Spatial structure and prediction of Land use change considering development projects in urban promotion districts

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Abstract:

In this paper, the actual conditions and the change structure of land use by using mesh data are studied in urban promotion area in a local hub city of Fukuoka, Japan. Firstly, all meshes are classified into 15 patterns based on distribution of land use. Then, transition probability models are made out based on the change of these 15 patterns. The Change structure of land use in an area depends on whether development projects are carried out or not. Therefore, all of the meshes are divided into two groups, and different transition probability models are proposed. Finally, a prediction method of land use is proposed under the consideration of the changing structure of meshes. Though our proposed approach is a macroscopic forecasting method of land use, it is useful to evaluate the effects of urban policies for development projects.

1. Introduction

Land use is changeable with the urban growth, development projects in urban promotion areas, such as land readjustment, laying out of a residential area, urban renewal, transportation facilities for urban infrastructure and so on. On the other hand, systems for keeping physical environment sound and good are also provided under the Town Planning and Zoning Act. Such development projects and development control by law have an influence on land use change, and it is important to analyze such a change in urban land use for the understanding of the urban spatial structure. In order to understand the urban spatial structure and to make a comprehensive land use plan in urban areas, all conditions such as land use changes caused by development projects, contingent changes and preservation efforts should be given consideration. In this paper, the changing structure of land use in urban promotion area are analyzed in consideration of the transition of the utilization pattern of meshes and the stable

combination of land use in a mesh. The changing structure of land use in a mesh is discussed, classifying meshes by whether large-scale projects have been done or not. Then, a new approach for the prediction of land use in urban promotion area is proposed, which becomes feasible to forecast future land use in consideration of various scenarios of large-scale projects.

2. Classification of mesh-zones by land use pattern

Fukuoka City has 3 terms of mesh data on land use – 1977,1985,1993. In the area of study, the urban promotion area of Fukuoka City, there are 2553 mesh zones of 250m x 250m. Mesh data is presented by 24 or 25 kinds of land use. This classification was made very carefully based on the present conditions of land use. However, in analyzing the present land use or forecasting land use for the future, they were subdivided too immoderately to analyze satisfactorily. Therefore, the 24 or 25 subdivisions were adjusted to 12 (Table 1).

Table 1. Division of Land Use

Division	Contents
Public	Government & Public offices, Education and Welfare
Residence	Residence
Commerce	Business, Commerce, Loging and Amusement facilities
Industry	Heavy industry, Industry and Suppliance processing facilities
Park	Park and Golf course
Transportation Facilities	Transportation facilities and Track laying area
Road	Road
Vacant	Vacant
Farmland	Paddy field, Field, Orchard, Pasture and Agricultural Facilities
Unused	Unused, others
Forest	Forest
River	River, Water surface, Seashore and Waterway

Table 2. Classification of Mesh Zone

No.	Patterns	Public	Res.	Com.	Ind.	Park	Trs	Road	Vacancy	Unused	Agr.	Forest	River	
1	Industrial pattern	1.4%	3.7%	2.3%	68.4%	0.4%	2.6%	9.6%	2.2%	1.3%	1.4%	1.5%	5.2%	73
2	Traffic facilities pattern	0.3%	3.0%	2.8%	2.3%	0.4%	73.7%	12.2%	1.9%	1.1%	1.2%	0.0%	1.1%	148
3	Transportation & road pattern	1.6%	8.5%	8.9%	7.6%	1.1%	31.5%	27.3%	7.3%	2.3%	2.0%	0.2%	1.6%	305
4	Mixed used pattern	2.6%	11.9%	10.3%	23.9%	3.1%	9.5%	14.5%	7.6%	4.3%	8.0%	0.8%	3.3%	241
5	Commercial pattern	5.8%	18.3%	28.2%	3.1%	1.5%	5.1%	22.8%	8.9%	1.3%	2.8%	0.1%	2.1%	642
6	Vacant use pattern	1.7%	5.1%	1.8%	1.4%	1.4%	2.7%	12.4%	66.5%	1.6%	1.4%	2.2%	1.7%	171
7	Public facilities pattern	69.3%	7.6%	2.5%	0.4%	1.6%	0.8%	7.9%	2.6%	1.3%	1.7%	1.4%	2.9%	167
8	Residential pattern with public	31.9%	27.2%	5.6%	1.3%	2.4%	2.2%	14.7%	4.3%	2.4%	2.5%	2.1%	3.3%	503
9	High density residential pattern	4.2%	52.3%	5.9%	0.9%	2.0%	1.1%	16.2%	5.5%	2.9%	3.9%	2.2%	3.0%	2,554
10	Residential pattern with park	6.3%	20.2%	7.6%	1.8%	27.8%	4.4%	16.0%	4.7%	4.3%	2.2%	1.8%	3.1%	122
11	Park pattern	3.2%	5.3%	1.5%	1.5%	62.5%	2.0%	8.5%	3.2%	3.0%	1.3%	5.6%	2.3%	122
12	Waterfront pattern	3.7%	15.3%	5.2%	2.7%	3.6%	1.7%	13.3%	4.3%	2.8%	5.0%	1.4%	40.1%	345
13	Unused pattern	2.7%	20.7%	2.8%	1.4%	3.0%	1.4%	11.1%	5.3%	20.8%	8.0%	18.8%	4.0%	676
14	Residential pattern with farmland	3.8%	22.6%	4.0%	1.9%	1.1%	2.2%	11.3%	4.4%	5.3%	37.6%	2.0%	3.7%	1,280
15	Forest pattern	1.6%	6.6%	0.5%	0.9%	1.2%	0.3%	4.1%	2.3%	4.5%	4.4%	70.3%	3.3%	310

note) Res. : Residence, Com. : Commerce, Ind. : Industrial, Trs. : Transport, Agr. : Agriculture
: Number of meshes in each pattern

All of the mesh data over 3 terms were classified statistically based on ratio of land

use area by principal component analysis and cluster analysis. The mesh zones were classified by using cluster analysis. When using the cluster analysis, it was impossible to use all data for the mesh zones because the amount of data was too large to analyze. Random sampling picked up 10% of all data. To reflect the present situation of land use more accurately, random sampling was repeated 5 times (over 3 terms). These data taken by random sampling were classified into 15 patterns by cluster analysis under the check of KS-test at 5% significance. After comparing the 15 patterns with all the land use data of Fukuoka City (2553 meshes x 3 terms), all the meshes of land use data were classified into 15 patterns by using RMS-error (Table 2). Considering Table 2, the characteristic of each pattern is expressed in Table 3.

Table 3. Characteristics of Each Pattern

NO.	PATTERNS	CHARACTERISTICS
1	Industrial pattern	The area where there are large and small factories.
2	Traffic facilities pattern	Traffic facilities like airport,station,terminal and transportation area.
3	Transportation & road pattern	The area which is used for physical distribution and loading and unloading.
4	Mixed used pattern	The use of this area is disordered. The land use status is unstable.
5	Commercial pattern	The area where there are many shops and department store.
6	Vacant use pattern	The area which is vacant for various use.
7	Public facilities pattern	The area which is used for public use
8	Residential pattern with public	Residential area near the public facilities.
9	High density residential pattern	The most generalized residential area. The range of this area is the vastest
10	Residential pattern with park	Low-density residential area with many parks. The environment is favourable.
11	Park pattern	The area which is used for large park ,zoo, play ground.
12	Waterfront pattern	The area which is faced to river and sea.
13	Unused pattern	The area which is unsued in the outskirts of city center.
14	Residential pattern with farmland	The traditional style of agricultural land
15	Forest pattern	The green area which is not urbanized in the outskirts of central city.

3. Spatial Structure and Change of Land Use Transition

Spatial structures of land use pattern are shown in Figure 1. From these maps, it can be said that the urban spatial structure of Fukuoka City is simple, centralized to one pole – the city center. Around the city center, residential area is located broadly. As it goes to the outskirts, many zones of agricultural area and forest are located. From the transformation of these maps marked by land use pattern over 3 terms, the meshes of commercial area increased, while residential area sprawled to the outskirts of the urban promoting area. Also, sub-city center formed, newly.

In order to predict the change of land use, it is very important to know which kind of land is easy to change or not, and which kind of land it will change into. From the study about changing structure and tendency of land use over 3 terms (1977-1985, 1985-1993), ultimate end of change can be grasped, and that study make it possible to predict the change of urban spatial structure. In this paragraph, the changing structures of land use and the ratio of maintenance are figured over 3 terms (1977-1985, 1985-1993). In Figure 2, the number over the arrows means the number of meshes that moved. Only the meshes that changed largely (over 10 meshes) are taken into consideration. The two numbers in the every box means the number of meshes before (left side) and after (right side) changing. The total ratios of keeping pattern are 71.1%
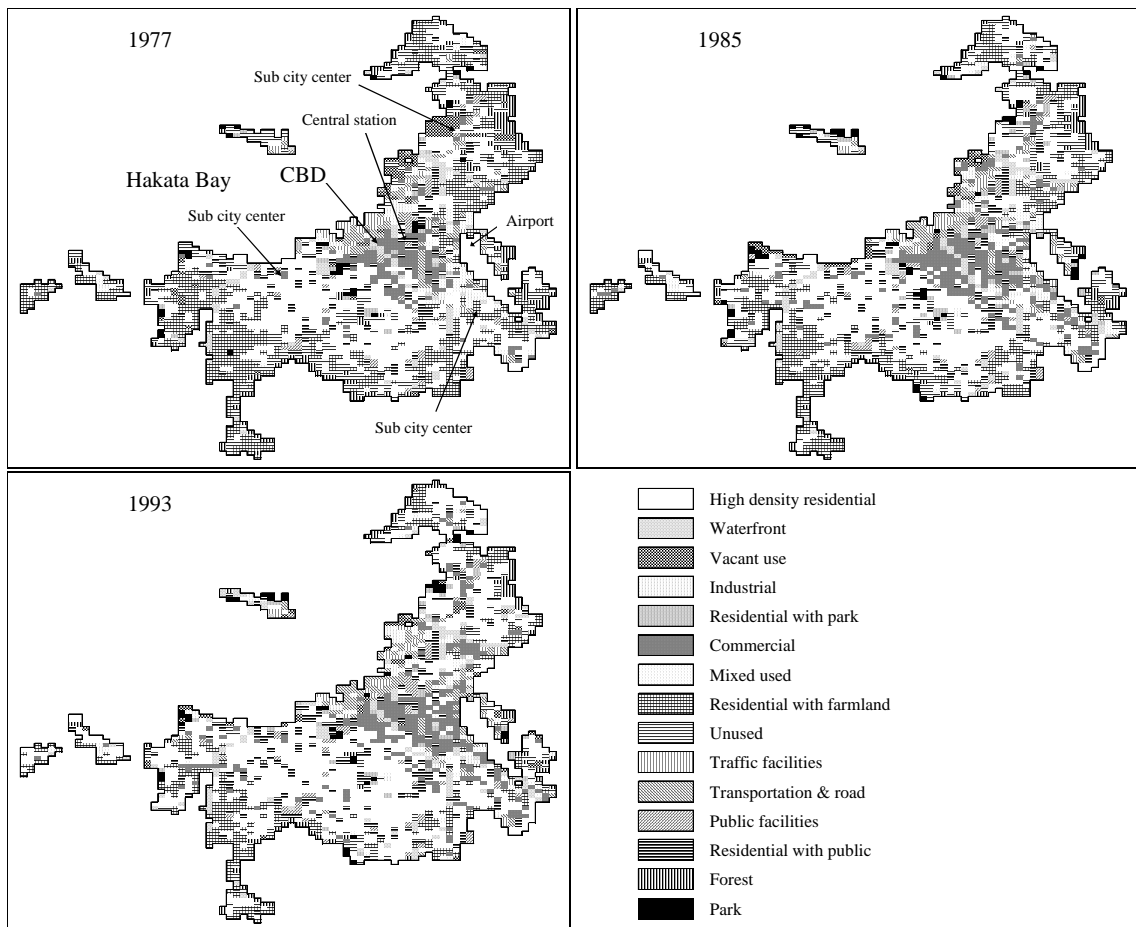
(1977-1985), 73.3% (1985-1993).

Figure 1. Spatial structure of land use pattern over 3 terms

In the first figure (1977-1985) in Figure 2, directions of change face to High-density residential area and Commercial area. The keeping ratios of these two areas are very high. On the other hand, the land use conditions of Unused area, Vacant area, Mixed used area and Transportation area were very unstable and easy to change. Also, many meshes of Forest changed into Unused area, Residential area with agriculture changed to various types of land use. That means the development in the outskirts of urbanization promoting area was proceeding. In the next figure (1985-1993), the directions of change concentrate to High-density residential strongly. The keeping ratio of Transportation area became high, on the other hand, that of commercial area became low. The land use conditions of Unused area, Vacant area, Mixed used area and Transportation area were still very unstable. From these two figures, it can be said that Unused area and Residential area with agriculture have a strong tendency to change into High-density residential area and Mixed used area are also very unstable and easy to change into Commercial area.
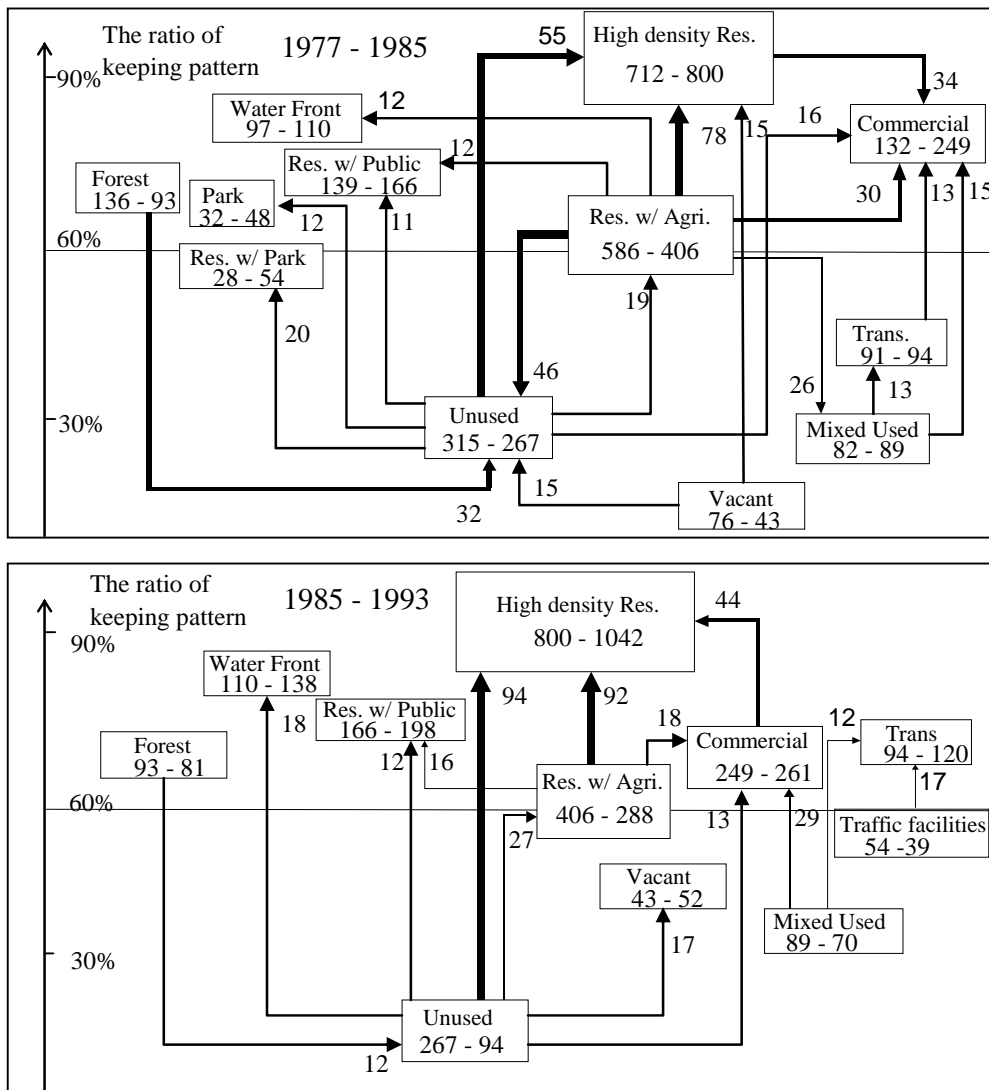
1977 - 1985

The ratio of keeping pattern

90% · 60% · 30%

High density Res. 712 - 800
Water Front 97 - 110
Res. w/ Public 139 - 166
Forest 136 - 93
Park 32 - 48
Res. w/ Park 28 - 54
Res. w/ Agri. 586 - 406
Commercial 132 - 249
Trans. 91 - 94
Mixed Used 82 - 89
Unused 315 - 267
Vacant 76 - 43

(55, 12, 12, 11, 12, 20, 78, 15, 16, 30, 13, 15, 34, 19, 46, 26, 13, 32, 15)

1985 - 1993

The ratio of keeping pattern

90% · 60% · 30%

High density Res. 800 - 1042
Water Front 110 - 138
Res. w/ Public 166 - 198
Forest 93 - 81
Res. w/ Agri. 406 - 288
Commercial 249 - 261
Trans 94 - 120
Traffic facilities 54 - 39
Vacant 43 - 52
Mixed Used 89 - 70
Unused 267 - 94

(44, 18, 18, 12, 16, 94, 92, 18, 12, 27, 13, 29, 17, 17, 12)

Figure 2. Changing structure of land use over 3 terms

4. Separation of Project Type Mesh and Non-Project Type Mesh

The mesh zones in which projects were carried out are called project type mesh and those in which projects were not carried out are called non-project type mesh in this paper. Land use is greatly changed by the carrying out of development projects. Therefore, it is necessary to classify mesh zones into project type and non-project type meshes. Also, mesh zones are to be further classified as to whether projects were carried out in the first period between 1977 and 1985, and in the second period between 1985 and 1993. Meshes are to be classified into the following four categories.

The first category is that of the meshes in which projects were carried out in the first period but not in the second period. The second category is that of meshes in which projects were not carried out in the first period but in the second. The third and fourth categories would consist respectively of those in which projects were carried out

in both periods and those in which projects were not carried out in either. Figure 3 is a relative frequency distribution that shows the changing ratios of the land use in each mesh of four categories. Changing ratio of land use means in this paper the sum of absolute value of increase (or decrease) rate of land use during a period. Figure 3 shows that the changing ratios of meshes during the first period where projects had been carried out were relatively high, distributed above the 0.2 or 0.3. Among these, the changing ratio of the land use in the first period of the third category classified as projects were carried out in both periods showed a different distribution from others. In this Figure of category 3, there is no peak-point. This means that in comparison to other categories, the third category includes many meshes in which big changes had occurred. On the other hand, the change ratios of the meshes in which projects had not been carried out were distributed below 0.3 or 0.4. From the peak-point of these, the relative frequency distribution of changing ratios during the first period of second category meshes seems like the shape of the first period of fourth category meshes. Also, the second period of first category meshes is like the shape of an exponential curve, and the shape of second period of fourth category is different from others. These 8 transition patterns can be classified into 5 types from the shapes and meanings of relative frequency distributions (Table 4).

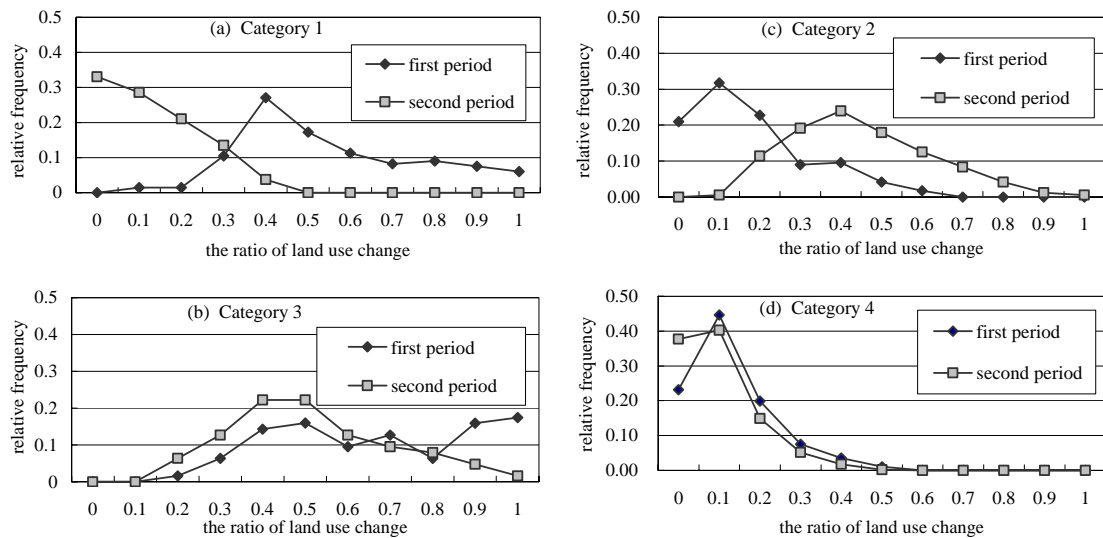Figure 3. Relative Frequency Distribution of Land Use Change Ratio in Four Categories

Table 4. Definition of Type

Category	First period	Second period	Number of Mesh
1	Project (Type 1)	Non-project (Type 4)	133
2	Project (Type 2)	Project (Type 3)	63
3	Non-project (Type 5)	Project (Type 1 & 2)	167
4	Non-project (Type 5)	Non-project (Type 5)	2190

Type 1: meshes where development projects have been carried out in that period and did not continue to the next period

Type 2: the meshes in the first period where development projects are being carried out in both periods.

Type 3: meshes in the second period where development projects are being carried out in both periods.

Type 4: meshes in the next period where development projects have been carried out in previous periods.

Type 5: meshes where development projects were not carried out through both periods.

5. Transition on Probability of Land Use Pattern

Transition of each pattern in 5 types mentioned above is shown in Table 5 and can be explained as follows.

(1) Type 1: This type is the transition of 133 meshes where project have been carried out in that period and did not continue to the next period, and the ratio of maintenance was low. Meshes of vacant use pattern, industrial pattern, residential pattern with forest, residential pattern with farmland and transportation & road pattern mainly changed to meshes of park pattern, high-density residential pattern, transportation & road pattern, industrial pattern and commercial pattern. There was no mesh that classified as public facilities pattern. It means that short-term projects are hard to be carried out in the meshes classified as public facilities pattern.

(2) Type 2,3: These types are 63 meshes where large-scale project are being carried out in both periods, and the ratio of maintenance was small. The meshes of type 2 have a tendency to change from meshes of vacant use pattern, forest pattern and residential pattern with forest to meshes of residential pattern with forest, vacant use pattern and commercial pattern. The meshes of type 3 were influenced by the project that were carried out previous period, and have a tendency to change into meshes of high-density residential pattern, industrial pattern, vacant use pattern and park pattern. There was no mesh classified as residential area with farmland and traffic facilities in type 3, because no mesh changed into those patterns in previous period. Also, some patterns including mere one or two meshes would be assumed to have no important meanings in this transition type.

(3) Type 4: This type is the transition of 133 meshes in the next period where large-scale project completed in previous periods. After the project finished, land use did not change so much, some type of transition, however, can be shown. In this type, meshes of park pattern, high-density residential pattern, transportation & road pattern, industrial pattern, commercial pattern and vacant use pattern mainly changed. Excluding 0.538, the maintenance ratio of meshes of industrial pattern, and those of other pattern are over 0.7. After transition of type 1, no mesh changed into forest. Therefore, transition probability of forest cannot be defined. When forecasting the next period, however, transition probability of all patterns should be defined. Therefore, transition probability of forest in type 4 was substituted, because there is high correlation between type 3 and type 4.

Table 5. Transition Probability Matrix in Each Type of Meshes

TYPE1

Pattern	1985	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1977	133	2	8	10	6	5	31	0	2	8	2	8	2	30	14	5
Industrial pattern	5	0.5	0	0.1	0	0	0.03	0	0	0	0	0	0	0.07	0	0
Traffic facilities pattern	4	0	0.13	0.1	0	0	0.03	0	0	0	0	0	0	0	0.07	0
Transportation & road pattern	16	0	0.63	0.2	0.33	0	0.03	0	0	0	0	0	0.5	0.13	0.07	0
Mixed used pattern	12	0.5	0	0	0.33	0.4	0.06	0	0	0	0	0	0	0.1	0.14	0
Commercial pattern	11	0	0.13	0.2	0.17	0.4	0	0	0	0	0	0.13	0	0.07	0.14	0
Vacant use pattern	10	0	0	0.1	0	0	0	0	0	0.63	0	0	0	0.1	0	0.2
Public facilities pattern	7	0	0	0	0	0	0	0.6	1	0	0	0.5	0	0	0.07	0
Residential pattern with public	6	0	0	0	0	0	0.1	0.4	0	0	0.5	0	0	0.07	0	0
High density residential pattern	16	0	0	0	0	0	0.32	0	0	0.38	0.5	0	0	0.03	0.07	0
Residential pattern with park	9	0	0.13	0.1	0	0	0.06	0	0	0	0	0.25	0	0.07	0.07	0
Park pattern	20	0	0	0	0	0.2	0.16	0	0	0	0	0.13	0	0.37	0	0.4
Waterfront pattern	3	0	0	0.2	0	0	0	0	0	0	0	0	0.5	0	0	0
Unused pattern	9	0	0	0	0.17	0	0.16	0	0	0	0	0	0	0	0.07	0.4
Residential pattern with farmland	5	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0.29	0
Forest pattern	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TYPE2

Pattern	1985	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1977	63	1	2	1	3	2	17	1	1	3	2	1	1	13	6	9
Industrial pattern	1	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0
Traffic facilities pattern	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transportation & road pattern	3	0	0.5	1	0	0	0.06	0	0	0	0	0	0	0	0	0
Mixed used pattern	3	0	0	0	0	0.5	0.06	0	0	0	0	0	0	0	0.17	0
Commercial pattern	10	0	0.5	0	0.33	0	0.18	0	0	0	0	0	0	0.38	0	0
Vacant use pattern	12	0	0	0	0.33	0	0.06	1	0	0.67	0.5	0	0	0.31	0	0.22
Public facilities pattern	1	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Residential pattern with public	2	0	0	0	0	0	0	0	1	0	0.5	0	0	0	0	0
High density residential pattern	3	0	0	0	0	0	0.12	0	0	0.33	0	0	0	0	0	0
Residential pattern with park	2	0	0	0	0	0	0	0	0	0	0	0	0	0.15	0	0
Park pattern	4	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0.33
Waterfront pattern	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11
Unused pattern	19	1	0	0	0.33	0	0.35	0	0	0	0	1	1	0.15	0.83	0.22
Residential pattern with farmland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest pattern	2	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0.11

TYPE3

Pattern	1985	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1993	63	1	0	3	3	10	12	1	2	3	2	4	1	19	0	2
Industrial pattern	5	0		0	0.33	0.3	0.08	0	0	0	0	0	0	0		0
Traffic facilities pattern	0	0		0	0	0	0	0	0	0	0	0	0	0		0
Transportation & road pattern	5	0		0.33	0.33	0.2	0	0	0	0	0	0	0	0.05		0
Mixed used pattern	8	1		0.33	0	0.4	0.17	0	0	0	0	0	0	0		0
Commercial pattern	2	0		0	0.33	0.1	0	0	0	0	0	0	0	0		0
Vacant use pattern	7	0		0	0	0	0.25	1	0	0	0	0	1	0.11		0
Public facilities pattern	2	0		0	0	0	0	0	0.5	0	0	0.25	0	0		0
Residential pattern with public	3	0		0	0	0	0.17	0	0	0	0	0	0	0.05		0
High density residential pattern	12	0		0	0	0	0.17	0	0	0.67	0	0	0	0.42		0
Residential pattern with park	3	0		0	0	0	0.08	0	0	0.33	0.5	0	0	0		0
Park pattern	7	0		0.33	0	0	0	0	0.5	0	0	0.5	0	0.16		0
Waterfront pattern	4	0		0	0	0	0.08	0	0	0	0	0	0	0.11		0.5
Unused pattern	2	0		0	0	0	0	0	0	0	0.5	0	0	0.05		0
Residential pattern with farmland	1	0		0	0	0	0	0	0	0	0	0	0	0.05		0
Forest pattern	2	0		0	0	0	0	0	0	0	0	0.25	0	0		0.5

TYPE4

Pattern	1985	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1993	133	5	4	16	12	11	10	7	6	16	9	20	3	9	5	0
Industrial pattern	6	1	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0
Traffic facilities pattern	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Transportation & road pattern	17	0	0	1	0	0	0	0	0	0	0.11	0	0	0	0	0
Mixed used pattern	9	0	0	0	0.58	0	0	0	0	0	0.11	0	0	0	0.2	0
Commercial pattern	16	0	0	0	0.33	0.73	0	0	0	0	0.11	0	0	0.11	0.4	0
Vacant use pattern	8	0	0	0	0	0	0.7	0	0	0	0	0.05	0	0	0	0.01
Public facilities pattern	9	0	0	0	0	0.09	0	0.86	0.17	0	0.11	0	0	0	0	0
Residential pattern with public	8	0	0	0	0	0.09	0	0.14	0.83	0	0	0	0	0.11	0	0.01
High density residential pattern	25	0	0	0	0	0.09	0.2	0	0	1	0	0	0	0.56	0.2	0
Residential pattern with park	5	0	0	0	0	0	0	0	0	0	0.44	0.05	0	0	0	0
Park pattern	18	0	0	0	0	0	0	0	0	0	0.11	0.85	0	0	0	0
Waterfront pattern	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Unused pattern	3	0	0	0	0	0	0.1	0	0	0	0	0.05	0	0.11	0	0.18
Residential pattern with farmland	2	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0.2	0
Forest pattern	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8

TYPE5

Pattern	Mesh	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mesh	4547	34	85	140	144	351	39	91	291	1472	64	34	196	464	945	197
Industrial Area	32	0.85	0	0	0.01	0	0	0	0	0	0	0	0.01	0	0	0
Traffic Facilities	79	0	0.82	0.06	0	0	0	0	0	0	0	0	0	0	0	0
Transportation Area	152	0	0.18	0.69	0.13	0.01	0	0	0	0	0.05	0	0.01	0.01	0.01	0
Mixed Used Area	118	0.15	0	0.04	0.44	0.01	0	0	0.01	0	0	0	0.01	0.02	0.03	0
Commercial Area	461	0	0	0.14	0.24	0.79	0.08	0.03	0.05	0.02	0.14	0	0.02	0.04	0.04	0
Vacant Area	40	0	0	0.02	0	0	0.69	0	0	0	0	0	0	0.02	0	0.01
Public Establishment	93	0	0	0	0	0	0	0.92	0.02	0	0	0	0	0	0	0
Residential Area With Public	334	0	0	0.01	0.01	0.04	0	0.04	0.84	0.01	0.09	0	0.01	0.03	0.03	0.01
High Density Residential Area	1753	0	0	0	0.04	0.13	0.08	0	0.03	0.95	0.08	0	0.04	0.26	0.17	0
Residential Area With Park	74	0	0	0.02	0.01	0.01	0	0	0.01	0	0.63	0.03	0	0.04	0	0
Park	36	0	0	0	0.01	0	0	0	0	0	0.02	0.97	0	0	0	0
Water Front Area	216	0	0	0.01	0.04	0.01	0	0	0.01	0	0	0	0.88	0.02	0.02	0
Unused Area	318	0	0	0.01	0.03	0	0.1	0	0	0.01	0	0	0.02	0.46	0.05	0.18
Residential Area With Agriculture	680	0	0	0.01	0.03	0.01	0.05	0	0.01	0	0	0	0.02	0.09	0.65	0
Forest	161	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0.8

(4) Type 5: This type of meshes is the transition of 2357 (in the first period) and 2190 (in the second period) where large-scale project were not carried out. The meshes of high-density residential pattern, residential pattern with farmland, residential pattern with forest, commercial pattern and public facilities pattern mainly changed. Also, the maintenance ratios of meshes of high-density residential pattern, waterfront pattern, industrial & road pattern and traffic facilities pattern are high but those of mixed used area and residential area with forest are low.

6. Forecasting Method of the Land Use Transition

6.1 Forecasting system of land use pattern of meshes

From the result mentioned above, it can be said that land use distribution of each land use pattern did not change. Therefore, it can be assumed that transition of land use

is from the change of land use pattern. Also, from the mesh data of two periods, 2/3 of all projects finished in a period, and 1/3 continued to next period. While it is hard to say that projects would not continue to third period (for 24 years), it is assumed that all projects would complete in 16 years or 2 periods.
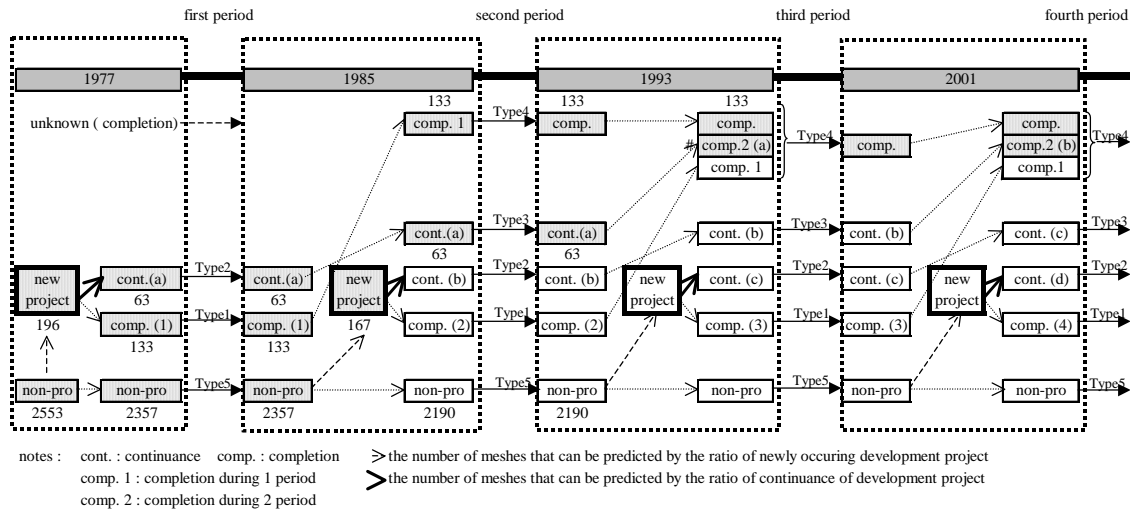

Figure 4. Land Use Forecasting System based on the Land Use Pattern

By these assumptions, land use forecasting system can be designed. Basically, transition probability model of land use pattern would be used. Transition of land use is different according to many conditions. In this paper, land use could be forecasted by using 5 types of transition probability matrix for land use pattern of meshes. Figure 4 shows the land use pattern forecasting system. All mesh data in 1977 were regarded as non-project type mesh, because there were no data before 1977. In 196 meshes of 2553, projects started, and 133 meshes of 196 meshes finished in first period (type 1), also 63 meshes left continued to next period (type2). The transition of land use in rest 2357 meshes accorded with type 5. Land use condition of 1985 can be forecasted by using transition probability of these three types of meshes. Next, 63 meshes where projects continued from previous period (type 3) and 133 meshes where project completed (type 4) can be forecasted respectively. Also, in the non-project type meshes from 1985 (2357 meshes), new projects started in 167meshes and, some meshes finished before 1993 (type 1), the other meshes continued to next period (type 2). The rest 2190 meshes would be non-project type of meshes (type 5). In type 5, it is considered that transition probabilities are some difference among the use zones that are the basic framework for land utilization in urban promotion area. Zoning system can control and lead urban land use by the Town Planning and Zoning Act. There are 12 zones in Japan now, and twelve transition probabilities are designed. Considering similarity of these probabilities, these could be 3 groups (residential, commercial and industrial area) with correlation coefficient by cluster analysis. Consequently, three transition probabilities are used in type 5. From the transition of land use pattern in these five types of mesh groups, land use patterns in 1993 can be forecasted. If this process is repeated, land use

patterns in every 8 years can be predicted.

Let the previous period be n and the next period n+1,the meshes in every land use pattern at the next period are obtained as follows:

$$P_i^{(n+1)} = T_i \quad P_i^{(n)} \ (\ i = 1,2,3,4,5 \ )$$

Where, $P_i^{(n+1)}$, $P_i^{(n)}$: Land use pattern vector of type i in the period of n or n+1

T_i : Transition probability matrix of land use pattern in type i (Table 5)

6.2 Concerning the newly occurring development project

In the above-mentioned prediction system, how to forecast the newly occurring development projects is as a remaining issue. This is fundamentally a matter of municipal policy, the civilian and private sector, and administration's development needs. In this study, future development projects are forecasted by drawing scenarios. On the grounds of these scenarios, the size and content of newly occurring development projects can be simulated. The following is proposed as an assumption of scenario.

Table 6. Ratio and Number of the Project Type Mesh in Each Pattern

| Pattern | Ratio | | | | | | | | Number | | |
| | 1977 | | | | 1985 | | | | 1977 | 1977 and 1985 | continuance ratio |
	Res.	Com.	Ind.	All	Res.	Com.	Ind.	All			
1 Industrial pattern	0	0	0.02	0.015	0	0	0.02	0.024	3	1	0.333
2 Traffic facilities pattern	0	0.01	0.04	0.051	0.01	0.01	0.04	0.060	10	2	0.200
3 Transportation & road pattern	0.01	0.02	0.04	0.056	0.02	0.01	0.05	0.090	11	1	0.091
4 Mixed used pattern	0.01	0	0.04	0.046	0	0	0.02	0.018	9	3	0.333
5 Commercial pattern	0.02	0.01	0.02	0.036	0	0	0.01	0.012	7	2	0.286
6 Vacant use pattern	0.18	0.01	0.06	0.245	0.01	0	0.05	0.060	48	17	0.354
7 Public facilities pattern	0.01	0	0	0.005	0.02	0	0.01	0.030	1	1	1.000
8 Residential with public pattern	0.02	0	0	0.015	0.01	0.01	0	0.018	3	1	0.333
9 High density residential pattern	0.06	0	0	0.056	0.06	0	0	0.060	11	3	0.273
10 Residential with park pattern	0.02	0	0	0.020	0.02	0	0	0.018	4	2	0.500
11 Park pattern	0.05	0	0	0.046	0.08	0	0	0.078	9	1	0.111
12 Waterfront pattern	0.02	0	0	0.015	0.01	0	0.01	0.024	3	1	0.333
13 Unused pattern	0.14	0.02	0.06	0.219	0.28	0	0	0.281	43	13	0.302
14 Residential with farmland pattern	0.07	0	0.04	0.102	0.05	0	0.08	0.132	20	6	0.300
15 Forest pattern	0.07	0	0	0.071	0.1	0	0	0.096	14	9	0.643

(1) The projects in the urban promotion area would be predicted as to whether present status is maintained, increased or decreased in this scenario.

(2) It could not be said that development projects in all of the urban area can be carried out easily. According to the patterns of the land use of the area, it is easy to carry out development projects in some areas and not so easy in others. Table 6 shows the distribution ratio in each patterns of the project type 196 mesh of the first period and 167 mesh of the second period. According to this Table, it can be said that development projects are easier to carry out in the meshes of residential pattern with farmland and residential pattern with forest. In contrast, projects could hardly be carried out in meshes of residential pattern with parks, commercial pattern, industrial pattern, and public facilities pattern.

(3) Development projects can be divided into those that complete in that period and

those that are continued in the next period. Table 6 shows the ratio of continuance of project in each pattern of mesh. Overall, the ratio of continuance is 35%. Excluding land use pattern specialized public facilities pattern that has only one mesh, it can be said that the continuance ratio in the forest pattern is relatively high while it is low in the park and transportation & road pattern.

(4) Although projects are newly carried out in every period, it is necessary to consider whether new projects can be carried out in the areas in which projects had been carried out in the past. However, as this study involves only short and mid-term predictions, it will be assumed that no other projects will be started in areas where projects had been carried out before.

Based on these assumptions of the beginning, continuance and termination of new projects, it was possible to design a more accurate prediction system.

7. Applying Result of Forecasting Models

By using the above-mentioned prediction models on the 2553 mesh of urban promotion area in Fukuoka City, changes in future land use patterns and land use distribution of urban area could be predicted. Projects concerning the urban express highways, subway, urban renewal, etc. have been planned but recently lack of local government finance and the changes in public demands has had the effect of restraining the implementation of new projects. Based on this recent tendency, the scenario in this study has the 167 new project-type mesh in the year 1985 decreased according to exponential curve to a number less than half in 40 years.
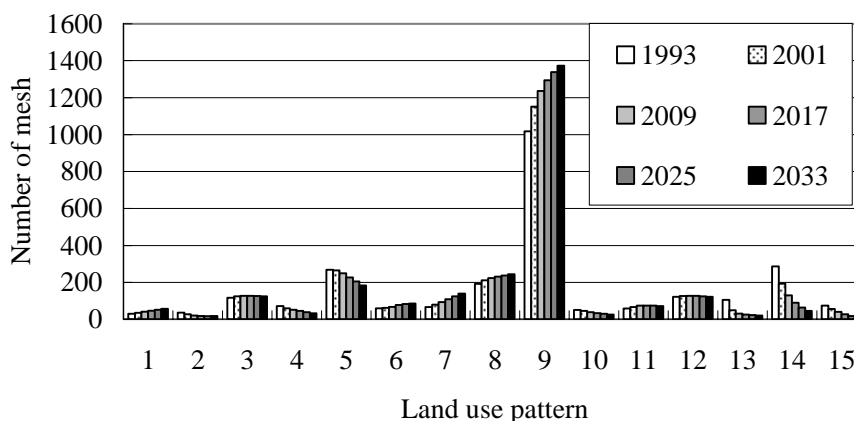

Figure 5. Result of Distribution of Meshes in Each Land Use Pattern

Figure 5 shows the forecasting results of the distribution of mesh numbers in each pattern meshes of residential pattern with farmland, unused pattern and forest pattern are decreasing, but the mesh numbers of high-density residential pattern are increasing. Especially meshes of residential pattern with farmland are decreasing so significantly that 287 meshes in 1993 are predicted to go down to a mere 45 in 2033. In addition, meshes of high-density residential pattern that consisted of 1018 mesh in the year 1993

will increase to 1374 meshes in the year 2033.

If the numbers of mesh in each pattern are predicted by applying models, land use distribution of meshes in urban area can be found by multiplying the land use distribution (Table 1) and mesh vector of land use pattern. Figure 6 shows the distribution of land use component ratio. Agricultural area, unused area and forest area in urban promotion area will decrease into half in the next 40 years while residential area, roads, and public area will increase. Residential area will increase from 30.8% to 35.0%. Roads will increase from 15.4% to 15.8%. Public area will go from 7.6% to 10.1%. On the other hand, rivers show no significant change.
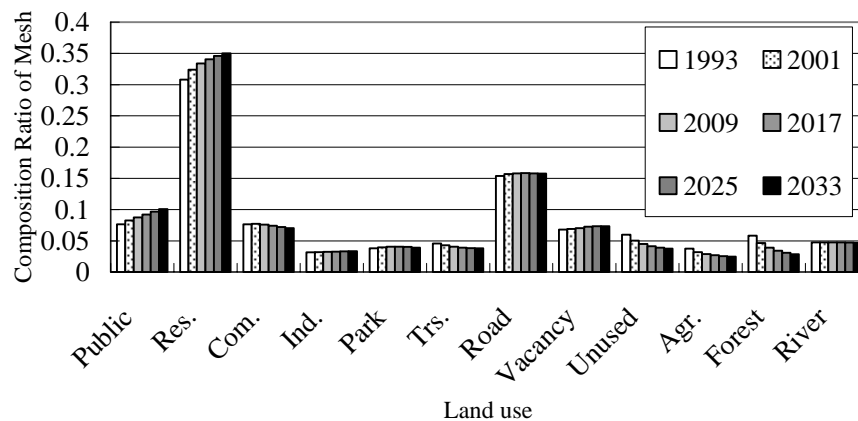

Figure 6. Result of Distribution of Each Land use

8. Conclusion

In this paper, a forecasting method of land use proposed based on land use pattern, the change of land use can be considered as the change of land use pattern and, average land use distribution in each pattern is stable regardless of time. Furthermore, development project could be handled as a fact that has a strong effect on land use change. Results are as follows:

(1) All mesh of Fukuoka urban area, Japan, was classified into 15 patterns by land use composition. Based on the classification, spatial and change structure of land use was studied. The spatial urban structure of Fukuoka city, Japan, is centralized to one pole, and it is getting to be multi polarized by sub-city center. Around the city center, residential area is located broadly. As it goes to the outskirts, many zones of agricultural area and forest are located. From the transformation of these maps marked by land use pattern over 3 terms, the meshes of commercial area increased, while residential area sprawled to the outskirts of the urban promoting area.

(2) In transition of urban spatial structure over 3 terms, it can be said that Unused area and Residential area with agriculture have a strong tendency to change into High-density residential area and Mixed used area are also very unstable and easy to change into Commercial area.

(3) Land use is greatly changed by the carrying out of development projects. Therefore,

meshes are to be classified into four categories. From four categories, five types of transition probability for the land use pattern by mesh were constructed respectively.

(4) Land use forecasting system considering development project was proposed. By using this system, changes in future land use patterns and land use distribution of urban area could be predicted. Based on the recent tendency of development project, the scenario in this study has the 167 new project-type mesh in the year 1985 decreased according to exponential curve to a number less than half in 40 years. As the result, mesh numbers of residential pattern with farmland, residential pattern with forest and forest pattern are decreasing, but the mesh numbers of high-density residential pattern are increasing. In land use ratio, residential area, roads, and public area will increase. According to this system, land use change can be predicted in assumption of a scenario of urban plans.

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