	Sapporo	0.0	6.8	5.1	1.1	0.7	1.7	5.2	6.4	7.2	1.6	3.3	6.1	8.1	10.5
2	Oshima	Hakodate	6.8	0.0	1.6	5.3	6.3	7.2	8.6	12.0	10.8	5.6	7.3	9.6	12.1	14.4
3	Hiyama	Esashi	5.1	1.6	0.0	4.9	5.8	7.2	8.1	11.5	10.3	5.0	6.7	8.9	11.4	13.7
4	Shiribeshi	Otaru	1.1	5.3	4.9	0.0	1.0	2.0	3.1	6.5	5.9	2.8	4.6	7.3	9.2	11.5
5	Sorachi	Iwamizawa	0.7	6.3	5.8	1.0	0.0	1.1	2.1	5.5	4.7	1.6	3.1	4.5	7.9	9.5
6	Kamikawa	Asahikawa	1.7	7.2	7.2	2.0	1.1	0.0	1.5	5.1	3.6	2.5	4.3	4.2	6.0	7.0
7	*Rumoi*	*Rumoi*	5.2	8.6	8.1	3.1	2.1	1.5	0.0	3.4	5.4	4.1	5.8	5.1	7.9	8.9
8	Soya	Wakkanai	6.4	12.0	11.5	6.5	5.5	5.1	3.4	0.0	6.8	7.6	9.0	9.0	9.5	9.5
9	Abashiri	Kitami	5.2	10.8	10.3	5.9	4.7	3.6	5.4	6.8	0.0	7.4	7.0	3.5	3.2	3.2
10	Iburi	Tomakomai	1.6	5.6	5.0	2.8	1.6	2.5	4.1	7.6	7.4	0.0	1.7	3.9	6.4	8.7
11	Hidaka	Shizunai	3.3	7.3	6.7	4.6	3.1	4.3	5.8	9.0	7.0	1.7	0.0	3.1	5.6	7.9
12	Tokachi	Obihiro	6.1	9.6	8.9	7.3	4.5	4.2	5.1	9.0	3.5	3.9	3.1	0.0	2.5	4.8
13	Kushiro	Kushiro	8.1	12.1	11.4	9.2	7.9	6.0	7.9	9.5	3.2	6.4	5.6	2.5	0.0	2.3
14	*Nemuro*	*Nemuro*	10.5	14.4	13.7	11.5	9.5	7.0	8.9	9.5	3.2	8.7	7.9	4.8	2.3	0.0

Table 16 Estimated Population of Each Block (Case 1)

(unit : thousand persons)

i	BLOCK	CENTER	1975	1980	1985
1	*Ishikari*	Sapporo	*1429*	*1642*	*1747 (−69)*
2	Oshima	Hakodate	499	514	508 (0)
3	Hiyama	Esashi	81	74	71 (0)
4	Shiribeshi	Otaru	337	323	313 (1)
5	Sorachi	Iwamizawa	524	502	537 (66)
6	Kamikawa	Asahikawa	565	583	590 (7)
7	Rumoi	Rumoi	97	90	84 (0)
8	Soya	Wakkanai	113	107	103 (0)
9	Abashiri	Kitami	374	371	366 (0)
10	Iburi	Tomakomai	467	484	478 (0)
11	Hidaka	Shizunai	106	103	99 (0)
12	Tokachi	Obihiro	347	358	361 (0)
13	Kushiro	Kushiro	297	305	308 (0)
14	Nemuro	Nemuro	97	98	97 (0)
T O T A L			5333	5554	5663 (4)

Note : difference from the standard case in parentheses

These results express the extended nature of the Sapporo metropolitan area. Because of the fact that there is little influence in other blocks, the overall effect of this highway on the total population of Hokkaido can be said to be neutral.

② *Case 2*

In Case 2, it is considered that the highway had reached Hakodate city in Oshima block, southward, by 1980. The time distances under this case and the simulation results are illustrated in Tables 17 and 18 and Figure 17. Populations of Oshima and Hiyama blocks increased but that of Iburi block situated between Ishikari and Oshima blocks decreased. This exhibits a weak point of highway-intermediate-cities.

Table 17 The Time-Shortest Distances Between Every Two Cities for Case 2 [1980−85]
(unit : hour)

i	BLOCK	CENTER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Ishikari	Sapporo	0.0	3.4	4.2	1.1	1.2	3.7	3.0	6.4	7.2	1.6	3.3	6.1	8.1	10.5
2	Oshima	Hakodate	3.4	0.0	1.6	3.8	4.6	7.0	6.4	9.8	10.6	4.8	6.4	6.8	9.3	11.8
3	Hiyama	Esashi	4.2	1.6	0.0	4.5	5.4	7.8	8.1	11.5	11.4	3.6	5.3	7.5	10.0	12.8
4	Shiribeshi	Otaru	1.1	3.8	4.5	0.0	2.3	4.7	3.1	6.5	8.2	1.6	3.3	7.3	9.2	11.5
5	Sorachi	Iwamizawa	1.2	4.6	5.4	2.3	0.0	2.4	2.9	6.4	6.0	1.6	3.1	5.0	7.9	9.5
6	Kamikawa	Asahikawa	3.7	7.0	7.8	4.7	2.4	0.0	1.8	5.1	3.6	4.0	4.3	4.2	6.0	7.0
7	Rumoi	Rumoi	3.0	6.4	8.1	3.1	2.9	1.8	0.0	3.4	5.4	4.1	5.8	5.1	7.9	8.9
8	Soya	Wakkanai	6.4	9.8	11.5	6.5	6.4	5.1	3.4	0.0	6.8	8.1	9.4	9.0	9.5	9.5
9	Abashiri	Kitami	7.2	10.6	11.4	8.2	6.0	3.6	5.4	6.8	0.0	7.4	7.0	3.5	3.2	3.2
10	Iburi	Tomakomai	1.6	4.8	3.6	1.6	1.6	4.0	4.1	8.1	7.4	0.0	1.7	3.9	6.4	8.7
11	Hidaka	Shizunai	3.3	6.4	5.3	3.3	3.1	4.3	5.8	9.4	7.0	1.7	0.0	3.1	5.6	7.9
12	Tokachi	Obihiro	6.1	6.8	7.5	7.3	5.0	4.2	5.1	9.0	3.5	3.9	3.1	0.0	2.5	4.8
13	Kushiro	Kushiro	8.1	9.3	10.0	9.2	7.9	6.0	7.9	9.5	3.2	6.4	5.6	2.5	0.0	2.3
14	Nemuro	Nemuro	10.5	11.8	12.8	11.5	9.5	7.0	8.9	9.5	3.2	8.7	7.9	4.8	2.3	0.0

Table 18 Estimated Population of Each Block (Case 2)
(unit : thousand persons)

i	BLOCK	CENTER	1975	1980	1985
1	Ishikari	Sapporo	1429	1642	1803 (−13)
2	Oshima	Hakodate	499	514	522 (14)
3	Hiyama	Esashi	81	74	76 (5)
4	Shiribeshi	Otaru	337	323	315 (3)
5	Sorachi	Iwamizawa	524	502	471 (0)
6	Kamikawa	Asahikawa	565	583	583 (0)
7	Rumoi	Rumoi	97	90	84 (0)
8	Soya	Wakkanai	113	107	103 (0)
9	Abashiri	Kitami	374	371	366 (0)
10	Iburi	Tomakomai	467	484	470 (− 8)
11	Hidaka	Shizunai	106	103	99 (0)
12	Tokachi	Obihiro	347	358	361 (0)
13	Kushiro	Kushiro	297	305	308 (0)
14	Nemuro	Nemuro	97	98	97 (0)
	T O T A L		5333	5554	5660 (1)

Note : difference from the standerd case in parentheses

As shown in this simulation, the increment or decrement is smaller than in Case 1, therefore it can be said that the effect of this highwayis not so significant.

③ *Case 3*

This case assumes the completion of Hokkaido Vertical Highway, Hakodate-Sapporo -Asahikawa, by 1980. Looking at Tables 19 and 20 and Figure 18, the simulation result is of almost the same composition of Case 1 and Case 2. That is, negative effect in Ishikari and Iburi blocks, positive in Oshima, Hiyama, Shiribeshi, Sorachi, and Kamikawa blocks are observed. But the negative effect in Ishikari block is larger and the positive in Oshima and Hiyama blocks is smaller than in Case 1. Thus, it is concluded that the dispersion of

Table 19 The Time-Shortest Distances Between Every Two Cities for Case 3 [1980－85]
(unit : hour)

i	BLOCK	CENTEQ	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	*Ishikari*	*Sapporo*	*0.0*	*3.4*	*4.2*	*1.1*	*0.7*	*1.7*	*3.0*	*6.4*	*5.2*	*1.6*	*3.3*	*6.1*	*8.1*	*10.5*
2	Oshima	Hakodate	3.4	0.0	1.6	3.8	3.6	4.7	6.4	9.8	8.2	4.8	6.4	6.8	9.3	11.8
3	Hiyama	Esashi	4.2	1.6	0.0	4.5	4.9	7.3	7.2	10.7	10.7	3.6	5.3	7.5	10.0	12.3
4	Shiribeshi	Otaru	1.1	3.8	4.5	0.0	1.0	2.0	3.1	6.5	5.9	1.6	3.3	7.3	9.2	11.5
5	Sorachi	Iwamizawa	0.7	3.6	4.9	1.0	0.0	1.1	2.1	5.5	4.7	1.6	3.1	4.5	7.9	9.5
6	Kamikawa	Asahikawa	1.7	4.7	7.3	2.0	1.1	0.0	1.5	5.1	3.6	2.5	4.3	4.2	6.0	7.0
7	Rumoi	Rumoi	3.0	6.4	7.2	3.1	2.1	1.5	0.0	3.4	5.1	4.1	5.8	5.1	7.6	8.6
8	Soya	Wakkanai	6.4	9.8	10.7	6.5	5.5	5.1	3.4	0.0	6.8	7.6	9.0	9.0	9.5	9.5
9	Abashiri	Kitami	5.2	8.2	10.9	5.9	4.7	3.6	5.1	6.8	0.0	7.4	7.0	3.5	3.2	3.2
10	Iburi	Tomakomai	1.6	4.8	3.6	1.6	1.6	2.5	4.1	7.6	7.4	0.0	1.7	3.9	6.4	8.7
11	Hidaka	Shizunai	3.3	6.4	5.3	3.3	3.1	2.5	5.8	9.0	7.0	1.7	0.0	3.1	5.6	7.9
12	Tokachi	Obihiro	6.1	6.8	7.5	7.3	4.5	4.2	5.1	9.0	3.5	3.9	3.1	0.0	2.5	4.8
13	Kushiro	Kushiro	8.1	9.3	10.0	9.2	7.9	6.0	7.6	9.5	3.2	6.4	5.6	2.5	0.0	2.3
14	Nemuro	Nemuro	10.5	11.8	12.3	11.5	9.5	7.0	8.6	9.5	3.2	8.7	7.9	4.8	2.3	0.0

Table 20 Estimated Population of Each Block (Case 3)
(unit : thousand persons)

i	BLOCK	CENTER	1975	1980	1985
1	Ishikari	Sapporo	1429	1642	1736 (−80)
2	Oshima	Hakodate	499	514	519 (11)
3	Hiyama	Esashi	81	74	71 (0)
4	Shiribeshi	Otaru	337	323	313 (1)
5	Sorachi	Iwamizawa	524	502	532 (61)
6	Kamikawa	Asahikawa	565	583	589 (6)
7	Rumoi	Rumoi	97	90	88 (4)
8	Soya	Wakkanai	113	107	103 (0)
9	Abashiri	Kitami	374	371	366 (0)
10	Iburi	Tomakomai	467	484	477 (− 1)
11	Hidaka	Shizunai	106	103	99 (0)
12	Tokachi	Obihiro	347	358	361 (0)
13	Kushiro	Kushiro	297	305	308 (0))
14	Nemuro	Nemuro	97	98	97 (0)
	T O T A L		5333	5554	5660 (1)

Note : difference from the standard case in parentheses

population from the center of Hokkaido, Ishikari block, to the northern areas is more considerable than to the southern areas.

④ *Case 4*

In this case we assume that Hokkaido Traverse Highway directed eastward, so Sapporo city and Shimizu town, which is located near Obihiro city in Tokachi block, are linked with each other by the highway by 1980. The distance in time and the simulation results are shown in Tables 21 and 22 and Figure 19. Population of Ishikari block greatly decreases and that of Tokachi block increases. The number of increment (decrement) is, as well as in Case 2, smaller than in Case 1 and Case 3.

Table 21 The Time - Shortest Distances Between Every Two Cities for Case 4 [1980−85]
(unit : hour)

i	BLOCK	CENTER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Ishikari	Sapporo	0.0	6.8	5.1	1.1	1.2	3.7	3.0	6.4	6.1	1.6	3.3	2.6	5.1	7.4
2	Oshima	Hakodate	6.8	0.0	1.6	5.3	6.8	9.2	8.6	12.0	11.7	5.6	7.3	8.2	10.7	13.0
3	Hiyama	Esashi	5.1	1.6	0.0	4.9	6.3	8.7	8.1	11.5	11.0	5.0	6.7	7.5	10.0	12.3
4	Shiribeshi	Otari	1.1	5.3	4.9	0.0	2.3	4.7	3.1	6.5	6.5	2.8	4.6	3.0	5.5	12.8
5	Sorachi	Iwamizawa	1.2	6.8	6.3	2.3	0.0	2.4	2.9	6.4	6.0	1.6	3.1	3.9	6.3	8.9
6	Kamikawa	Asahikawa	3.7	9.2	8.7	4.7	2.4	0.0	1.8	5.1	3.6	4.0	4.3	4.2	6.0	7.0
7	Rumoi	Rumoi	3.0	8.6	8.1	3.1	2.9	1.8	0.0	3.4	5.4	4.1	5.8	5.1	7.9	8.9
8	Soya	Wakkanai	6.4	12.0	11.5	6.5	6.4	5.1	3.4	0.0	6.8	8.1	9.4	9.0	9.5	9.5
9	Abashiri	Kitami	6.1	11.7	11.0	6.5	6.0	3.6	5.4	6.8	0.0	6.1	7.0	3.5	3.2	3.2
10	Iburi	Tomakomai	1.6	5.6	5.0	2.8	1.6	4.0	4.1	8.1	6.1	0.0	1.7	2.6	5.0	7.4
11	Hidaka	Shizunai	3.3	7.3	6.7	4.6	3.1	4.3	5.8	9.4	7.0	1.7	0.0	3.1	5.6	7.9
12	Tokachi	Obihiro	2.6	8.2	7.5	3.0	3.9	4.2	5.1	9.0	3.5	2.6	3.1	0.0	2.5	4.8
13	Kushiro	Kushiro	5.1	10.7	10.0	5.5	6.3	6.0	7.9	9.5	3.2	5.0	5.6	2.5	0.0	2.3
14	Nemuro	Nemuro	7.4	13.0	12.3	7.8	8.9	7.0	8.9	9.5	3.2	7.4	7.9	4.8	2.3	0.0

Table 22 Estimated Population of Each Block (Case 4)
(unit : thousand persons)

i	BLOCK	CENTER	1975	1980	1985
1	Ishikari	Sppporo	1429	1642	1811 (-5)
2	Oshima	Hakodate	499	514	508 (0)
3	Hiyama	Esahi	81	74	71 (0)
4	Shiribeshi	Otaru	337	323	321 (0)
5	Sorachi	Iwamizawa	524	502	471 (0)
6	Kamiawa	Asahikawa	565	583	583 (0)
7	RumOi	Rumoi	97	90	84 (0)
8	Soya	Wakkanai	113	107	103 (0)
9	Abashiri	Kitami	374	371	366 (0)
10	Iburi	Tomakomai	467	484	478 (0)
11	Hidaka	Shizunai	106	103	99 (0)
12	Tokaka	Obihiro	347	358	375 (14)
13	Tok	kuahiro	297	305	309 (1)
14	Nemuro	Nemuro	97	98	97 (0)
	T O T A L		5333	5554	5666 (7)

Note : difference from the standard case in parentheses

⑤ *Case 5*

We assume in Case 5 that Hokkaido Traverse Highway reached Kushiro and Kitami blocks farther eastward by 1980. The time distances and the simulation results are presented in Tables 23 and 24 and Figure 20. Abashiri, Tokachi, and Kushiro blocks notablly had a large number of persons, while Ishikari block showed a decrease in Case 4. With regard to the east areas, the effect in Abashiri block is not so significant and in Tokachi block is slightly smaller than in Case 4. In Kushiro block the positive effect is now larger than in Abashiri block.

Table 23 TheITime - Shortest Distances Between Every Tow Cities for Case 5 [1980−85]
(unit : hour)

i	BLOCK	CENTER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Ishikari	Sapporo	0.0	6.8	5.1	1.1	1.2	3.7	3.0	6.4	3.5	1.6	3.3	2.6	3.4	5.7
2	Oshima	Hakodate	6.8	0.0	1.6	5.3	6.8	9.2	8.6	12.0	9.0	5.6	7.3	8.2	8.9	11.2
3	Hiyama	Esashi	5.1	1.6	0.0	4.9	6.3	8.7	8.1	11.5	8.4	5.0	6.7	7.5	8.2	10.6
4	Shiribeshi	Otaru	1.1	5.3	4.9	0.0	2.3	4.7	3.1	6.5	3.8	2.8	4.6	3.0	3.7	6.0
5	Sorachi	Iwamizawa	1.2	6.8	6.3	2.3	0.0	2.4	2.9	6.4	4.7	1,6	3.1	3.9	4.6	6.9
6	Kan ikawa	Asahikawa	3.7	9.2	8.7	4.7	2.4	0.0	1.8	5.1	3.6	4.0	4.3	4.2	5.0	7.0
7	Rumoi	Rumoi	3.0	8.2	8.1	3.1	2.9	1.8	0.0	3.4	5.4	4.1	5.8	5.1	6.8	8.9
8	Soya	Wakkanai	6.4	12.0	11.5	6.5	6.4	5.1	3.4	0.0	6.8	8.1	9.4	9.0	8.5	9.5
9	Abashiri	Kitami	3.5	9.0	8.4	3.8	4.7	3.6	5.4	6.8	0.0	3.4	5.1	1.9	1.7	3.2
10	Iburi	Tomakomai	1.6	5.6	5.0	2.8	1.6	4.0	4.1	8.1	3.4	0.0	1.7	2.6	3.3	5.6
11	*Hidaka*	*Shizunai*	3.3	7.3	6.7	4.6	3.1	4.3	5.8	9.4	5.1	1.7	0.0	3.1	5.0	4.9
12	Tokachi	Obihiro	2.6	8.2	7.5	3.0	3.9	4.2	5.1	9.0	1.9	2.6	3.1	0.0	1.8	4.1
13	Kushiro	Kushiro	3.4	8.2	8.2	3.7	4.6	5.0	6.8	8.5	1.7	3.3	5.0	1.8	0.0	2.3
14	Nemuro	Nemuro	5.7	11.2	10.6	6.0	6.9	7.0	8.9	9.5	3.2	5.6	4.9	4.1	2.3	0.0

Table 24 Estimated Population of Each Block (Case 5)
(unit : thousand persons)

i	BLOCK	CENTER	1975	1980	1985
1	Ishikari	Sapporo	1429	1642	1807 (-9)
2	Oshima	Hakodate	499	514	508 (0)
3	Hivama	Esashi	81	74	71 (0)
4	Shiribeshi	Otaru	337	323	321 (0)
5	Sorachi	Iwamizawa	524	502	471 (0)
6	Kamikawa	Asahikawa	565	583	583 (0)
7	Rumoi	Rumoi	97	90	84 (0)
8	Soya	Wakkanai	113	107	103 (0)
9	Abashiri	Kitami	374	371	367 (1)
10	Iburi	Tomakomai	467	484	477 (-1)
11	Hidaka	Shizunai	106	103	99 (0)
12	Tokachi	Obihiro	347	358	374 (13)
13	*kushiro*	*Kushiro*	*297*	305	314 (6)
14	Nemuro	Nemnro	97	98	98 (1)
	T O T A L		5333	5554	5668 (9)

Note : difference from the standard case in parentheses

⑥ *Case 6*

This case assumes the completion of the whole plan, that is the composition of Cases 3 and 5. Thus Hokkaido had the two important trunk line routes which would run through crosswise by 1980. Asahikawa, Sapporo and Hakodate are linked by Hokkaido Vertical Highway and Sapporo and Kitami as well as Kushiro are also linked by Hokkaido Traverse Highway. Looking at Tables 25 and 26 and Figure 21, we find that Sorachi block gained the largest positive effect and that contrariwise Ishikari block obtained the largest negative effect, though it is somewhat smaller than in Case 3. In Oshima and Hiyama blocks, the positive effects are also smaller than in Case 3. The negative effect in Iburi block now grows larger owing to Oshima and Tokachi block's population absorptivity. On

Table 25 The Time - Shortest Distances Between Every Two Cities for Case 6 [1980－85]
(unit : hour)

i	BLOCK	CENTER	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Ishikari	Sapporo	0.0	3.4	4.2	1.1	0.7	1.7	3.0	6.4	3.5	1.6	3.3	2.6	3.4	5.7
2	Oshima	Hakodate	3.4	0.0	1.6	3.8	3.6	4.7	6.4	9.8	5.6	4.8	6.4	4.7	5.5	7.9
3	Hiyama	EsashiOtaru	4.2	1.6	0.0	4.5	4.9	7.3	7.2	10.7	6.3	3.6	5.3	5.5	6.2	8.5
4	Shiribeshi	Iorachi	1.1	3.8	4.5	0.0	1.0	2.0	3.1	6.5	3.8	1.6	3.3	3.0	3.7	6.0
5	Sorachi	Kamikawa	0.7	3.6	4.9	1.0	0.0	1.1	2.1	5.5	3.7	1.6	3.1	2.8	3.6	5.9
6	Kamikawa	Rumoi	1.7	4.7	7.3	2.0	1.1	0.0	1.5	5.1	3.6	2.5	4.3	4.2	6.0	7.0
7	Rumoi	Wakkanai	3.0	6.4	7.2	3.1	2.1	1.5	0.0	3.4	5.1	4.1	5.8	5.1	7.9	8.9
8	Soya	Kitami	6.4	9.8	10.7	6.5	5.5	5.1	3.4	0.0	6.8	7.6	9.0	9.0	8.5	9.5
9	Abashiri	Tomakomai	3.5	5.6	6.3	3.8	3.7	3.6	3.1	6.8	0.0	3.4	5.1	1.9	1.7	3.2
10	Iburi	Shizunai	1.6	4.8	3.6	1.6	1.6	2.5	4.1	7.6	3.4	0.0	1.7	2.6	3.3	5.6
11	Hidaka	Shizunai	3.3	6.4	5.3	3.3	3.1	4.3	5.8	9.0	5.1	1.7	0.0	3.1	5.0	4.9
12	Tokachi	Obihiro	2.6	4.7	5.5	3.0	2.8	4.2	5.1	9.0	1.9	2.6	3.1	0.0	1.8	4.1
13	Kushir	Kushiro	3.4	5.5	6.2	3.7	3.6	6.0	7.9	8.5	1.7	3.3	5.0	1.8	0.0	2.3
14	Nemuro	Nemuro	5.7	7.9	8.5	6.0	5.9	7.0	8.9	9.5	3.2	5.6	4.9	4.1	2.3	0.0

Table 26 Estimated Population of Each Block (Case 6)
(unit : thousand persons)

i	BLOCK	CENTER	1975	1980	1985
1	Ishikaari	Sappor	1429	1642	1761(-55)
2	Oshima	HakodateEs	499	514	513 (5)
3	Hiyama	Esashi	81	74	71 (0)
4	Shiribeshi	Otaro	337	323	316 (4)
5	Sorachi	Iwamizawa	524	502	526 (55)
6	Kamikawa	Asahikawa	565	583	589 (6)
7	Rumoi	Rumoi	97	90	88 (4)
8	Soya	Wakkanai	113	107	103 (0)
9	Abashiri	Kitami	374	371	368 (2)
10	Iburi	Tomakomai	467	484	468(-10)
11	HidaKa	Shizunai	106	103	99 (0)
12	Tokachi	Obihiro	347	358	377 (16)
13	Kushiro	Kushiro	297	305	314 (6)
14	Nemuro	Nemur	97	98	98 (1)
	T O T A L		5333	5554	5691 (32)

Note : difference from the standard case in parentheses

the other hand, in Abashiri, Tokachi and Kushiro blocks, the positive effects become larger than in Case 5.

We can probably say that the composition of these two highways should have more various effects than the simple sum of each of them and that the population distribution over many regions is well-controled in this case.

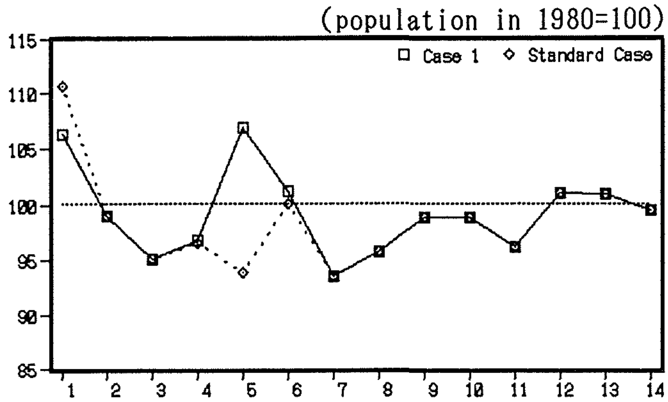

Figure. 16 Difference between Standard Case and Case 1

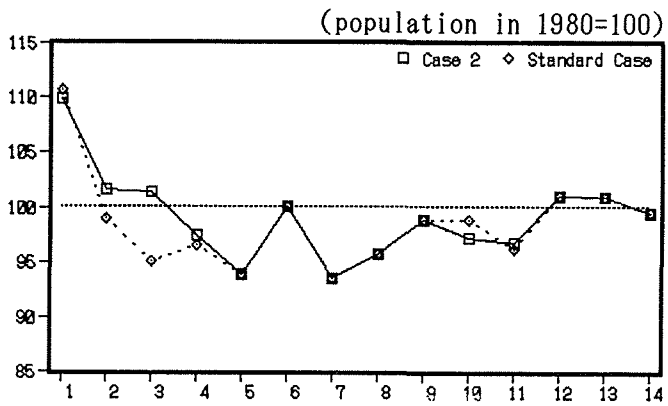

Figure. 17 Difference between Standard Case and Case 2

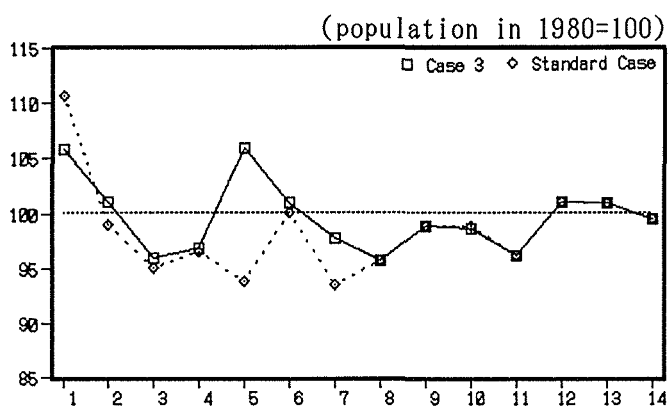

Figure. 18 Difference between Standard Case and Case 3

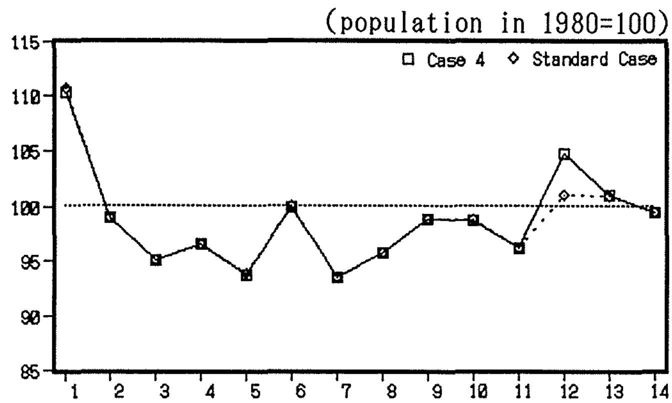

Figure. 19 Difference between Standard Case and Case 4

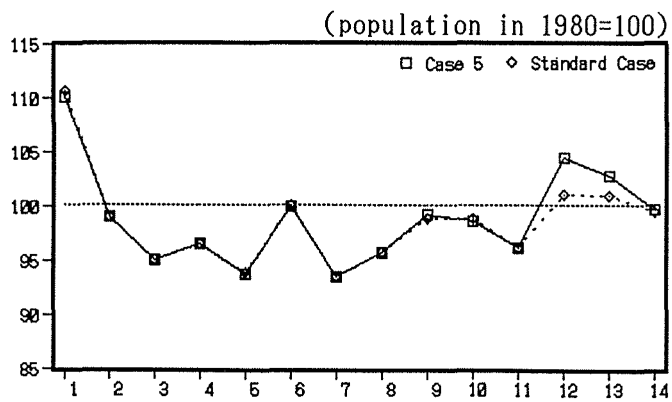

Figure. 20 Difference between Standard Case and Case 5

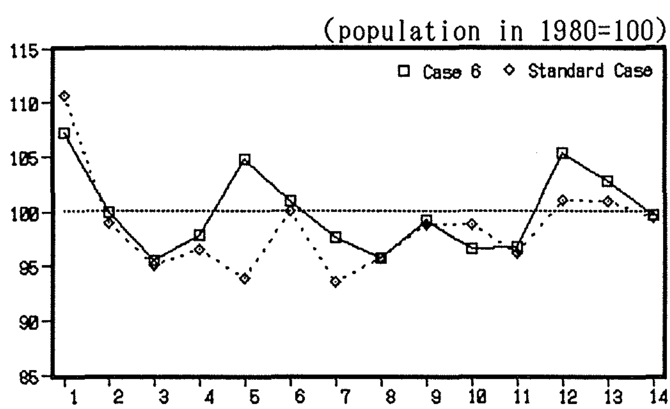

Figure. 21 Difference between Standard Case and Case 6

5. Conclusion

This paper has examined the improvement of the interregional imbalance of population distribution in Hokkaido prefecture by employing Dynamic Self-Organization Theory. In this study, we have developed the population distribution model originally introduced by Allen et.al. into a corroborative model. From our study, it was confirmed that our model can trace the actual evolution of regional pupulation distribution and well appraise the effects on the population distribution caused by the construction of the highways. Further research involves more precise parameter estimation in the sense of statistics, formulation of more realistic attractivities than those in our model and investigation of evolution of population distribution caused by various projects for regional development.

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