AN APPROACH FOR TRANSITION PROBABILITY MODEL OF URBAN LAND USE BASED ON THE CHANGE OF LAND USE PATTERNS AND THE SEPARATION OF LARGE-SCALE PROJECTS/ NON-PROJECTS AREAS

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Abstract: This paper describes the spatial structure of urban promotion area in Fukuoka City based on the present conditions and the change structure of land use by using mesh data. Firstly, all meshes are classified into 15 patterns based on the present conditions of land use then, transition probability models are made out based on the change of these 15 patterns. The feature and structure of change in the land use of 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 designed. 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 in the investigation of urban policies for development projects and in the evaluation of their effects.

Key Words: Land use planning, Change structure of land use, Transition probability model of land use pattern, Development project

1. INTRODUCTION

Urban structure means spatial distribution or geographical pattern of city function, and it can be explained from the viewpoints of land use and transportation. As the functional activities in the urban area are various according to land use, trip behavior is different. It means that studying the land use and the activities occurred in specialized area could make it possible to understand trip behavior and to predict the traffic demand for the future. In the previous study[1] of the authors, urban spatial structure has been analyzed from both viewpoints of traffic demand and land use, synthetically, and the results showed that urban land use structure can be predicted from the relationship between land use and transportation. As a next step, the transition of land use would be predicted, in this paper.
While the land use in city area 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, have an influence on land use. In fact, they change the spatial structure of land use in urban area. 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×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. 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×3 terms), all the meshes of land use data were classified into 15 patterns by using RMS-error (Table 1). Considering Table 1, the characteristic of each pattern is expressed as in Table 2.

Table 1. Classification of Mesh Zone

No.	Patterns	Public	Res.	Com.	Ind.	Park	Trs	Road	Vacancy	Unused	Agr.	Forest	River	Σ
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
Σ : Number of meshes in each pattern

Table 2. 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. TRANSITION OF URBAN SPATIAL STRUCTURE OVER 3 TERMS

3.1 Cross table of Land Use Transition

Tables 3 and 4 reveal the transition of land use pattern of meshes, in every 8 years. From these two Tables, it can be said that over the 3 terms, meshes of mixed used pattern were largely transformed into meshes of commercial pattern. Also, meshes of vacant use pattern and residential pattern with park were transformed into meshes of high-density residential pattern. Meshes of vacant use pattern were transformed into meshes of high-density residential pattern, between 1977 and 1985. On the other hand, between 1985 and 1993, meshes of residential pattern with park were transformed into meshes of high-density residential pattern to a large extent. After 1985, the method of developing residential areas was changed from the earlier meshes of developing residential areas in the outskirts of the city to increasing the density in residential meshes.

Table 3. Transition of Each Pattern in Land Use during First Period (1977-1985)

pattern	1985															
1977	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	sum
1	18			3									1			22
2		43	9		2					1						55
3	1	8	53	4	13	3		1		4		2	1	1		91
4	1		13	38	15	1		2	3	1	1		6	1		82
5		1	1	4	114		1	5	2	1	1	1	1			132
6	2	1	2	3	6	17		3	15	2	6		15	3	1	76
7					3	1	44	2								50
8				1	10		4	113	3	2		3		3		139
9			1		34	7		9	641	2		4	9	5		712
10					5	1		6	2	14						28
11					1		4			3	23		1			32
12	1		2	1					1			84	5	3		97
13	2		8	9	16	9	1	11	55	20	12	3	150	19		315
14		1	5	26	30		1	12	78	4		12	46	371		586
15						4		2			5	1	32		92	136
sum	25	54	94	89	249	43	55	166	800	54	48	110	267	406	93	2553

Table 4. Transition of Each Pattern in Land Use during Second Period (1985-1993)

pattern	1993															
1985	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	sum
1	18		1	5							1					25
2		32	17	2		3										54
3		3	70	5	9	2			1	1	1	1	1			94
4	3		9	35	29				3			6		4		89
5	3		7	5	173		2	10	44	1		1		3		249
6	1	4	3	2		22		2	5	1		2	1			43
7						1	49	5								55
8			1	1	7		7	140	7		1		1	1		166
9			1		2			6	781	3		5		2		800
10			4	1	5		1	3	4	31	2	1	2			54
11					2	1	1		1	1	33	4	3		2	48
12					3	2		2	8			94			1	110
13	1		2	2	13	17	1	12	94	1	4	18	70	27	5	267
14			5	12	18	3		16	92	1		4	4	251		406
15						1	1	2	2			2	12		73	93
sum	26	39	120	70	261	52	62	198	1042	40	42	138	94	288	81	2553

3.2 Change of Land Use Distribution in Each Land Use Pattern

It is very important to consider that land use change means whether the change of land use distribution in each pattern or just the change of land use pattern according as time passes. Figure 1 shows land use distribution in each pattern of 1977,1985,1993. These four are something special of all figures of 15 patterns. Land use distribution of high density residential pattern, waterfront pattern, industrial pattern, residential pattern with park, commercial pattern, traffic facilities pattern, public facilities pattern and residential area with public are very stable, but in mixed used pattern and unused pattern and forest pattern distribution of land use shows a little change. However, it can be said that land use distributions of each pattern are very stable and almost same regardless of time. It means, also, that the assumption that distribution of land use is not change in each pattern. Under this assumption, transition of land use can be understood by studying the change of land use pattern.

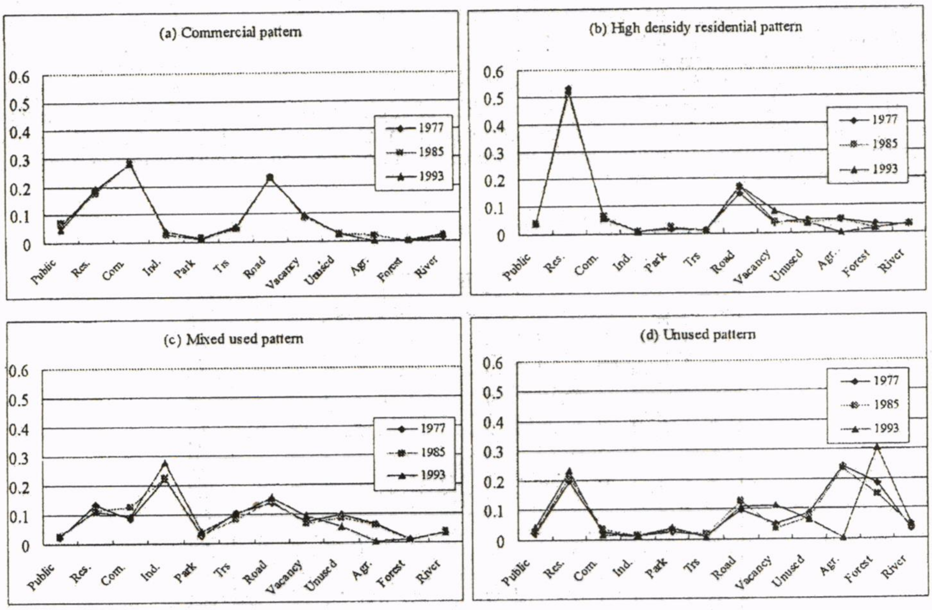

Figure 1. Change of Land Use Distribution

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. Figure2 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. Figure2 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.

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.

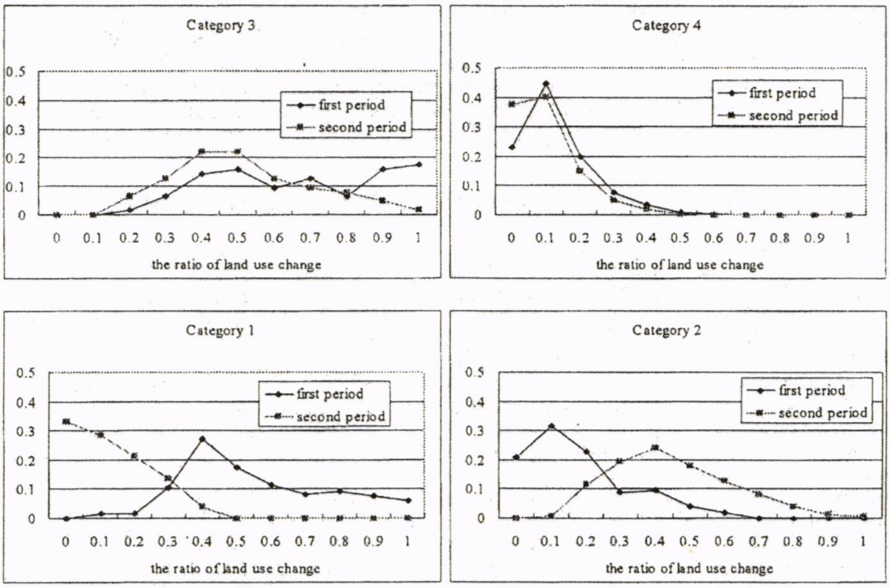

Figure 2. Relative Frequency Distribution of Land Use Change Ratio in Four Categories

5. TRANSITION PROBABILITY OF LAND USE PATTERN

Transition of each pattern in 5 types mentioned above can be explained as below.
(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.

(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.

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

6. LAND USE DISTRIBUTION IN EACH PATTERN

In this chapter, land use distribution in each pattern of a mesh is examined according to the 5 types of transition probabilities. Firstly, in 63 meshes of type 3, as meshes belonging to each pattern are of small number, the land use distribution could be regarded as a peculiar case. These meshes should be managed especially. As correlation coefficients between 6 patterns including more than 5 meshes of type 3 and those of type 1 are over 0.91, these two types could be considered together, regardless of the continuation of projects. Table 6-(a) shows land use distribution of these 196 meshes. Secondly, the distribution of 63 meshes belonging to type 2 can be shown as in Table 6-(b). While, as previously stated, there was no mesh of residential pattern with farmland and traffic facilities pattern in this type of transition, and meshes belonging to each pattern are of small number as type 3, land use distribution of this type would be managed independently because it is different from other types. Lastly, land use distribution of 2357 (in the first period) and 2190 (in the second period) meshes where large-scale projects were not carried out can be shown as in Table 6-(c). However, transitions of two periods are extremely same. Therefore, in this study, the land use distribution of second period was adopted.

Table 7 shows the correlation coefficients between these 3 types of land use distribution in a mesh as to 15 patterns. Distributions of first group (type 3 and type 1) and third group (type 5) is very similar, also the second group (type 2) is similar to other two groups excluding some patterns - residential pattern with forest and waterfront pattern. In case of meshes of residential pattern with forest, this pattern of the second group mainly consisted of unused area, but that of the others mainly consisted of forest. It is because that the classification of the land use surveys in 1985 and 1993 is different, also the definition of forest and unused area changed. The correlation coefficient of meshes of waterfront pattern between second group and the others is low. It is because that the number of water front type of mesh in second group is one, especially of small number. As a result, it can be assumed the land use distributions of each pattern are almost same.

Table 6. Land Use Distribution in Each Pattern

(a) type 1&3 : 196 meshes (1993)

	Land use pattern														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Public	0.013	0.001	0.003	0.011	0.012	0.031	0.593	0.365	0.037	0.057	0.032	0.063	0.047	0.109	0.070
Res.	0.002	0.044	0.028	0.065	0.082	0.044	0.043	0.304	0.504	0.205	0.053	0.133	0.219	0.264	0.000
Com.	0.003	0.007	0.046	0.048	0.386	0.022	0.024	0.016	0.022	0.053	0.014	0.001	0.002	0.029	0.000
Ind.	0.727	0.018	0.112	0.353	0.052	0.010	0.001	0.005	0.006	0.010	0.002	0.000	0.000	0.021	0.003
Park	0.019	0.663	0.307	0.147	0.094	0.025	0.004	0.003	0.016	0.019	0.028	0.000	0.000	0.000	0.084
Trs.	0.161	0.189	0.421	0.163	0.185	0.140	0.121	0.165	0.213	0.210	0.125	0.107	0.115	0.181	0.029
Road	0.052	0.047	0.043	0.116	0.098	0.610	0.040	0.049	0.107	0.100	0.045	0.070	0.184	0.054	0.019
Vacancy	0.000	0.003	0.022	0.052	0.023	0.027	0.088	0.025	0.030	0.292	0.628	0.071	0.077	0.043	0.000
Unused	0.014	0.002	0.005	0.010	0.036	0.014	0.019	0.002	0.017	0.014	0.006	0.001	0.032	0.227	0.000
Agr.	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.146	0.003	0.000	0.001
Forest	0.000	0.000	0.000	0.015	0.000	0.025	0.006	0.034	0.017	0.009	0.035	0.001	0.305	0.000	0.786
River	0.009	0.027	0.013	0.021	0.031	0.051	0.060	0.033	0.031	0.031	0.033	0.406	0.016	0.071	0.009

(b) type 2 : 63 meshes (1985)

	Land use pattern														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Public	0.000		0.000	0.037	0.001	0.040	1.000	0.299	0.004	0.015	0.039	0.000	0.008		0.000
Res.	0.000		0.000	0.016	0.003	0.069	0.000	0.130	0.443	0.189	0.012	0.000	0.094		0.040
Com.	0.024		0.008	0.243	0.608	0.002	0.000	0.209	0.011	0.006	0.006	0.000	0.013		0.243
Ind.	0.852		0.025	0.268	0.040	0.045	0.000	0.001	0.000	0.002	0.008	0.000	0.010		0.019
Park	0.016		0.332	0.058	0.036	0.000	0.000	0.012	0.000	0.013	0.040	0.000	0.027		0.000
Trs.	0.107		0.556	0.162	0.231	0.048	0.000	0.094	0.296	0.085	0.074	0.000	0.162		0.100
Road	0.000		0.078	0.091	0.078	0.746	0.000	0.023	0.128	0.084	0.002	0.000	0.067		0.000
Vacancy	0.000		0.000	0.000	0.001	0.035	0.000	0.108	0.021	0.408	0.645	0.000	0.039		0.000
Unused	0.000		0.000	0.091	0.000	0.001	0.000	0.000	0.043	0.039	0.004	0.000	0.027		0.000
Agr.	0.000		0.000	0.031	0.001	0.009	0.000	0.101	0.046	0.110	0.166	0.000	0.440		0.060
Forest	0.000		0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.048	0.000	0.500	0.043		0.538
River	0.000		0.000	0.002	0.001	0.005	0.000	0.018	0.006	0.000	0.004	0.500	0.070		0.000

(c)type 5 : 2190 meshes (1993)

	Land use pattern														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Public	0.016	0.005	0.019	0.040	0.051	0.012	0.704	0.312	0.042	0.057	0.010	0.035	0.045	0.043	0.014
Res.	0.045	0.030	0.091	0.140	0.194	0.088	0.090	0.285	0.526	0.239	0.084	0.162	0.232	0.266	0.080
Com.	0.025	0.028	0.108	0.116	0.268	0.018	0.032	0.054	0.059	0.070	0.031	0.056	0.021	0.048	0.004
Ind.	0.682	0.029	0.088	0.240	0.037	0.012	0.002	0.010	0.009	0.014	0.036	0.033	0.015	0.020	0.011
Park	0.016	0.727	0.331	0.069	0.053	0.057	0.009	0.020	0.011	0.043	0.030	0.023	0.009	0.024	0.002
Trs.	0.078	0.142	0.245	0.152	0.234	0.224	0.082	0.159	0.168	0.166	0.079	0.141	0.109	0.133	0.047
Road	0.020	0.022	0.068	0.081	0.091	0.539	0.030	0.057	0.077	0.061	0.046	0.053	0.097	0.072	0.041
Vacancy	0.004	0.001	0.012	0.038	0.016	0.016	0.009	0.027	0.021	0.277	0.660	0.040	0.039	0.015	0.009
Unused	0.004	0.006	0.016	0.077	0.028	0.010	0.006	0.026	0.036	0.020	0.004	0.048	0.073	0.315	0.036
Agr.	0.000	0.000	0.000	0.001	0.002	0.000	0.001	0.001	0.001	0.009	0.000	0.002	0.004	0.003	0.001
Forest	0.024	0.000	0.002	0.009	0.002	0.006	0.014	0.015	0.016	0.010	0.012	0.009	0.306	0.016	0.716
River	0.085	0.010	0.018	0.038	0.024	0.019	0.021	0.034	0.033	0.035	0.008	0.398	0.051	0.046	0.039

Table 7. Correlation Coefficient among Land Use Distributions in Land Use Pattern

	Land use pattern	(a)*(b)	(b)*(c)	(a)*(c)
1	Industrial pattern	0.9932	0.9913	0.9820
2	Traffic facilities pattern	NO DATA	NO DATA	0.9940
3	Transportation & road pattern	0.9751	0.8451	0.9067
4	Mixed used pattern	0.6780	0.7896	0.8396
5	Commercial pattern	0.9724	0.7848	0.8662
6	Vacant use pattern	0.9805	0.9326	0.9744
7	Public facilities pattern	0.9738	0.9888	0.9828
8	Residential pattern with public	0.6774	0.6958	0.9909
9	High density residential pattern	0.9641	0.9286	0.9888
10	Residential pattern with park	0.8218	0.8304	0.9728
11	Park pattern	0.9497	0.9493	0.9909
12	Waterfront pattern	0.4884	0.5089	0.8873
13	Unused pattern	-0.0900	-0.1169	0.9420
14	Residential pattern with farmland	NO DATA	NO DATA	0.9231
15	Forest pattern	0.8734	0.8822	0.9811

Note: (a),(b) and (c) follow Table 6

7. FORECASTING METHOD OF THE LAND USE TRANSITION

7.1 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.

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 3 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). 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:

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

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)

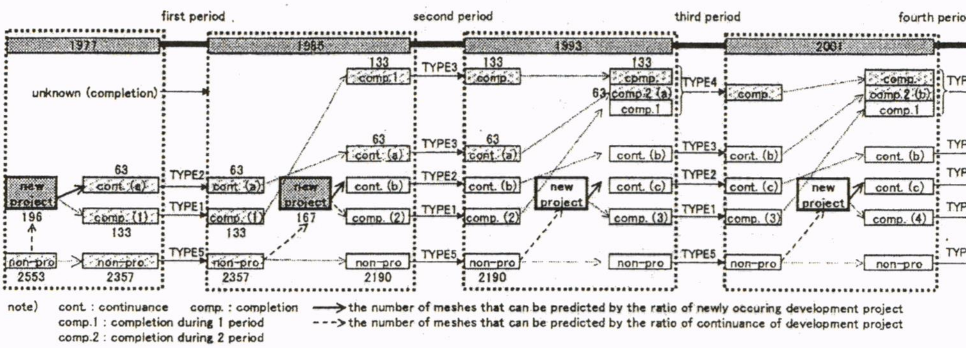

Figure 3. Land Use Forecasting System based on the Land Use Pattern

7.2 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.

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 8 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 9 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.

Table 8. Distribution Ratio in Each Patterns of the Project Type Mesh

	Pattern	1977	1985
1	Industrial pattern	0.015	0.024
2	Traffic facilities pattern	0.051	0.060
3	Transportation & road pattern	0.056	0.090
4	Mixed used pattern	0.046	0.018
5	Commercial pattern	0.036	0.012
6	Vacant use pattern	0.245	0.060
7	Public facilities pattern	0.005	0.030
8	Residential pattern with public	0.015	0.018
9	High density residential pattern	0.056	0.060
10	Residential pattern with park	0.020	0.018
11	Park pattern	0.046	0.078
12	Waterfront pattern	0.015	0.024
13	Unused pattern	0.219	0.281
14	Residential pattern with farmland	0.102	0.132
15	Forest pattern	0.071	0.096

correlation coefficient : 069

Table 9. Ratio of Continuance of Development Project in Each Pattern

	Pattern	1977	1985	maintenance ratio
1	Industrial pattern	3	1	0.333
2	Traffic facilities pattern	10	2	0.200
3	Transportation & road pattern	11	1	0.091
4	Mixed used pattern	9	3	0.333
5	Commercial pattern	7	2	0.286
6	Vacant use pattern	48	17	0.354
7	Public facilities pattern	1	1	1.000
8	Residential pattern with public	3	1	0.333
9	High density residential pattern	11	3	0.273
10	Residential pattern with park	4	2	0.500
11	Park pattern	9	1	0.111
12	Waterfront pattern	3	1	0.333
13	Unused pattern	43	13	0.302
14	Residential pattern with farmland	20	6	0.300
15	Forest pattern	14	9	0.643
		196	63	0.321

7.3 Prediction of land use distribution

If the numbers of mesh in each pattern are predicted by applying models as mentioned in previous sections, land use distribution of meshes in urban area can be found by multiplying the land use distribution (Table 1) for every pattern and mesh vector of land use pattern. According to whether projects are carried out or not, a different output is produced by multiplying each type with a different distribution. Types 1,3 and 4 would be multiplied by Table 6-(a), type 2 by Table 6-(b) and type5 by Table 6-(c). Namely, letting that land use distribution of each type be S, the land use distribution for each type is obtained as follows:

$$S_a = A_{(a)} \cdot (P_1 + P_3 + P_4)$$
$$S_b = A_{(b)} \cdot P_2$$
$$S_c = A_{(c)} \cdot P_5$$

Where, A (a)-(c): type (a) - (c) of land use distribution of each pattern (Table 6).

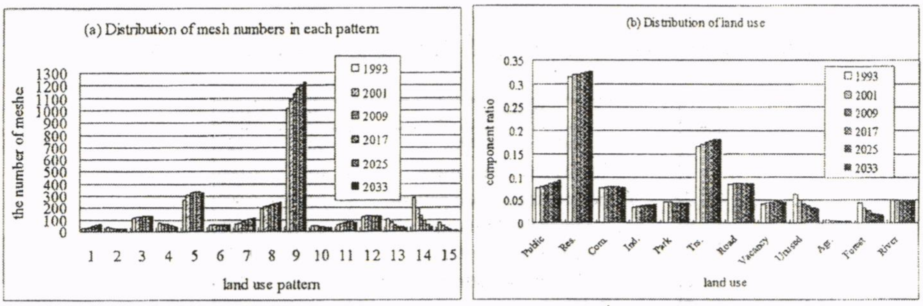

Figure 4. Predicted Distribution of Meshes in Each Land Use Pattern and of Land Use

7.4 Transition Probability Model Not Considering Development Project

It is very difficult to predict new project and the result can be various according to the scenario. In this paragraph, another transition probability model was designed by using land use of non-project meshes to test how precisely the model works. For the accuracy, different transition probability models should be made out for each of the use zones that are the basic framework for land utilization in urban areas. First, 8 transition probability model were designed according to the present zoning system, and these 8 models could be 4 groups by cluster analysis and considering the purpose of system. Figure 5 shows the present condition and predicted value of land use on these 4 groups, or residential-only zone, residential zone, commercial zone and industrial zone. In the figure 5-(d) of industrial zone, a little gap between the present condition and predicted value can be observed. However, it can be said that the result on the whole is capable of extraordinary precision. Table 9 shows the result of χ^2 test at 1 % significance.

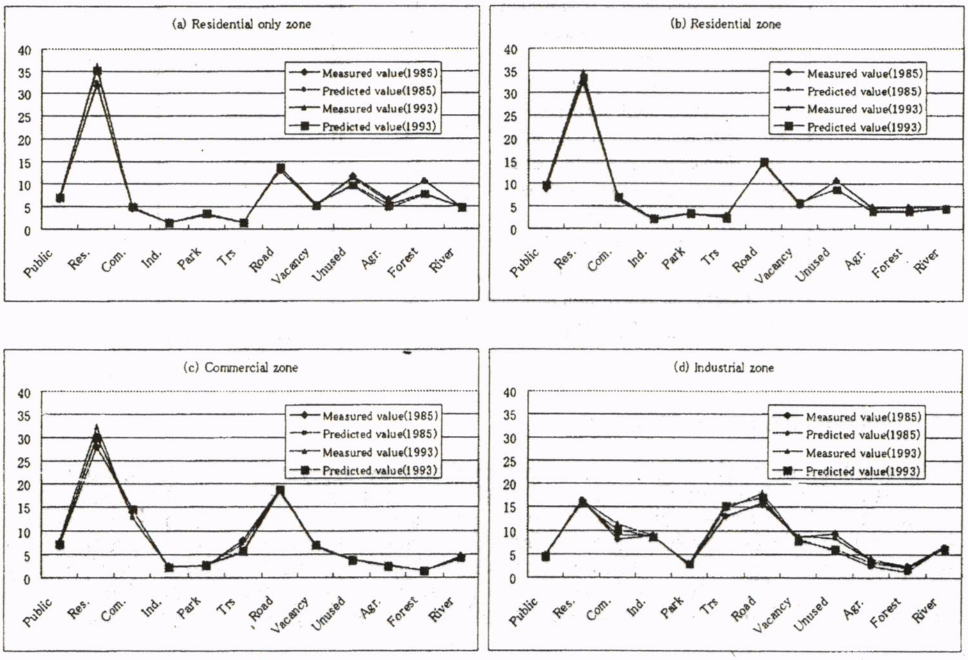

Figure 5. Prediction by Transition Probability Model on Non-project Meshes

Table 9. χ^2-Test of Transition Probability Model

χ^2-test			
Residential only zone		Residential zone	
$\chi 2(0.01, fd=13)=27.69$		$\chi 2(0.01, fd=14)=29.14$	
85	93	85	93
11.751	21.951	11.982	10.473
Commercial zone		Industrial zone	
$\chi 2(0.01, fd=12)=26.22$		$\chi 2(0.01, fd=14)=29.14$	
85	93	85	93
16.589	19.655	10.933	26.010

8. 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 4-(a) shows the forecasting results of the distribution of mesh numbers in each pattern meshes 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. Especially meshes of residential pattern with farmland are decreasing so significantly that 287 meshes in 1993 are predicted to go down to a mere 39 in 2033. In addition, meshes of high-density residential pattern that consisted of 1018 mesh in the year 1993 will increase to 1229 meshes in the year 2033.
Figure 4-(b) shows the distribution of land use component ratio. Agricultural 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 31.4% to 32.6%. Roads will increase from 16.6% to 18.2%. Public area will go from 7.5% to 9.2%. On the other hand, vacant area, unused area, and rivers show no significant change.

9. CONCLUSION

A forecasting method of land use proposed in this paper is based on the idea that by classifying meshes into patterns, 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) 5 types of transition probability for the land use pattern of meshes were made out respectively. Considering these 5 types, type 4 and type 5 are very similar to each other and the continuance ratio of patterns in these types is higher. The continuance ratio in the other types is low.
(2) Land use distribution of each pattern mesh was considered, and adjusted to 3 groups as to the beginning, continuance and termination of new projects. Land use distributions in these 3 groups excluding some patterns are very similar and stable.
(3) Land use forecasting system considering development project was designed as to Figure 3. According to this system, land use change can be predicted in assumption of a scenario of urban plans.

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