AN EVALUATION METHOD OF TRANSPORT PROJECTS WITH THE AID OF RURBAN (RANDOM UTILITY / RENT-BIDDING ANALYSIS) MODEL

Kazuaki MIYAMOTO
Associate Professor
Department of Civil Engineering
Yokohama National University
Yokohama-Japan

Takayuki NOAMI
Graduate Student
Department of Civil Engineering
Yokohama National University
Yokohama-Japan

Yuhei KUWATA
Senior Researcher
Transportation Planning Department
Hokkaido Engineering Consultants
Sapporo-Japan

Ken-ichi YOKOZAWA
Senior Researcher
Transportation Planning Department
Hokkaido Engineering Consultants
Sapporo-Japan

1. INTRODUCTION

Large-scale transport projects such as motorway network developments and new railway constructions in a metropolitan area bring about a variety of effects all over the area. However, for these effects to be substantially felt, some kinds of landuse development should accompany such large-scale transport projects. Consequently, it is very important to estimate properly these effects during the planning stage. For this purpose, various landuse models have been developed in transport studies to forecast not only future trip generation but also the indirect effects of the projects.

The aims of the present study are to develop an evaluation method for transport projects in relation to the land market, and to build an operational personal-computer aided system which applies the evaluation method effectively to actual projects. In the end, it is hoped that the study will provide a practical planning tool based on a sound theory to realize integrated landuse-transport planning in a metropolis.

The main model of the system is a landuse simulation model based on random utility and rent-bidding analysis (RURBAN). The earlier version of the model has been reported in Miyamoto and Yagi (1987), Miyamoto (1987), and Miyamoto and Kitazume (1990). The present version has been improved not only in its theoretical basis but also in its operational functions.

The RURBAN has been developed to be an operational landuse model based on an exact theoretical model in the urban economics so that future landuse can be predicted quantitatively by considering small units of land. In the land market of a metropolis, RURBAN represents demand and supply as well as their equilibrium by each small unit of land which is called a zone in this study. Within a given zone, the random utility of a locator group represents the demand for land of the group while the random rent-bidding of a locator group determines the supply of land to the group in the said zone. The RURBAN assumes an equilibrium between the demand and supply. This is attained by the adjustments of the level of utility of each locator group in the whole area and of the rent in each zone. In addition, RURBAN is expressed in a very simple manner with a set of structural equations.

The present personal-computer aided system can analyze the effects of transport projects such as road network development of both ordinary trunk roads and motorways as well as rail transit construction. Regarding landuse policy measures, other kinds of infrastructure developments to improve regional conditions as well as changes of landuse control zoning area can also be taken into consideration. These policy alternatives can be inputted easily with the aid of personal-computer graphics which the study developed originally for the system. The main items which the system can output are as follows; distribution of landuses, population and employment by industrial sector, rent (land price), level of utility by locator group, and the size of land occupied by a unit of locator group, all of which can also be represented by personal-computer graphics.

The present system has been applied in the evaluation and the analysis for value capture of some proposed transport projects in the Sapporo Metropolitan area in Japan.

2. RURBAN MODEL DEVELOPMENT

2.1 Assumptions and Basic Concepts

2.1.1. Assumptions

This study discusses landuse in a limited metropolitan area, which is hereafter called the "study area". The study area is assumed to be a closed city, which means that, in the analysis, the location demand is provided 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. Also, no locator outside the study area can bid a higher rent than the locators inside. Therefore, the area outside the closed city need not 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 the land. Furthermore, the land price is assumed to be proportional to the rent. Hence, the only basis for this discussion is rent.

To segment the demand side in the land market, locators are classified according to their characteristics into a limited number of groups, called "locator groups" hereafter. These 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. The zones are regarded as discrete options in the analysis of location choice with random utility.

2.1.2. Basic Concepts of General Equilibrium in this Study

2.1.2.1. General Equilibrium in this Study

In this study, the land market is grasped from the two viewpoints of locators and sites. If a locator chose a certain site, that site must give the locator the highest utility from among the alternative sites. On the other hand, it is also explained as that the locator must bid the highest rent among the alternative locators at the site. The former viewpoint assumes that the rent at all the alternative sites must be given in the utility analysis, whereas the latter assumes that the level of utility of all the locators should be given in the rent-bidding analysis. Under these prepositions, each analysis can determine the partial equilibrium for a locator and a site, respectively.

At the level of aggregated locator groups and zone, the market can also be similarly explained, although probabilistic consideration should be introduced to represent the coexistence of a number of locators of various groups in a zone which consists of a lot of sites. Locators belonging to a group are distributed in the zones in proportion to the probabilities with which the zones give the group the highest utility. The area share of locator groups in a zone is also proportional to the probabilities that the locator groups bid the highest rent at the zone. At this level of modeling, the rents in all zones and the levels of utility of all locator groups are indispensable in the former and the latter explanations, respectively. In case either the rents of all zones or the levels of utility of all locator groups are given in the analysis, the landuse distribution in the study area can only be obtained by either the utility or rent-bidding analyses, i.e., by the partial equilibrium analysis. However, this is not the case when landuse changes are studied is an actual planning stage. The change of the rents as well as the levels of utility should be also estimated during the actual planning, particularly in the case of transport development projects for evaluating benefit and its distribution.

In this study, it is assumed to find out a state of general equilibrium of land market within the study area. The state of general equilibrium can be obtained through either equilibrium rents of all zones or equilibrium levels of utility of all locator groups, since the determination of the former naturally brings about the settlement of the latter and vice-versa. This general equilibrium is defined in this study as that state when the location demand of a locator group in a zone is equal to the land supply of the zone for all pairs of locator group and zone within the study area. In addition, 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 or flow values but include the total landuse pattern for all the locations or stock values. Therefore, such areas where housings are built but nobody is living are regarded not as residential areas but as vacant or non-used areas in this model. The model deals only with actual use of land.

2.1.2.2. Demand for land derived from the Partial Equilibrium

For a locator group, all zones in the study area are options in its location choice. However the amount of its location in a particular zone depends on the corresponding utility in that zone which is represented by a "representative" indirect utility. The indirect utility, which is the maximum utility the locator can attain if it locates itself in that zone, is assumed to be distributed randomly around a represented utility. Every locator belonging to a group is assumed to locate itself in a zone which is expected to give it an equal level of utility. The same level of utility is obtained as a probabilistic expectation of the maximum utility for all zones. This is derived from a random utility model or discrete choice model in the partial equilibrium analysis which deals with a locator group only. The demand function, which is also derived from a discrete choice model, is then defined as the probabilistic expectation of the number in a group locating itself in a zone. In addition, it is implicitly assumed that the utility includes factors regarding the location behavior such as the cost of relocation from the present location and both monetary, and time cost of the building construction.

The discrete choice model based on the random utility theory has been developed to analyze a variety of practical problems [Ben-Akiva and Lerman(1986)]. In the field of landuse analysis, discrete choice models have been applied to analyze locator behavior in choosing a location from alternative sites[see Lerman(1981), Anas(1983) and Miyamoto et. al.(1986)]. This analysis is closely related to the utility maximizing principle.

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

2.1.2.3. Supply of Land derived from the Partial Equilibrium

First of all, in this study, physical provision such as housing or building construction is not regarded as supply of land, although most models such as Anas(1983) and Echenique(1983) deal with housing and floor developer as a supplier.

The supply of land is defined in this study as follows. At each site in the study area, the existing locator is bidding the highest rent which becomes the actual rent. This means that the imaginary landowner supplies the site for the maximum bidder at the maximum bid-rent. However there are a number of sites in each zone, and their characteristics are not necessarily the same within 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 one locator group such as one type of household in a mono-centric city is dealt with, the bid-rent represents nothing but indirect utility. In such a situation, if a boundary condition such as the agricultural rent is given in the analysis, 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 the preceding analysis, in the sense that there are several locator groups in the market. Since all the urban landusers 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 models, Ellickson(1981) proposed a rent-bidding system to determine which locator would likely be the highest bidder. Following this study, Lerman and Kern(1982) proposed a way to calibrate bid-rent by considering the actual land price, and Gross(1988) 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 landuse. Consequently, the existing random bidding models are, in general, used mainly for estimating willingness to pay or actual rent for residential use only. Few applications of existing models employ a scheme as that of RURBAN as mentioned above.

2.2. Formulation

2.2.1. Derivation of Demand Function from Utility Analysis

The discussion in this section is mainly on residential location [see Miyamoto and Kitazume (1990)]. However, as is well know in the urban economics, the concepts presented here can be extended to other urban locations such as business-commercial and industrial.

I : a locator group
S : a zone
U_{IS} : logarithmic utility of locator group I at zone S

q_{IS} : amount of land occupied by a unit of locator groups *I* in zone *S*
X_{ISK} : logarithmic locational conditions in zone S (except rent)
R_s : logarithmic rent at site s
α_{IK}, β_I and θ_I : parameters for locator i

$$U_{IS} = \boldsymbol{\alpha}_I X_{IS} - \beta_I R_S \quad (1)$$
$$q_{IS} = \theta_I \exp(-R_S) \quad (2)$$

where,

$$\boldsymbol{\alpha}_I = \{\alpha_{I1}, \alpha_{I2}, \cdots, \alpha_{IK}\} \quad (3)$$
$$X_{IS} = \{X_{IS1}, X_{IS2}, \cdots, X_{ISK}\}^t \quad (4)$$

Assuming that the utility is distributed randomly around the values given by equation (1) based on the random utility model and with additional terms which represents the scale of the zone as a choice alternative and measure of the heterogeneity of sites in the zone, [see Ben-Akiva and Lerman (2)], the following equation is obtained.

$$U^R_{IS} = U_{IS} + (1/\mu) \ln L_{IS} + (1/\mu) \ln V_{IS} + \varepsilon_{IS} \quad (5)$$
$$U_{IS} = \boldsymbol{\alpha}_I X_{IS} - \beta_I B^*_S \quad (6)$$
$$L_{IS} = A_S / q_{IS} \quad (7)$$
$$V_{IS} = [1/(L_{IS} \cdot N_I)] \cdot \sum_{I} \sum_{s \in S} \exp \mu (U_{Is} - U_{IS}) \quad (8)$$

where

U^R_{IS}: random utility of locator group *I* in zone *S*
ε_{IS} : random term
L_{IS} : number of sites for the use of locator *I* in zone *S*
V_{IS} : measure of heterogeneity of elemental sites in zone
B^*_s : representative rent at zone S
μ : positive scale parameter of indirect utility function

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

$$\text{Prob}(U \mid I \text{ in } S) = \frac{\exp(\mu U_{IS} + \ln L_{IS} + \ln V_{IS})}{\sum_T \exp(\mu U_{IT} + \ln L_{IT} + \ln V_{IT})} \quad (9)$$

Based on the probability mentioned in equation (9), the expected number of locations of group *I* in zone *S* is given as follows in the case that there are no competitors to locate in the zone,

$$\Psi_{IS} = N_I \, \text{Prob}(U \mid I \text{ in } S) \quad (10)$$

where,

N_I : number of individual locators belonging to locator group *I*

For better understanding, equation (10) is rewritten in terms of the area as given in equation (11).

$$\Phi^{u}_{IS} = q_{IS} \cdot \Psi_{IS} = q_{IS} \cdot N_I \, \text{Prob} \; (U \mid I \text{ in } S) \tag{11}$$

In this study, Φ^{u}_{IS} is regarded as the demand function of locator group I in zone S.

2.2.2. Derivation of Supply Function from Rent-Bidding Analysis

The supply function is derived from the rent-bidding model, which is similar to the derivation of the demand function.

$$\text{Prob} \; (B \mid S \text{ for } I) = \frac{\exp \; (\omega B_{IS} + \ln N_I + \ln W_{IS})}{\sum_J \exp \; (\omega B_{JS} + \ln N_J + \ln W_{JS})} \tag{12}$$

where,

$$B_{IS} = \{\alpha_I X_{IS} - U^*_I\} / \beta_I \tag{13}$$

$$W_{IS} = [1 / (N_I \cdot L_{IS})] \cdot \sum_{i \in I} \sum_{s \in S} \exp \omega \; (B_{is} - B_{IS}) \tag{14}$$

W_{IS} : measure of heterogeneity of individual locators in locator group
ω : positive scale parameter of bid-rent function

Then, the supply function of zone S for locator group I in terms of area, is given as follows.

$$\Phi^{b}_{IS} = A_{IS} \, \text{Prob} \; (B \mid S \text{ for } I) \tag{15}$$

2.2.3. Equilibrium Condition

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.

$$\Phi^{u}_{IS} = \Phi^{b}_{IS} \tag{16}$$

The equation represents the equilibrium condition in terms of location area. It can be easily rewritten to represent the equilibrium in terms of numbers of locations. In this problem, we have to find equilibrium rents and equilibrium levels of utility which are dealt with a given value in the demand side and the supply side analyses,respectively. In order to satisfy equation (15) for all pairs of locator group and zone, the following conditions are derived. The level of utility for locator group I and the rent in zone S, which can be regarded as R_s, are given as in equations (17) and (18) with additional conditions given by equations (19) and (20).

$$U^*_I = (1/\mu) \cdot \ln \sum_S \exp \; (\mu U_{IS} + \ln L_{IS} + \ln V_{IS}) \tag{17}$$

$$B^*_S = (1/\omega) \cdot \ln \sum_I \exp \; (\omega B_{IS} + \ln N_I + \ln W_{IS}) \tag{18}$$

$$V_{IS} = W_{IS} \tag{19}$$

$$\mu \beta = \omega \tag{20}$$

The first two 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. Whereas equation (19) represents the relation of heterogenuities of both utility and rent bidding functions. Equation (19) also shows the relation of both scale parameters. Assuming that μ is common among locator groups, β should be also common among locator groups since ω is assumed to be unique in the logit model of rent-bidding.

2.2.4. Basic Equations of the RURBAN model

Based on the abovementioned discussions, the structural equations of RURBAN are shown as follows,

$$\mu U_{IS} = \mu \alpha_I X_{IS} - \omega B^*_S \tag{21}$$
$$q_{IS} = \theta_I \exp(-B^*_S) \tag{22}$$
$$L_{IS} = A_S / q_{IS} \tag{23}$$
$$\omega B_{IS} = \mu \alpha_I X_{IS} - \mu U^*_I \tag{24}$$
$$U^*_I = (1/\mu) \cdot \ln \sum_S \exp(\mu U_{IS} + \ln L_{IS} + \ln V_{IS}) \tag{25}$$
$$B^*_S = (1/\omega) \cdot \ln \sum_I \exp(\omega B_{IS} + \ln N_I + \ln V_{IS}) \tag{26}$$

There are $(4I \cdot S+I+S)$ unknown variables such as U_{IS}, B_{IS}, q_{IS}, L_{IS}, U^*_I, B^*_S, and there are an equal number of independent equations.

2.3. Parameter Estimation

2.3.1. General

Since the rent-bidding function is regarded as a variation of the indirect utility function, the two functions have common parameters as was shown before. There are several options in calibrating the parameters. The first option is to calibrate them simultaneously by the most likelihood estimation method taking both probabilities. The second is to estimate adjusted values of the parameters obtained separately by utility analysis and rent-bidding analysis (Miyamoto and Kitazume 1990). The third is to appropriate the parameters estimated by one analysis to the other. In this paper, the third method of parameter estimation is adopted, and the parameters are estimated by rent-bidding analysis alone. The validity of the estimated parameters for the utility function is confirmed by the goodness-of-fit of estimated distribution of locators to the observed distribution. The reasons for the adoption of the calibration procedure are, that it is very stable to estimate the parameters with the rent-bidding functions because there are enough number of samples for estimation; that the former two methods didn't give better results in spite of the additional difficulties encountered in their usage; and that the goodness-of-fit of estimated distribution of locators to the observed distribution shows satisfactory results as is described in the application part in this study.

Regarding V_{IS}, it is estimated to compensate for the discrepancies between landuse pattern calculated by both utility and rent-bidding functions without V_{IS} and observed pattern as will be explained later.

2.3.2. Assumptions regarding Scale Parameters

Since the logit model is adopted to represent the randomness of both utility and rent-bidding in this study, the scale parameters μ and ω should be assumed to be identical among zones and locator groups, respectively. However, it cannot be incorrect to consider the variance of households in rent-bidding as being the same as those of commercial and business activities. Although the introduction of the probit model may solve the problem in this regard, it will bring about other problems. These problems include the estimation of the probit model which is much more complex than that of the logit model and that the basic structural equations of the model using the probit model cannot be represented with so simple forms as those in the case of the logit model. These problems not withstanding, the selection of random model should depend on the total evaluation of possible models. For this purpose, parameter estimation should ideally be conducted with the two models for the comparison of goodness-of-fit between them.

2.4. RURBAN Model Building

2.4.1. General

The RURBAN model is a quasi-dynamic type model which is the most popular among landuse models. With this model type, the simulation will be carried out for a limited period (such as 5 years), and the locational demand for each period is determined by the number of individual locators in each locator group, and the available area of land in each zone both physically and legally will be given exogenously to the model. In addition, locational conditions other than those which are obtained endogenously in the model should be also determined as alternative cases to be forecasted.

The equilibrium rent in each zone and the equilibrium level of utility of each locator group at the end of the previous period are not prerequisites in the simulation, although the simulation can be conducted with much less time in the case that it starts with the distribution of each locator group in each zone.

3. PERSONAL-COMPUTER AIDED SYSTEM

3.1 Basic Concepts for System Development

3.1.1. The Role of the Personal-Computer System

In this study, a computer support system is being developed for two purposes; to support analysis of policy measure alternatives with the RURBAN model as well as to support both developments of the RURBAN simulation model and the personal-computer system itself. Since landuse analysis essentially deals with the space itself together with various types of necessary data, it is nearly impossible to conduct analysis by using quantitative landuse models without understandable graphic devices. This is the case not only during planning stages of the model but also during the development stage of the system itself. In the development stage of the model, the system will work for better calibration of the model and for better understanding of the performance of the model. In the planning stage, the system will give the planner more opportunities to learn the plausible effects of policy measure alternatives. The learning will enable him to find a better set of policy measures from the viewpoint of the planning objectives. The system is prepared not to produce a number of useless alternatives for analysis but to effectively find out valuable alternatives worth considering.

3.1.2. Principles for System Development

Three principles are set up in the development of the computer support system. The first principle is that the system be equipped with user-friendly human-interface. The second is that the hardware of the system corresponds with the scale of the model and the size of the study area. The third is that the system structure be flexible for future version-up of any part of the system. Following these principles, the system has been developed as follows.

With respect to interface for operation, all operations can be done through interaction with the computer. A person operating the system can input data or select an option from the menu only by operating a "mouse".

Regarding the hardware of the system, a 32-bit personal-computer which is now very popular even in developing countries, is adopted because of its availability as well as its relatively lower cost of system maintenance.

As for the system structure, it is designed such that every step is independent from each other. Each step has its input data and output data and is linked with other steps only through the data. The concept of the system structure is very similar to that of relational database modelling. In the system, if a new or revised step is introduced, it is linked with the other existing steps by setting up new "relations" which are steps of data converter.

3.2. Functions of Personal Computer System

3.2.1. Policy Measures to be Analysed

The present version of the system has functions to input graphically the following policy measure alternatives; transport network development, and landuse regulations. Regarding transport facilities, the system can deal with any combination of new constructions of motorway, ordinary road and rail-transit. As for landuse regulations, the function has been installed in the system to change landuse control zoning which is usually reviewed when big transport projects are planned.

In addition, the system can conceptually deal with any policy alternatives which can be adequately translated into the variables of the model. Presently, other policy alternatives other than the abovementioned can be analysed with the keyboard by the simulation model developer.

3.2.2. Base Map of the System

The present system has a base map for both input and output of spatial data. The base map is a set of image data of geographical map of the study area together with the grid system in the background which is used to adjust distortion with the coordinates. The base map is represented on the CRT screen in part and the operator can either scroll vertically or move horizontally the map to input data graphically. Figure 1 to 3 show the move of the base map on screen in the case of motorway rout selection. The base map is also used for changing landuse control zoning as shown in Figure 4.

3.2.3. Outputs of the System

The system can output graphically the results of simulation by grid map. Presently travel time to principal points, landuse by area, land price and average area for one housing unit can be readily represented with a very simple mouse operation. These outputs are represented by the total value of each case as well as difference from those of a standard case. Examples of the outputs are shown in Figure 6 to 9.

4. APPLICATIONS

4.1 Study Area and Unit of Analysis

The actual study area is Sapporo City, the capital of the northern main island of Japan, with an area of about 1,000 Km^2 and a population of about 1.6 million. There are several proposals regarding transport investments. The simulation model is being built to forecast the impacts of those proposed transport projects together with landuse regulations.

The unit of land in the analysis, which is called the zone in the theoretical development, is about 1 km × 1 km grid. As for the locators, they are classified into five groups; residential, business and central commercial, neighborhood commercial, industrial and agricultural locator groups. The agricultural group represents non-urban landuses as well as vacant land.

4.2.2. Goodness-of-Fit

To test the goodness-of fit of the rent-bidding model to actual landuse distribution, the distribution is calculated by the probability based on the rent-bidding function excluding V_{is}. The correlation coefficient between estimated and observed landuses by zone are 0.8128(residential), 0.7677(business/central commercial), 0.5070(neighborhood commercial), 0.8245(industrial) and 0.8334(agriculture). Although all the correlation coefficients between estimated and observed distributions are very high, all of them seem acceptable. In addition, there will be no problem in actual forecast, because V_{is} is introduced to fill the discrepancies.

The result of the goodness-of-fit of utility functions which employ the parameters estimated in rent-bidding analysis shows that the parameters obtained in rent-bidding analysis are also useful in utility analysis.

4.3. Examples of Simulation Output

The landuse analysis system with personal-computer aided system for the Sapporo metropolitan Area is named RURBAN/Sapporo. Examples of the simulation outputs are shown in Figure 5 to 8. Since RURBAN/Sapporo gives not only the rents of all zones but also the levels of utility of all locator groups, the outputs are very helpful for the determination of who should shoulder or share the cost in infrastructure development project. Through interaction with the personal-computer, the performance of RURBAN is being investigated. In addition, the system is being applied to actual project evaluations in the region.

5. CONCLUDING REMARKS

This study is originally 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 also intended to make not only the theoretical

Figure 1 Scrolling Base Map and Rout Selection of A Motorway (1)

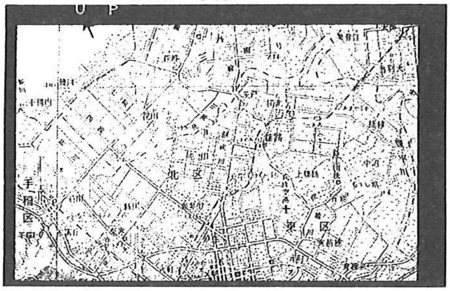


Figure 2 Scrolling Base Map and Rout Selection of A Motorway (2)

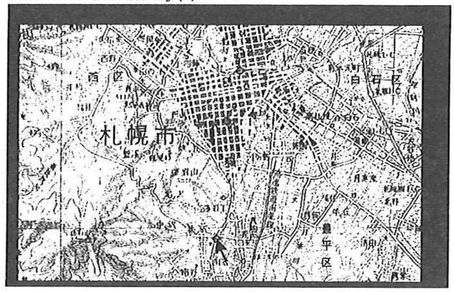


Figure 3 Scrolling Base Map and Rout Selection of A Motorway (3)

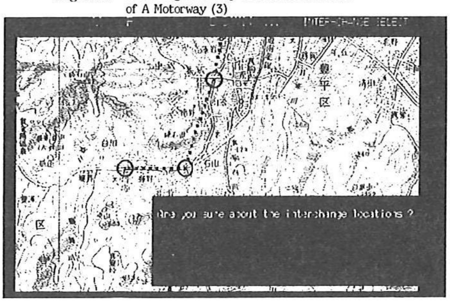


Figure 4 Operation of Change of Landuse Control Zoning

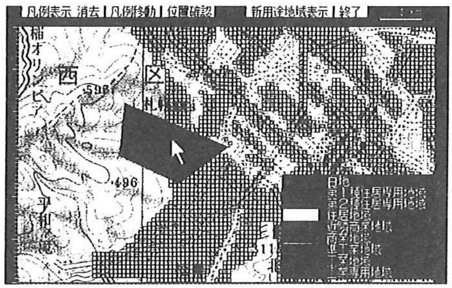


Figure 5 Change of Travel Time to the Central Station

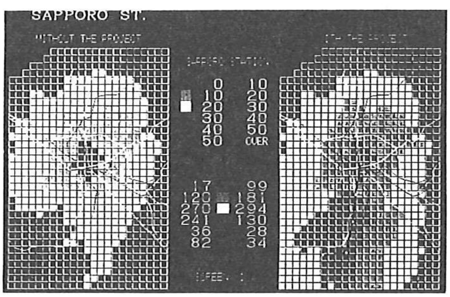


Figure 6 Change of Residential Area (comparison with do nothing case)

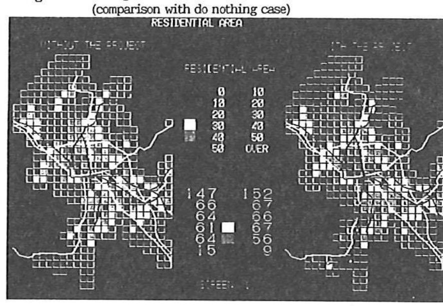


Figure 7 Change of Residential Area (difference from do nothing case)

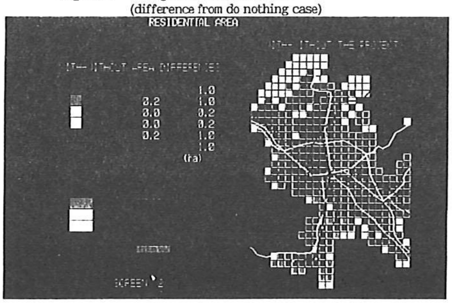
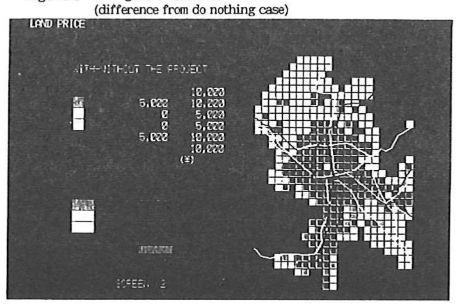


Figure 8 Change of Land Price (difference from do nothing case)



development but also the mathematical expressions as simple as possible for better understanding of the users.

In addition, it is expected that even complex cities with multiple centers can be analyzed quantitatively by RURBAN using computer simulations. This means that computer-oriented numerical analysis method using RURBAN may be able to solve complex problems which classical analytical approach cannot solve.

BIBLIOGRAPHY

1) Anas, A. and Duann (1983), Dynamic Forecasting of Travel demand, Residential Location and Land Development: Policy Simulations with the Chicago Area Transportation / Land Use Analysis System, Paper prepared for presentation at the International Symposium on New Directions in Urban modeling.
2) Ando, A. (1988) "Modeling Aggregate Location and Demolition Probabilities: An Application to a Metropolitan Land Use Simulation Model, Studies in Regional Science, Vol. 18, pp. 187-204, Japan Society of Regional Science.
3) Alonso, W. (1964), "Location and Land Use ", (Harvard Univ. Press).
4) Ben-Akiva, M., and Lerman, S. R. (1986), "Discrete Choice Analysis : Theory and application to Predict Travel Demand", (The MIT Press).
5) Ben-Akiva, M., Gunn, H. F. and Silman, L. A. (1984), "Disaggregate Trip Distribution Models", Proc. of Japan Society of Civil Engineers, No. 347, IV-1, pp. 1-17.
6) Ellickson, B. (1981), "An Alternative Test of the Hedonic Theory of Housing Market", Journal of Urban Economics, 9, pp. 56-79.
7) Echenique, M. (1983): The Use of Integrated Land Use and Transportation Models: the case of Sao Paulo, Brazil, and Bilbao, Spain, Proceedings of the Workshop in the Practice of Transportation Planning, International Center for Transportation Studies, Amalfi, Italy.
8) Gross, D., J. (1988), "Estimating Willingness to Pay for Housing Characteristics : An Application of the Ellickson Bid-Rent Model", Journal of Urban Economics, 24, pp. 95-112.
9) Lerman, S. R. (1981), "Neighborhood Choice and Transportation Service, Text for the Seminar on Transportation System and Planning", Research Institute for Planning and Transportation.
10) Lerman, S. R. and Kern, G. R. (1982), "Hedonic Theory, Bid Rents, and Willingness to Pay: Some Extensions of Ellickson's Results", Journal of Urban Economics, 10.
11) Miyamoto, K., Nakamura, H. and Shimizu, E. (1986), "A Land Use Model Based on Disaggregate Behavioral Analyses", Proceeding of the Fourth World Conference on Transport Research, pp. 1535-1550.
12) Miyamoto, K. and Yagi, S. (1987), "A large-Scale Land Use Model based on the Random Utility / Bidding Theory", Proceedings of the International Symposium on Transport, Communication and Urban Form, pp. 235-250, Monash University.
13) Miyamoto, K. (1987), "A Pilot Model of Land Use Simulation with consideration of the Randomness of both Utility and Bid-Rent", Infrastructure Planning Review, pp. 15-26, Japan Society of Civil Engineers.
14) Miyamoto, K. and Kitazume (1990), K.:"A Land-Use Model based on Random Utility /Rent-Bidding Analysis(RURBAN)", Proceedings of the Fifth World Conference on Transport Research, Vol. 4, pp. 107-121.
15) Webster, F. V., Bly, P. H. and Paulley, N. J. (ed.)(1988), "Urban Land-Use and Transport Interaction - Report of the ISGLUTI -", (Avebury).