A LAND-USE MODEL BASED ON RANDOM UTILITY / RENT-BIDDING ANALYSIS (RURBAN)

Kazuaki Miyamoto[1], Keiichi Kitazume[2]

1) Department of Civil Engineering
Yokohama National University
Hodogaya-ku, Yokohama,
240 Japan

2) Nomura Research Institute
Kamakura,
Japan

INTRODUCTION

In the evaluation of transport projects, it is essential to forecast land use changes in the surrounding area. For this purpose, many kinds of land use models or integrated land use - transport models have been developed to quantitatively forecast changes in land use, and some of them have further function to predict land price to analyze property value change; Webster et. al(11).

Existing land use models can be classified roughly into two categories; analytical models and operational models. Models of the former type, which are developed in urban economics, are usually too simple to simulate actual cities; Alonso(1). Models of the latter type are, in general, too operational to exactly represent the theory in the urban economics. Though many models have been developed in order to satisfy both theoretical completeness and practical applicability, few operational models which deal with small units of land have enough consistency with the theory in the urban economics.

The aim of this study is to develop an operational land use model based on an exact theoretical model in the urban economics, so that future land use can be predicted quantitatively by considering small units of land.

The model proposed in this study employs both the concepts of random utility and random rent-bidding to make the basic theory in the urban economics applicable to quantitatively forecast land use changes in an actual metropolitan area. Consequently, the model is hereafter called RURBAN (<u>R</u>andom <u>U</u>tility / <u>R</u>ent-<u>B</u>idding <u>AN</u>alysis model).

The RURBAN represents demand and supply as well as their equilibrium by each small unit of land, called zone in this study, in the land market of a metropolis. The random utility of a locator group in a zone represents the demand for land of the group in the zone, and the random rent-bidding of a locator group in a zone determines the supply of land to the group in the zone. The RURBAN assumes the equilibrium between these demand and supply which is represented by the level of utility of each locator group in the whole area and the rent in each zone. In addition, the size of land occupied by a unit of locator group in a zone is an endogenous variable in the RURBAN. It implicitly represents the multistoried use of land.

The model in this paper is a revision of the previous models which are reported in Miyamoto et.al(9) and Miyamoto(10) in the senses of the relationship between random utility and random rent-bidding, equilibrium condition, parameter estimation and general model structure.

In addition, this paper describes both theoretical development and actual application of RURBAN. Although the simulation model built for the application is not yet complete one, the provisional results obtained by the model show the validity of the theoretical development to a certain extent.

BASIC CONCEPTS AND ASSUMPTIONS

Assumptions

This study discusses land use in a limited metropolitan area, which is hereafter called the "study area". The study area is assumed to be a closed city, which means the following: the location demand is provided in the analysis from outside the model. The locators have no alternative sites outside the study area; in other words, there is no site outside the study area which gives them a higher utility. No locator outside the study area can bid a higher rent than the locators inside. Therefore, the area outside the closed city need not to be considered.

To deal with the land market simply and conveniently, every zone in the study area is assumed to be owned by its own imaginary landowner. In the case that a landowner is actually using the land himself, it is assumed that he is paying the imputed rent to himself. With this assumption, it is not necessary to explicitly consider the ownership of land. In addition, the land price is assumed to be proportional to the rent, so that the basis for this discussion is rent only.

To segment the demand side in the land market, locators are classified into a limited number of groups, called "locator groups" hereafter, according to their characteristics. The groups represent discrete options in the random rent-bidding analysis. The supply side of the land market is segmented by aggregating individual sites into "zones" based on locational conditions, which are small units of land in this study as mentioned before. The zones are regarded as discrete options in the analysis of location choice with random utility.

Basic Concept regarding the Land Market

Market Equilibrium

The study area is assumed to be in a state of market equilibrium. This general equilibrium in the land market means that location demand of a locator group in a zone is equal to land supply of the zone for the locator group for all pairs of locator group and zone in the study area. In this study, the demand and supply are defined as land being used by a locator group in a zone, and land being offered by a zone for a locator group, respectively. They represent not only newly generated ones or flow values but total land use pattern for all the locations or stock values.

Demand for Land

For a locator group, all zones in the study area are options in its location choice, but the chances of its location in a particular zone depends on the corresponding "representative utility" there. The representative utility can be derived from the utility of the individual locators belonging to the group. The demand function is defined as the probabilistic expectation of the number in a group locating themselves in a zone which is derived from random utility model or discrete choice model.

The discrete choice model based on the random utility theory has been developed to analyze a variety of practical problems; Ben-Akiva and Lerman (2). In the field of land use analysis, discrete choice models have been applied to analyze locator behavior in choosing a location from alternative sites; see Lerman(6) and Miyamoto et.al(8). This analysis is closely related to the utility maximizing principle.

Though the conventional idea of random utility model is applied in the analysis of location choice in the RURBAN, choice makers are basically aggregated as locator groups so that the model is not disaggregate but aggregate.

Supply of Land

At each site in the study area, the existing locator is bidding the highest rent which becomes the actual rent. It means that the landowner supplies the site for the maximum bidder at the maximum bid-rent. But there are a number of sites in each zone, and their characteristics are not necessary the same in the whole zone. Therefore, it is assumed that the land in each zone is supplied to locator groups according to their "representative bid-rents" in the zone. The supply function of a zone for a locator group is given as an expectation obtained from the probability that a locator group is the highest rent-bidder in the zone. The probability is given by the random rent-bidding analysis.

As long as only residential location in a mono-centric city is dealt with, the bid-rent represents nothing but utility. In such a situation, either utility analysis or bid-rent analysis is enough to explain the residential location in the urban economics.

The approach of this study is completely different from such analysis, in the sense of that there are several locator groups in the market. Since all the urban land users are taken into consideration in this study, the random rent-bidding model can be interpreted as a land supply model "from the view point of the imaginary land owner".

As for the existing study on random bidding model, Ellickson (4) proposed a rent-bidding system to determine which locator would likely be the highest bidder. Following this study, Lerman and Kern(7) proposed a way to calibrate bid-rent by considering the actual land price, and Gross(5) applied their concepts actually and obtained some practical results. But these analyses are limited to finding the maximum bidder and estimating land price only, and they cannot be applied directly to forecast land use. Consequently, the existing random bidding models are, in general, used mainly for estimating willingness to pay or actual rent for residential use only, and few applications of existing models employs such idea as that of RURBAN mentioned above.

UTILITY AND RENT-BIDDING OF A LOCATOR AT A SITE

Utility Function

The discussion, in this section, is mainly on residential location and the concepts can be extended to other urban locations such as business-commercial and industrial, as well known in the urban economics. In the study area, every individual locator is given the highest utility at the present site he is located in rather than at other potential sites. The disadvantage of locating at other sites includes the disutility caused by relocation from the present site.

The utility function is expressed by a Cobb-Douglas type function, because it should be continuous and should have a first derivative. The followings are the notations for the formulation of the model.

i : individual locators
s : individual sites
U'_{is} : utility of locator i at site s
z : amount of the composite goods
q : amount of land
X'_{sk} : locational conditions at site s $(k=1,2,\ldots,K)$
Y_i : income of locator i
P : unit price of the composite goods
R'_s : rent at site s
α_{ik}, β_i, γ_i : parameters for locator i

The utility of a locator i at a site s is given in the equation,

$$U'_{is} = \prod_k X'^{\alpha_{ik}}_{sk} \cdot q^{\beta_i} \cdot z^{\gamma_i} \tag{1}$$

It is more convenient to analyze the logarithm of U'_{is} as below, and it does not change the characteristics of the original utility function.

$$U_{is} = \ln U'_{is} = \sum_k \alpha_{ik} \ln X'_{sk} + \beta_i \ln q + \gamma_i \ln z \tag{2}$$

There is a budget constraint for the locator i which is written as follows,

$$Y_i = R'_s \cdot q + P \cdot z \tag{3}$$

In general, it is often the case that budget equation includes commuting cost but it is omitted in this equation. The reason is that, in Japan, they are usually covered by the employer.

Assuming that the individual locator is taking this budget constraint into consideration while trying to maximize his utility, the indirect logarithmic utility function, denoted by U_{is}, can be derived as follows,

$$U_{is} = \ln U'_{is} - const. = \sum_k \alpha_{ik} \ln X'_{sk} - \beta_i \ln R'_s \tag{4}$$

In this equation, constant term is excluded, because it has no meaning in the utility function. By replacing the expressions with the followings,

$$X_{sk} = \ln X'_{sk}, \quad R_s = \ln R'_s, \quad \alpha_i = \{\alpha_{i1}, \alpha_{i2}, \ldots, \alpha_{iK}\}$$

$$\text{and} \quad X_s = \{X_{s1}, X_{s2}, \ldots, X_{sK}\}^t$$

the indirect utility function can be expressed as follows,

$$U_{is} = \boldsymbol{\alpha}_i X_s - \beta_i R_s \tag{5}$$

At the same time, the amount of land occupied by the locator i at the site s is given with a constant for the locator i, θ_i, as follows,

$$q_{is} = \beta_i Y_i / R'_s (\gamma_i + \beta_i) = \theta_i / R'_s = \theta_i \exp(-R_s) \tag{6}$$

Rent-Bidding Function

The rent-bidding function of a locator at a site is obtained by maximizing the following logarithmic rent function under the constraint that he maintains a certain level of utility given by the equation (9).

$$B'_{is} = (Y_i - P \cdot z) / q \tag{7}$$

$$B_{is} = \ln B'_{is} = \ln (Y_i - P \cdot z) - \ln q \tag{8}$$

$$U^*_i = \alpha_i X_s + \beta_i \ln q + \gamma_i \ln z - const. \tag{9}$$

The following is the logarithmic bid-rent function of locator i at site s,

$$B_{is} = \{\alpha_i X_s - U_i^*\} / \beta_i \tag{10}$$

Random Utility / Rent-Bidding of an individual locator at a site

Assuming that both utility and rent-bidding are distributed randomly around the values given by the equations (5) and (10) based on the random utility and random bidding models, the following equations are obtained.

$$U^R_{is} = U_{is} + \varepsilon_{is} \tag{11}$$

$$B^R_{is} = B_{is} + \xi_{is} \tag{12}$$

where

U^R_{is} and B^R_{is} : random utility/rent-bidding
U_{is} and B_{is} : systematic parts of the random utility/rent-bidding
ε_{is} and ξ_{is} : random parts of the random utility/rent-bidding

RANDOM UTILITY AND LAND DEMAND FUNCTION OF A LOCATOR GROUP IN A ZONE

Random Utility of a Locator Group in a Zone

Based on the random utility of an individual locator at a site, random utility function of a locator group *I* in a zone *S*; U^R_{IS}, can be derived with additional terms representing the scale of the zone as a choice alternative and the measure of the heterogeneity of sites in the zone, see Ben-Akiva and Lerman(2). In this chapter, a locator group and a zone are denoted by *I* (and *J*) and *S* (and *T*), respectively.

$$U^R_{IS} = U_{IS} + (1/\mu)\, ln\, L_{IS} + (1/\mu)\, ln\, V_{IS} + \varepsilon_{IS} \tag{13}$$

$$L_{IS} = A_S / q_{IS} \tag{14}$$

$$V_{IS} = [1/(L_{IS} \cdot N_I)] \sum_{i \in I} \sum_{s \in S} exp\, \mu\, (U_{is} - U_{IS}) \tag{15}$$

where

L_{IS} : number of sites for the use of locator *I* in zone *S*
V_{IS} : measure of heterogeneity of elemental sites in zone *S*
N_I : number of individual locator in locator group *I*
μ : positive scale parameter of indirect utility function

The Probability of Location Choice

Assuming that the random term, ε_{IS} is independently and identically Gumbell distributed with a same scale parameter of μ, the probability of the locator group *I* choosing the zone *S* is given by the logit model as follows,

$$Prob\,(U \mid locator\ I\ choosing\ zone\ S)$$

$$= exp\,(\mu U_{IS} + ln\, L_{IS} + ln\, V_{IS}) \Big/ \sum_{T} exp\,(\mu U_{IT} + ln\, L_{IT} + ln\, V_{IT}) \tag{16}$$

The Demand Function of a Locator Group in a Zone

Based on the probability mentioned in equation (16), the expected number of locations of group I in zone S, $\Phi^u{}_{IS}$, is given as follows in the case that there are no competitors to locate in zone S.

$$\Phi^u{}_{IS} = N_I \; Prob \; (U \mid locator \; I \; choosing \; zone \; S) \tag{17}$$

Therefore, $\Phi^u{}_{IS}$ can be regarded as the demand function of locator group I in zone S.

RANDOM RENT-BIDDING AND LAND SUPPLY FUNCTION OF A ZONE FOR A LOCATOR GROUP

Random Rent-Bidding of a Locator Group in a Zone

Very similar to the utility function, random rent-bidding function of a locator group I in a zone S, $B^R{}_{IS}$, is derived as follows,

$$B^R{}_{IS} = B_{IS} + (1/\omega) \ln N_I + (1/\omega) \ln W_{IS} + \xi_{IS} \tag{18}$$

$$W_{IS} = [1/(N_I \cdot L_{IS})] \sum_{s \in S} \sum_{i \in I} exp \; \omega \, (B_{is} - B_{IS}) \tag{19}$$

where

W_{IS} : measure of heterogeneity of individual locators in locator group I

ω : positive scale parameter of bid-rent function

The Probability of Locator Choice

Assuming that the random term ξ_{IS} is also independently and identically Gumbell distributed with a same scale parameter ω, the probability of the zone S supplying itself to the locator group I is given by the logit model as follows,

$$Prob \; (B \mid zone \; S \; supplying \; for \; locator \; I)$$

$$= exp \, (\omega B_{IS} + \ln N_I + \ln W_{IS}) / \sum_J exp \, (\omega B_{JS} + \ln N_J + \ln W_{JS}) \tag{20}$$

The Supply Function of a Zone for a Locator Group

Applying the probability defined in (20), the expected number of sites supplied from zone S for locator group I ; $\Phi^b{}_{IS}$, in the case that there are no competing zones for the location of group I is given as follows, which can be regarded as the supply function of zone S for locator group I.

$$\Phi^b{}_{IS} = L_{IS} \; Prob \; (B \mid zone \; S \; supplying \; for \; locator \; I) \tag{21}$$

EQUILIBRIUM CONDITION IN THE LAND MARKET

Since both demand and supply functions are derived, the general equilibrium condition is given by the following equation for all pairs of locator group and zone. Hereafter, a locator group and a zone are re-denoted by i (and j) and s (and t), respectively.

$$\Phi^{u}_{is} = \Phi^{b}_{is} \tag{22}$$

The equation represents the equilibrium condition in terms of number of locations. It can be easily rewritten to represent the equilibrium in terms of location area.

From this equation, the following conditions are derived to realize the equilibrium in the land market of the study area. The Level of utility for locator group i and the representative rent in zone s, which can be regarded as R_s, are given as follows,

$$U^{*}_{i} = (1/\mu)\ ln \sum_{s} exp\,(\mu U_{is} + ln\ L_{is} + ln\ V_{is}) \tag{23}$$

$$B^{*}_{s} = (1/\omega)\ ln \sum_{i} exp\,(\omega B_{is} + ln\ N_{i} + ln\ W_{is}) \tag{24}$$

Both functions are the so-called log-sum functions which represent the modes of the maximum utility distribution of a locator group i and maximum bid-rent distribution in a zone s, respectively. In addition, there are two more conditions, one that V_{is} should be equal to W_{is} and another that $\mu\beta_{i}$ be equal to ω. Assuming that μ is common among locator groups, β should be also common among locator groups, because ω is unique in this model. Consequently, the followings are additional conditions,

$$V_{is} = W_{is} \tag{25}$$

$$\mu\beta = \omega \tag{26}$$

(13), (18), (23) and (24) are the basic equations of RURBAN with conditions of (25) and (26).

PARAMETER ESTIMATION

General

Parameter estimation of both random utility and random rent-bidding models is usually conducted using the most likelihood method, if data regarding both individual locators and sites are available. In the RURBAN, there are some alternative methods of parameter estimation; the conventional most likelihood estimation as in the conventional logit model analysis, and the multiple regression analysis based on data aggregated by zone and locator group. In this study, both random utility and rent-bidding models are considered for both aggregated locator groups and sites so that aggregated data of location pattern can be used for the estimation. In addition, it is easier for aggregated data to maintain consistency with the total location patterns in the study area.

Based on these considerations, the numbers of location by locator group and zone are used to represent location patterns in the area. Therefore, parameter estimation is done based on the aggregated data with multiple regression analysis explained hereafter.

In addition, parameter estimation of utility function is conducted separately from that of rent-bidding function in this study, whereas an integrated approach is possible and is better with respect to the theory as long as the equilibrium is ensured. The reason is that the integrated estimation of the two functions cannot be expected to get better results in spite of the difficulty of estimation procedures.

Utility Analysis

In the state of equilibrium, the ratio between the numbers of locations of group i in two zones is assumed to be equai to the ratio of demands of the group for the two zones as follows,

$$(F_{is}/F_{it}) = \Phi^{u}{}_{is}/\Phi^{u}{}_{it}$$

$$= exp\{\mu\alpha_i(\mathbf{X}_s-\mathbf{X}_t) - \mu\beta(R_s-R_t)$$

$$+ (ln\ L_{is} - ln\ L_{it}) + (ln\ V_{is} - ln\ V_{it})\} \tag{27}$$

where

F_{is} : the number of locations of group i in zone s

Since neither of V_{is} or V_{it} can be directly measured, they are treated as residual terms in the estimation. Taking the terms contained in the function of L_{is}; equation (14), into consideration, the following equation is derived for parameter estimation,

$$ln\ (F_{is}/F_{it}) - ln\ (A_s/A_t) - (R_s - R_t)$$

$$= \mu\alpha_i(\mathbf{X}_s-\mathbf{X}_t) - \mu\beta(R_s - R_t) \tag{28}$$

As the left hand side can be calculated with observed data, it is used as the dependent variable of the multiple regression analysis. Since $\mu\beta$ is common among locator groups, samples by each locator group are pooled in a bundle for a single regression equation with specific variables for each locator's conditions.

Rent-Bidding Analysis

According to the supply function of zone s for each locator group, the ratio of number of locations between two locator groups in the zone s can be regarded to be equal to the ratio of supply in terms of number of locations between the two locator groups as follows,

$$F_{is}/F_{js} = \Phi^{b}{}_{is} / \Phi^{b}{}_{js}$$
$$= (A_s/q_{is}) \exp(\omega B_{is} + \ln N_i + \ln V_{is}) / (A_s/q_{js}) \exp(\omega B_{js} + \ln N_j + \ln V_{js}) \quad (29)$$

If R_{js} is observed land price for land use j at a representative point in zone s, it can be assumed to be equal to B_{js}. Based on this assumption and simplifying the expression, the following equation is used for parameter estimation from the random rent-bidding view point,

$$R_{js} = [1/(1+\omega)] \ln (F_{is}/F_{js}) + B_{is} + \mathrm{CONST}_{i-j} \quad (30)$$

The CONST_{i-j} is a constant for the pair of i and j given by U^*_i, U^*_j, N_i, N_j, V_i, V_j, θ_i and θ_j. Parameter estimation can be done base on the equation with land price data which can be regarded as the representative bid-rent by using multiple regression analysis.

Adjustment of Estimated Parameters

Since there are two estimates for parameters from both functions of utility and rent-bidding, it is necessary to derive unique values of parameters. As the variance of each estimate is obtained by the regression analysis, a weighted average of the two estimates can be calculated based on their estimated variance. In this study, the weighted averages are employed as the values of parameters for simulation model.

RURBAN MODEL BUILDING

General

The RURBAN model is a quasi-dynamic type model which is the most popular among land use models. That is, the simulation will be carried out for a limited period (such as 5 years), and the locational demand for each period, by number of individual locators in each locator group will be given exogenously to the model. In addition, for each period, there will be market equilibrium which should be decided by the rent in each zone and the level of utility of each locator group.

Prerequisites for forecasting are a land use pattern, in other words, the distribution of each locator group in each zone, the equilibrium rent in each zone and the equilibrium level of utility of each locator group at the end of the previous period.

Incorporation of Non-Urban Land Uses

Non-urban land uses such as agriculture rarely expand their area, but play very important role in the supply of land for urban land uses in a metropolis. The former fact indicates that it is not necessary to represent the utility or demand function of non-urban land uses explicitly. The latter suggests that non-urban land uses should be taken into account in the supply function of land. Based on these considerations, the non-urban land uses are incorporated in the RURBAN in the following manner,

(1) The utility of the non-urban land uses are not explicitly considered in the model.
(2) Since whether non-urban land uses hand over their land to other urban uses or not depends on their own preference; portfolio selection or captive decision making to keep them, modeling of the behavior is beyond the frame of the study. But their propensities can be measured, to some extent, by estimating their bid-rent based on the observed land use pattern in each zone, as is explained in the following section.
(3) In the simulation, the bid-rent of non-urban land uses in each zone is assumed to increase/decrease by a constant value uniformly in every zone. The shift may be forecast based on the change of rate of interest or expectation of land price increase based on the tendency of the previous years.
(4) The amount of area used by non-urban land uses in each zone, is estimated in the simulation as the area after deducting urban land uses from the available land both physically and legally.

Initial Adjustment

There are initial residuals in the numbers of locations between observed data and values calculated directly from the estimated parameters. Theoretically they can be regarded as V_{is}. But the V_{is} calculated by the utility function is not necessarily to be equal to that by rent-bidding function. The discrepancies between them can be considered to be caused by the fact that the actual land market is not in the state of equilibrium defined in this study. Of course, the discrepancies are mainly caused by the uncertainty in the data processing.

The bid-rent in each zone of non-urban land use group is calibrated as a constant to represent its actual share in the zone in the random rent-bidding model.

APPLICATION

General

Though the RURBAN model, based on the above-mentioned theoretical development, is not completely computerized yet, a simplified pilot model for forecasting has been provided with calibrated utility and rent-bidding functions.

The actual study area is the Sapporo City, the capital of the northern main island of Japan, with an area of about 1.1 thousand Km^2 and a population of about 1.5 million. There are several proposals regarding transport investment. The simulation model is being built to forecast the impacts of those proposed transport projects.

The unit of land in the analysis, which is called the zone in the theoretical development, is about 1km × 1 km grid. As for the locators, they are classified into four groups, those are residential, business and central commercial, neighborhood commercial and industrial locator groups. In addition, non-urban land uses are aggregated as a group whose locational utility is treated to be unique in the whole study area but bid-rent differs according to the actual land use pattern in each zone as explained in the previous chapters.

Utility and Rent-Bidding Functions Estimated

Parameter estimation was done with using data of 1981. The estimated parameters are shown in Table 1. Although other explanatory variables were originally included in this estimation, they are omitted after considering either the t-value or the sign of the parameter. In addition, land price is used instead of rent because only the data of the former is available.

Though it cannot be said that the parameters estimated by the utility analysis shown in the left column in the Table 1 have full consistency with those by rent-bidding analysis in the center column of the table, it seems that there is, in general, no fatal inconsistency between them. The discrepancy between two sets of parameters may be caused by not only problems in data but also that there is inconsistency between the model assumptions and actual land market, especially that actual land market is not always in the state of equilibrium.

A set of parameter values are obtained by taking an average of estimates by both utility and rent-bidding analyses with weights based on their estimated variances. Judging from the estimated standard errors of the adjusted parameters, they have enough statistical significance.

Simulation

By using data of 1981 and with adjustment to completely regenerate the observed land use pattern in 1981, a simulation was conducted to forecast the 1986 land use pattern in 1 km × 1 km grids. Figure 1 shows the comparison between observed and estimated changes of residential area during the period from 1981 to 1986. Although the model used in this case study is not complete yet, the results show satisfactory values for the correlation coefficients between observed changes in land use patterns and those estimated by the model. The values are 0.8795 in residential use, 0.8108 in business and commercial use and 0.9557 in industrial use.

Since there are little changes in the location conditions during the period, it seems partly that the contribution of the initial adjustment yield high correlation coefficients. Consequently, it is necessary to make a simulation for a longer period with distinct changes in location conditions to test the significance of the parameters of both utility and rent-bidding functions.

TABLE 1 Estimation and Adjustment of Parameters of Utility and Rent-Bidding Functions

Explanatory Variable	Parameter (Standard Error)					
	Utility		Bid-Rent		Adjustment	
Locator Group Locational Condition	$\mu\alpha$		α/β		$\mu\alpha(=\omega\alpha/\beta)$	
Residential						
Distance to Primary School (m)	-0.220	(0.0726)	-0.221	(0.0670)	-0.154	(0.0270)
Time to the Sapporo Station (min)	-0.137	(0.111)	-0.414	(0.0545)	-0.242	(0.0307)
Number of Shops in the Zone	0.243	(0.0302)	0.182	(0.0397)	0.157	(0.0240)
Business and Central Commercial						
Distance to the Nearest Station (m)	-0.0370	(0.125)	-0.0228	(0.0234)	-0.0141	(0.0225)
Floor-Area Ratio (%)	1.33	(0.142)	0.198	(0.0292)	0.134	(0.0234)
Time to the Sapporo Station (min.)	-0.0686	(0.185)	0.0477	(0.0468)	-0.0298	(0.0226)
Neighborhood Commercial						
Distance to the Nearest Station (m)	-0.117	(0.0288)	-0.0234	(0.0230)	-0.0328	(0.0225)
Facing Trunk Road (dummy)	-0.00482	(0.0946)	0.223	(0.180)	0.0553	(0.0249)
Number of Households in the Zone	0.667	(0.0495)	0.122	(0.0193)	0.0929	(0.0227)
Time to the Sapporo Station (min)	-0.142	(0.0986)	-0.212	(0.0440)	-0.129	(0.0242)
Industrial						
Industrial Use District (dummy)	-0.122	(0.0853)	-0.253	(0.0874)	-0.145	(0.0286)
Time to Highway Interchange (min)	-0.0322	(0.0349)	-0.0938	(0.0345)	-0.0504	(0.0226)
Common in Utility Analysis	$\mu\beta$				$\mu\beta(=\omega)$	
Land Price (yen)	0.604	(0.0371)			0.605	(0.0371)
Common in Bid-Rent Analysis			$1/(1+\omega)$			
Ratio of Number of Location			0.0735	(0.0183)		
Bid-Rent Constants in comparison with Residential			CONST$i-j$			
Business and central Commercial			2.03	(0.245)		
Neighborhood Commercial			1.48	(0.293)		
Industrial			0.994	(0.292)		
Multiple Correlation Coefficient	0.6430		0.8483			

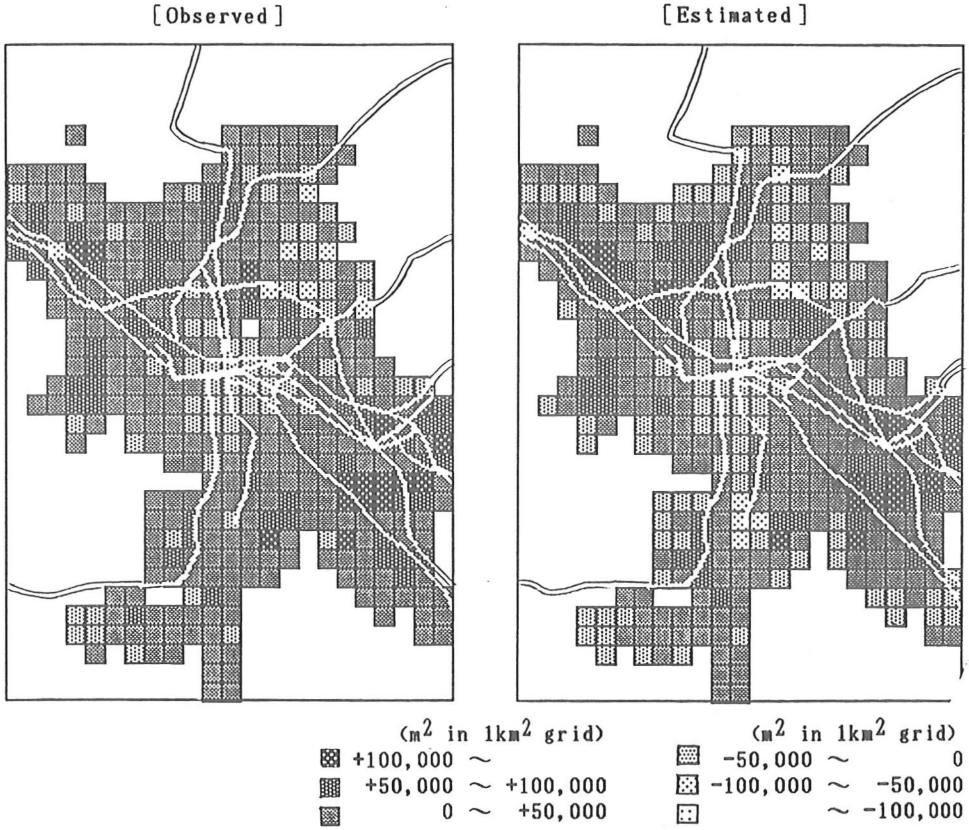

Figure 1 Comparison of Residential Area Change between Observed and Estimated by RURBAN (1981-1986)

CONCLUDING REMARKS

This paper is mainly concerned with the theoretical aspects of the RURBAN. However, the model also has practical value, because its parameters can be estimated and calibrated by using actual data, as shown in the application. In other words, this study is intended to fill the gap between analytical models in the urban economics and operational models in the field of engineering by using the random utility / rent-bidding model.

It is expected that even complex cities can be analyzed quantitatively by the RURBAN using computers. Then computer-oriented analysis using RURBAN may be able to solve complex problems which classical analytical approach can never solve.

However there still remain some points to be examined in this version of RURBAN; the validity of model assumptions, reliability of parameter estimation and forecasting performance of the model. Along with the development of Sapporo version, it is expected that there will be some improvements in both theory and operationality of RURBAN.

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