THEORETICAL REBUILDING OF RURBAN AND THE APPLICATION TO A METROPOLIS WITH DETAILED AREA UNIT OF ANALAYSIS

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Abstract: The aim of the present paper is to improve RURBAN (Miyamoto and Udomsri (1996) and Wegener (2003) in the following terms; (1) to rebuild the theoretical interpretation and the model building to solve the inconsistencies and incompleteness found in the existing model, (2) to apply the new model to a metropolis with more detailed area unit of analysis and expanded functions of the decision support system, and (3) to validate the effectiveness of the system as a DSS in real planning and project evaluation. The size of zones in the study area ranges from ten thousands square meters in the city centre to millions in the suburbs, whereas the number of zones is as many as 8,000. The results of parameter estimations for the new model are satisfactory and the performance of the whole system demonstrates the functions in the pre and post-evaluation stages of implementing a set of policy measures.

Keywords: Land Use Model, RURBAN, Decision Support System, Area Unit of Analysis, Number of Zones, Detailed Attributes of Zone, Household Type

1 INTRODUCTION

There have been many urban models or land use and transport models developed in the world as introduced by Wegener (2003). Most of the models employ rather large size of zones. A model named RURBAN (*Random Utility/Rent-Bidding ANaysis model*) (Miyamoto and Udomsri (1996), Wegener (2003) has initially intended to apply to an application that has small size of zones. This is because land use structures in Japan or Asian countries are so complex that large size of zones cannot well describe the urban structure. At the initial development, RURBAN employed 1km^2 grid for the unit of analysis due to the data availability. Moreover, when the area unit of analysis becomes smaller, there will be other problems in addition to the difficulty of data acquisition or the computation load for simulation. Besides the well known Modified Area Unit Problem, there are some points in which inconsistency of the interpretation as a behavioural model is found. Although RURBAN is not at all an analytical model but it is an operational model based on the statistical analysis, the theoretical consistency is essentially required.

The objectives of the present paper is to improve RURBAN in the following aspects: (1) to rebuild the theoretical interpretation and the model building in order to solve the inconsistencies and incompleteness found in the existing model, (2) to apply the new model to a metropolis with more detailed area unit of analysis and to expand functions of the decision support system (DSS), and (3) to validate the effectiveness of the system as a DSS in real planning and project evaluation. In order to achieve the high resolution model applications, a detailed zone system in the Sapporo Metropolitan Area, which is established for the basic survey for urban planning, is employed for the case study. The size of zone ranges from 10,000 square meters in the centre of the city to 1,000,000 in the suburbs. The total number of zones is as many as 8,025. Furthermore, the model equations are transferred into equations for parameter estimation by taking the scale effects of zone size and the number of locator group into consideration. The parameter estimation was successfully conducted and obtained enough number of explanatory variables with significant t-values for five groups of urban activities. The model is then validated with respect to the land use and land price at the base year. The validated model has been integrated with an existing transport model in such a way that the system becomes an integrated land use/transport model. In this regard, a set of interface is equipped to the model so that the interaction between models can be effectively executed. As an efficient DSS, the system is equipped with more user-friendly GUI in various functions. Finally, this paper presents the model application to test several transport policy measures including transport network improvement.

2 THE OUTLINE OF RURBAN

Firstly, in order to segment the demand side in the land market, the urban locators are classified according to their characteristics, i.e., a limited number of locator groups are defined. 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 their locational conditions. The zones are regarded as discrete options in the location choice analysis with random utility. The land market is grasped from two viewpoints of locators and sites. If a locator chooses a particular site, it implies that the site gives the locator the highest utility compared with the alternative sites. On the other hand, the locator must bid the highest rent among the alternative locators for the site. At the level of aggregated locator groups and zones, 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 number of sites. Locators belonging to a group are distributed in zones in proportion to the probability of each zone to give the group the highest utility. The area shared by a locator group in a zone is also proportional to the probabilities that the locator group bid the highest rent at the zone. These probabilities are determined by the Logit models in RURBAN. At this level of modelling, " rent in all zones" and "level of utility of all locator groups" are indispensable in the former and the latter explanations, respectively.

In accordance with the above model description, the structural equations of RURBAN are shown as follows.

$$\mu U_{IS} = \mu \alpha_I X_{IS} - \omega B_{IS}^* \quad (1)$$

$$q_{IS} = \theta_I \exp(-B_S^*) \quad (2)$$

$$L_{IS} = \frac{A_S}{q_{IS}} \quad (3)$$

$$\omega B_{IS} = \mu \alpha_I X_{IS} - \mu U_I^* \quad (4)$$

$$U_I^* = \frac{1}{\mu} \ln \sum_S \exp(\mu U_{IS} + \ln L_{IS} + \ln w_{IS}) \quad (5)$$

$$B_S^* = \frac{1}{\omega} \ln \sum_I \exp(\omega B_{IS} + \ln N_I + \ln w_{IS}) \quad (6)$$

I : the locator group

S : the zone

U_{IS} : the systematic part of random utility of locator group I in zone S

B_{IS} : the systematic part of random bid-rent of locator group I in zone S

q_{IS} : the amount of land used by a unit of locator group I in zone S

X_{IS} : location conditions (except rent) : $(X_{IS1}, ..., X_{ISk}, ...)$

α_I : parameters for locator group I: $(\alpha_{I1}, ..., \alpha_{Ik}, ...)^t$

L_{IS} : the number of available sites for the use of locator group I in zone S

U_I^* : the level of utility of locator group I

B_S^* : the representative rent of zone S

μ : a positive scale parameter of indirect utility function in location choice

ω : a positive scale parameter of bid-rent function

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

A_s : available area of zone S

w_{IS} : the measure of heterogeneity of individual locators in locator group I and individual site in zone S

θ_I : a parameter of locator group I

Equation (1) represents an indirect utility of a locator group I in a zone S. Equation (2) gives the amount of land used by a unit of the group in the zone which is inversely proportional to representative rent of the zone. This function implicitly represents multi-storeyed uses of land in a high land price area. Equation (3) shows the number of available sites for the use of the group at the zone. The number of optional sites in the zone affects the probability of the group to choose the zone. Equation (4) represents bid-rent of the group at the zone. This equation is a kind of dual equation of Equation (1). Equation (5) gives the level of utility of the group in the whole area. It is a logsum function of all utilities of the group in the study area. Finally, Equation (6) represents the representative rent in the zone which is also a logsum function. The latter two functions give key values which determine the general equilibrium of the land market as discussed earlier.

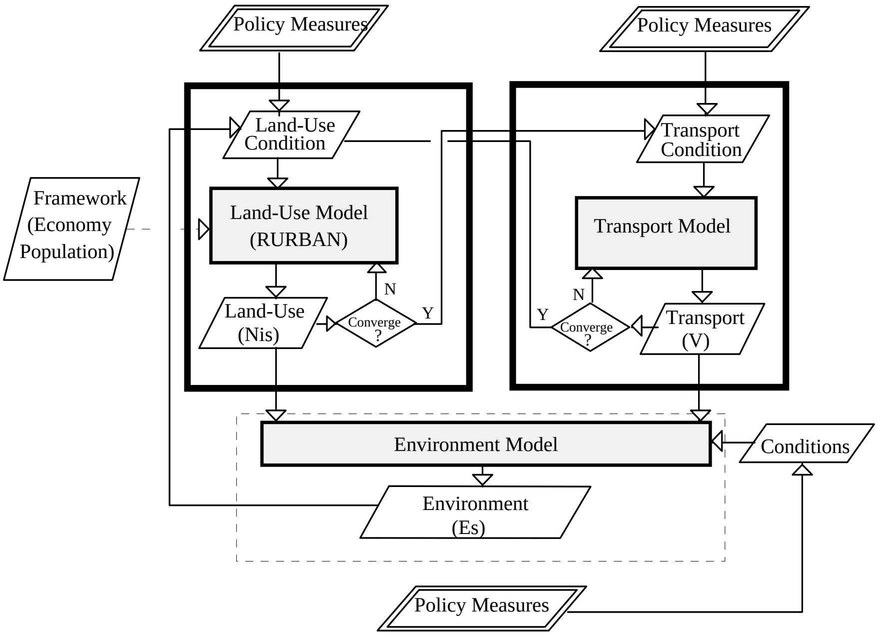

Figure 1 Concept of RURBAN System

3 THEORETICAL IMPROVEMENTS

3.1 Interpretation as a Behavioural Model

As described earlier that RURBAN employs both random utility and random rent-bidding, it can be said that bid-rent is another expression of locator's utility. The reason why RURBAN employs rent-bidding in the model is simply to determine land price of each zone. However, the old interpretation that the demand side, the supply side and the equilibrium are considered is not very theoretical-consistent as a behavioural model, since the land owner's behaviour from the supply side is not explicitly explained. Therefore, the following urban system is prepared as an interpretation of the equilibrium in RURBAN.

(1) A closed city is considered.
(2) The number of a locator group is exogenously given to the city.
(3) All the locators in the group are in differential.
(4) The city is divided into zones.
(5) Each zone is owned by an absent land owner.
(6) Each parcel of land is differential in each zone and readjusted at the beginning of each term.
(7) The land rent is offered by the land owner based on the equilibrium price of the previous term.
(8) At the beginning of each term, a locator applies to a zone with the area size he wants to use inside the zone based on the land rent.
(9) The utility of the locator is given by a random utility.
(10) The number of locator in a group who applies to the zone is given by the expected value based on the choice probability.
(11) All of the locators belonging to a locator group that is unique throughout the city so far as they locate themselves in the city and the level of utility is given by the logsum value of the group.
(12) If the demand for a zone exceeds the available area in the zone, the land owner raises the land rent.
(13) When the land rent is converged, the market is regarded as in the state of equilibrium.
(14) The equilibrium land rent is equal to the logsum value of random rent-bidding.
(15) The bid-rent of non-urban land use is given as a boundary condition.

3.2 Adjustment of Modifiable Area Unit Problem

The new system employs very detail spatial unit, i.e., small zones. Since the zone size of the new system ranges from 10,000 square meters in the centre of the city to 1,000,000 in the suburbs, the following adjustment is employed in the utility function. That is, the model equations are transferred into equations for the parameter estimation by taking the scale effects of the zone size and the number of locator group into consideration.

From the utility analysis, the choice probability of locator I choosing zone S is

$$P_{IS} = \frac{\exp(U_{IS} + \gamma_I \ln L_{IS})}{\sum_{S'} \exp(U_{IS'} + \gamma_I \ln L_{IS'})} \tag{7}$$

where

$$U_{IS} = \sum_k \alpha_{Ik} X_{Ik} - \beta_I \ln B_S \quad \text{: the utility of locator } I \text{ in zone } S \tag{8}$$

$$P_{IS} = \frac{N_{IS}}{N_I} \quad \text{: the proportion of locator } I \text{ locating in zone } S \tag{9}$$

$$L_{IS} = \frac{A_S}{q_{IS}} \quad \text{: the number of site available to locator } I \text{ in zone } S \tag{10}$$

B_S : represented by the land price in zone S

$\alpha_{Ik}, \beta_I, \gamma_I$: parameters

$0 \leq \gamma_I \leq 1$

Note that the denominator in (7) can be omitted because it is the same for each locator *i* when choosing all zone S. Then, take logarithm and disregard the denominator of (7),

$$\ln P_{IS} = V_{IS} + \gamma_I \ln L_{IS} \tag{11}$$

Substitute (8), (9), and (10) and into (11), we obtain

$$\ln\left(\frac{N_{IS}}{N_I}\right) = \sum_k \alpha_{Ik} X_{Sk} - \beta_I \ln B_S + \gamma \ln L_{IS} + \ln C_1 \tag{12}$$

where C_1 represents the error component

Since $q_{IS} = \dfrac{\theta_I}{B_S}$, the logarithm of (10) can be rewritten as

$$\ln L_{IS} = \ln\left(\frac{A_S}{\theta_I / B_S}\right) = \ln\left(\frac{A_S B_S}{\theta_I}\right) \tag{13}$$

Substitute (13) in (12),

$$\begin{aligned} \ln\left(\frac{N_{IS}}{N_I}\right) &= \sum_k \alpha_{Ik} X_{Sk} - \beta_I \ln B_S + \gamma_I \ln \frac{A_S B_S}{\theta_I} + \ln C_1 \\ &= \sum_k \alpha_{Ik} X_{Sk} - \beta_I \ln B_S + \gamma_I \ln A_S B_S - \gamma_I \ln \theta_I + \ln C_1 \\ &= \sum_k \alpha_{Ik} X_{Sk} - \beta_I \ln B_S + \gamma_I \ln A_S + \gamma_I \ln B_S - \gamma_I \ln \theta_I + \ln C_1 \end{aligned} \tag{14}$$

Rearrange and grasp the constant terms,

$$\begin{aligned} \ln\left(\frac{N_{IS}}{N_I}\right) &= \sum_k \alpha_{Ik} X_{Sk} + \left(\gamma_I - \beta_I\right) \ln B_S + \gamma_I \ln A_S - \gamma_I \ln \theta_I + \ln C_1 \\ &= \sum_k \alpha_{Ik} X_{Sk} + \left(\gamma_I - \beta_I\right) \ln B_S + \gamma_I \ln A_S + C_2 \end{aligned} \tag{15}$$

Parameters in the above equation can be estimated by regression analysis where the left hand side is taken as dependent variable.

Similarly, from the bid rent analysis, the choice probability of zone S choosing locator I is

$$P_{IS} = \frac{\exp(B_{IS} + \kappa_I \ln N_I)}{\sum_J \exp(B_{JS} + \kappa_J \ln N_J)} \tag{16}$$

$$P_{IS} = \frac{A_{IS}}{A_S} \quad \text{: proportion of land area used by locator } I \tag{17}$$

$$B_{IS} = \frac{1}{\beta_I}\left(\sum_k \alpha_{Ik} X_{Sk} - U_I^*\right)$$: bid rent function of locator I for zone S (18)

$\beta_I, \alpha_{IK}, \kappa_I$: parameters

$0 \le \kappa_I \le 1$

For each pair of locator I and J in any zone S, the proportion of choice probability is

$$\frac{P_{IS}}{P_{JS}} = \frac{A_{IS}}{A_{JS}} = \frac{\exp(B_{IS} + \kappa_I \ln N_I)}{\exp(B_{JS} + \kappa_I \ln N_I)} \tag{19}$$

Take logarithm of (19),

$$\ln\left(\frac{A_{IS}}{A_{JS}}\right) = B_{IS} - B_{JS} + \kappa_I \ln N_I - \kappa_J \ln N_J + C_I - C_J \tag{20}$$

Substitute the bid rent of (18) into (20),

$$\ln\left(\frac{A_{IS}}{A_{JS}}\right) = \frac{1}{\beta_I}\left(\sum_k \alpha_{Ik} X_{Sk} - U_I^*\right) - \frac{1}{\beta_J}\left(\sum_k \alpha_{Jk} X_{Sk} - U_J^*\right) + \kappa_I \ln N_I - \kappa_J \ln N_J + C_I^3 - C_J^3 \tag{21}$$

Rearrange the constant terms,

$$\ln\left(\frac{A_{IS}}{A_{JS}}\right) = \frac{1}{\beta_I}\sum_k \alpha_{Ik} X_{Sk} - \frac{1}{\beta_J}\sum_k \alpha_{Jk} X_{Sk} + \kappa_I \ln N_I - \kappa_J \ln N_J + C_I^4 - C_J^4 \tag{22}$$

With the estimated value of β and α from the utility analysis, κ and the constant terms can be estimated by regression analysis of (22).

4 THE NEW SYSTEM OUTLINE FOR SAPPORO

As illustrated in Figure 2, the new RURBAN system has been developed with the concept of modular structure, in which each sub-system is connected through standard interface module. The central database, at the same time, is accessible from every system component. The main code is written in Java Language, which makes the system be platform-independent, meaning that it can runs on any operating system having Java virtual machine installed. The system can be connected with the conventional transport model by means of interface module, which calculates the interzonal travel impedance and gives input to the land use part. In addition, the system is designed with the end-user in mind. User interacts with the system through the Graphical Interface under Windows Environment, such as selecting project options, setting the control total, editing the network, executing the simulation, visualizing the output in the GIS environment, etc. This makes easier for decision makers as well as the community to participate in the planning/evaluation.

The starting window of the system allows users to construct a new project and to retrieve the existing projects, which provides full functions of file manipulation. The Main Panel, shown in Figure 3, provides the full operational functions, including execute the land-use simulation by RURBAN, add transport policy, adjust the simulation control total, launch the GIS to view the output.

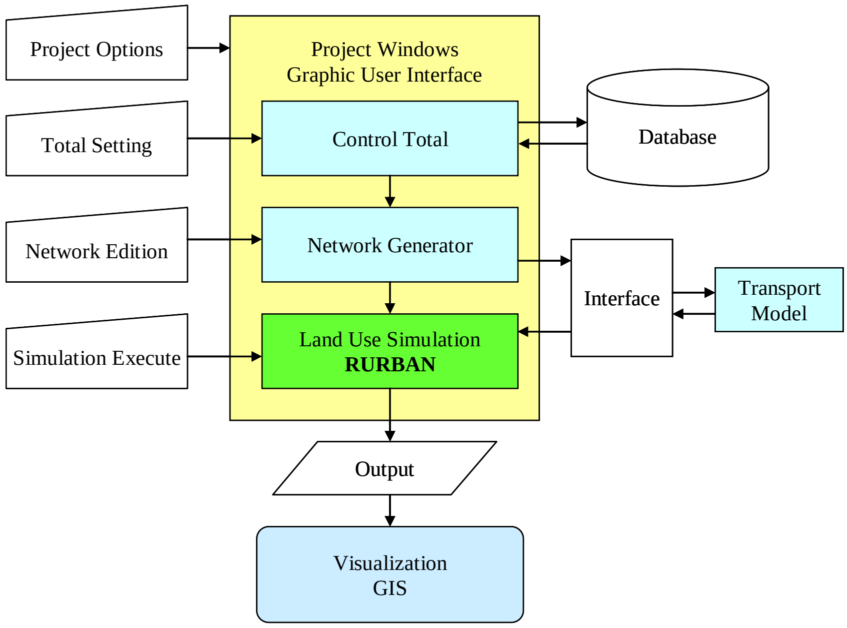

Figure 2 System Structure

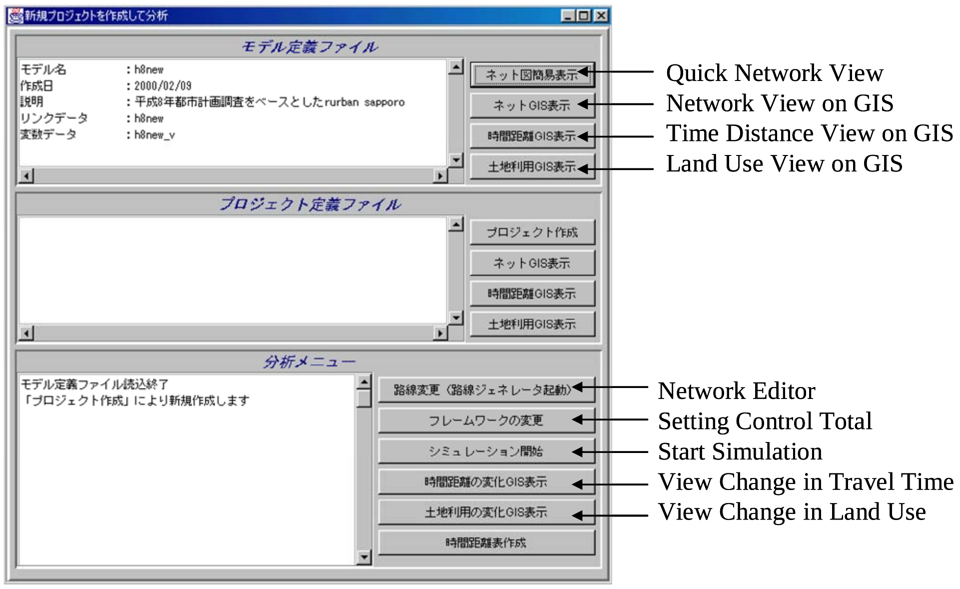

Figure 3 Main Panel

In particular, transport policy can be incorporated in the analysis by means of editing the network, e.g., adding/deleting node or link, changing the link properties/conditions under the network edition module, as shown in Figure 4. The module also provides file manipulation so that the network edition/transport policy measure can be saved separately for the future simulation. Then, the change in transport condition is realized by means of travel impedance, presently by interzonal travel time, which is determined by the external transport model through appropriate interface.

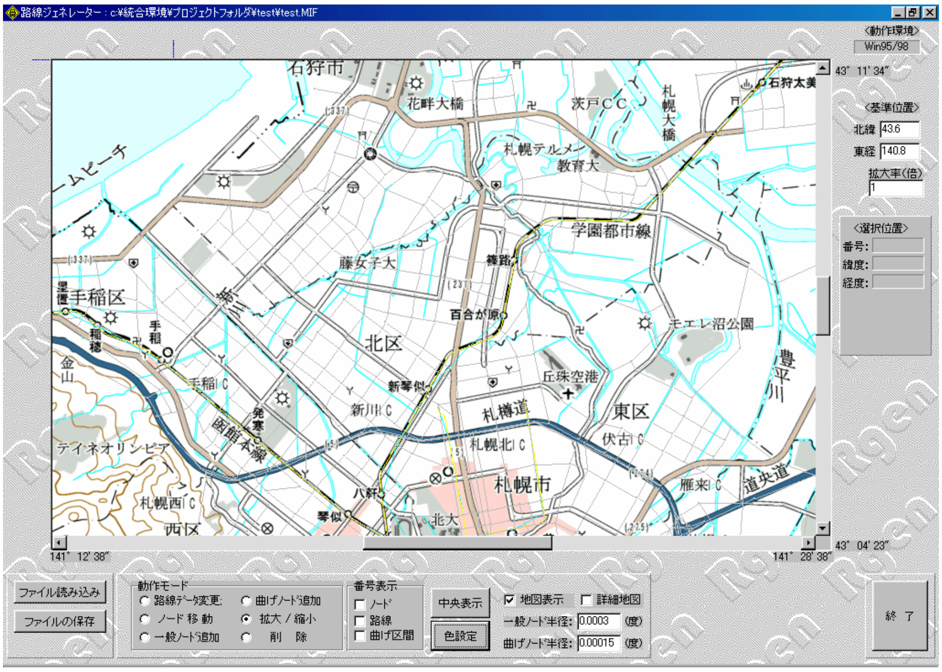

Figure 4 Network Editor Module

Next, the model simulation such as developing a scenario requires an estimate of the regional population and employment growth over the desired forecasting time horizon (often 20 years). Aggregate population and employment (locator) are exogenous values considered across the study area. The control total can then be adjusted by using the economic framework setting module, as shown in Figure 5. The growth rate and the future forecast can be specified graphically for each type of locator. In the RURBAN for Sapporo Metropolitan Area, six types of urban locators are defined: Manufacturing industry, Business firm, Retail and Restaurant, Single household family, Married household family, and Two-or-more household family.

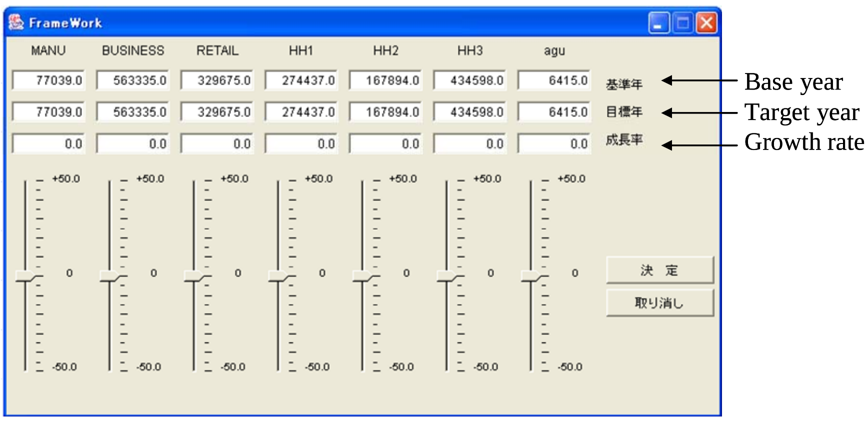

Figure 5 Control Total Setting

After finishing the model run, the output can be viewed graphically under the GIS environment, presently using MapInfo Professional. Customization is done such that the zonal number of each type of locator can be shown by one-click on a toolbar. This again provides the practitioner-friendly environment so that the technical result can be transferred to the community more efficiently.

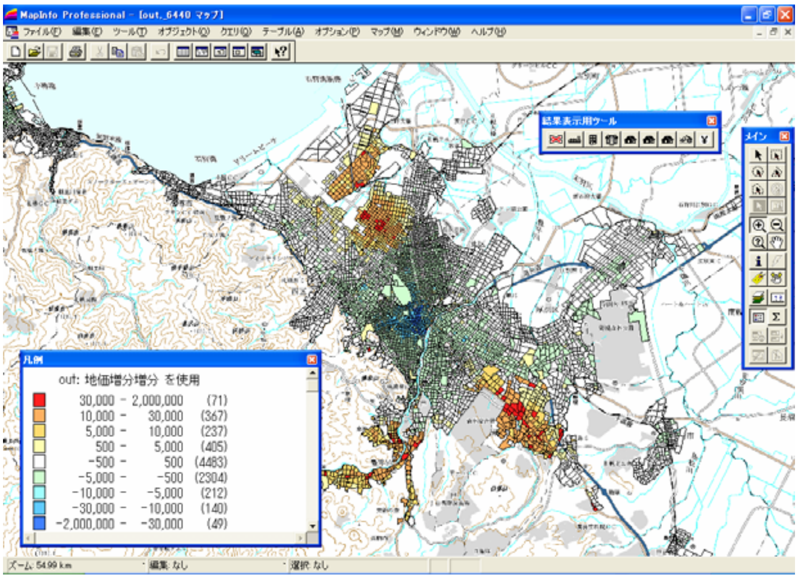

Figure 6 Output View on Customized GIS

5 GIS WITH DETAILED UNIT OF ANALYSIS

In the present study, the new RURBAN is built for Sapporo Metropolitan area of Japan, which is located in its northern main island. It is markedly monocentric with about two millions population. The detailed zone system in the Sapporo Metropolitan Area, which has been established for the basic survey for urban planning, is employed for the case study. The size of zone ranges from 10,000 square meters in the centre of the city to 1,000,000 in the suburbs. The number of zones is 8,025 in the city center, as shown in Figure 7.

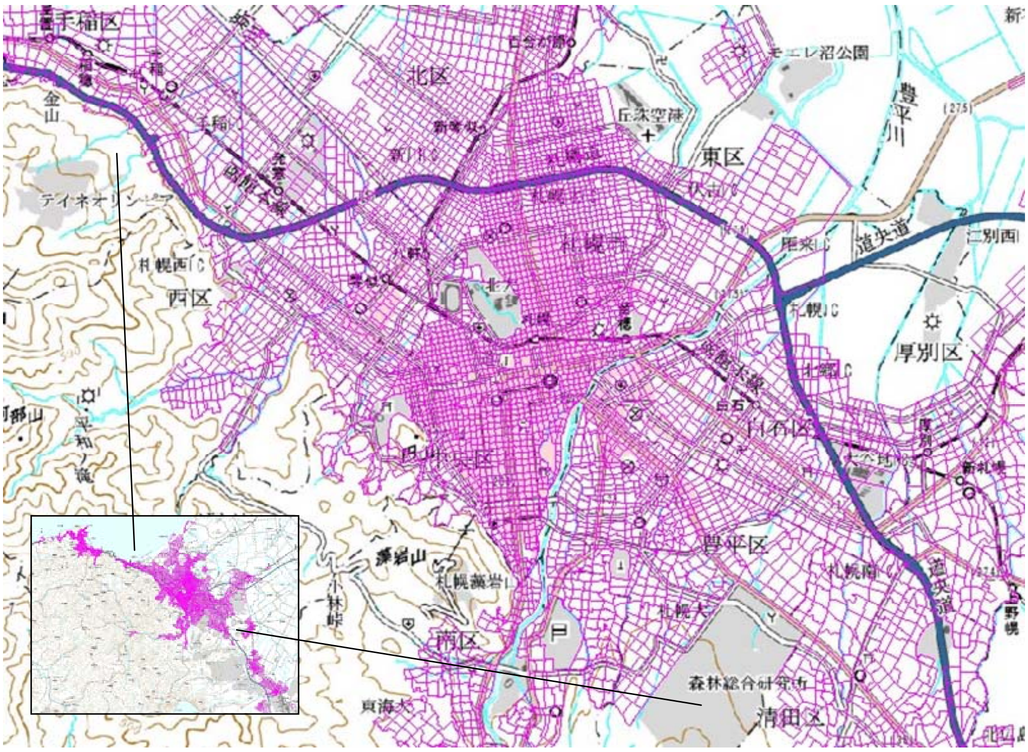

Figure 7 High Resolution Zone System

In term of transport facility, the public transport modes are well provided in the area: several commuter railway lines (JR lines), three subway lines, as well as the efficient bus network. Meanwhile, the road transport is well organized with the well connected road network, both local street and expressway. In total, the transport network in the present system is consisted of 3,940 links and 2,406 nodes, which forms the main four link types, as shown in Figure 8.

Figure 8 Transport Network

In the GIS, the detailed zone system with the transport network provides the basic unit for data storage and further analysis. Various kinds of necessary data collected at different years are overlaid in the system: land prices, household by type, population by different category, employment by industry category and household category, land use by land category, etc. In addition, a raster map is inserted as a background image for better visualization.

6 PARAMETER ESTIMATION AND CALIBRATION

The parameters are estimated by using the technique presented in Section 3.2. The results of the estimation are shown in Table 1 to Table 6. It is found that almost of all parameters of variables for locators are significantly estimated obtaining the expected sign. Let us notice that the parameter for the developable land shows the significant of the zone size effect. In words, the larger the zone is, the more attractive it is.

Moreover, care attention is given to the potential of the zone for development. In this case, the potential for commercial and residential land use is considered. The potential for commercial use represents the accessibility of each zone to retail/ restaurant bossiness locators while the potential for residential use represents the accessibility to residential locators. Mathematically, the potential for land use in zone i P_i is written as:

$$P_i = \sum_j f(N_j, t_{ij}) \tag{23}$$

where N_j is the number of household or employee of retail/ restaurant in zone j, t_{ij} is the interzonal time from zone *i* to zone *j* , and *j* the is other zones than *i*. In this study, three forms of the potential function (f) are employed:

$$f_1 = N_j \times \exp(-t_{ij}),\ \ f_2 = \frac{N_i}{t_{ij}},\ \ f_3 = \frac{N_i}{t_{ij}^2}$$

Table 1 Manufacturing Industry

Explanatory Variable	*Unit*	*Parameter*	*t-value*
Travel time to Sapporo station by car	min	-1.1270E-02	-5.02
Travel time to nearest IC by car	min	-1.0437E-02	-2.69
Percent of road surface in zone	%	4.5406E-06	1.99
Floor area ratio	%	2.9918E-03	7.97
Log of land price	log(yen/m^2)	-1.7498E-01	-3.31
Log of developable land	log(m^2)	2.9740E-01	6.58
Dummy of industrial land category	-	1.0288E+00	15.81

Table 2 Business Firm

Explanatory Variable	*Unit*	*Parameter*	*t-value*
Minimum travel time to nearest station	min	-7.3794E-03	-2.51
Dummy of facing to the main road	-	9.4276E-02	4.17
Percent of road surface in zone	%	4.6458E-06	4.05
Floor area ratio	%	2.1225E-03	11.78
Log of land price	log(yen/m^2)	1.6948E-01	8.55
Log of developable land	log(m^2)	3.2108E-01	15.88
Potential (f1) = Employee × exp(-travel time)	person /exp(min)	5.8377E-05	7.13
Dummy for commercial land category	-	1.6148E-01	4.60

Table 3 Retail/Restaurant

Explanatory Variable	*Unit*	*Parameter*	*t-value*
Minimum travel time to nearest station	min	-6.8662E-03	-1.75
Dummy of facing to the main road	-	1.9461E-01	7.12
Percent of road surface in zone	%	3.5336E-06	2.44
Floor area ratio	%	2.4339E-03	11.12
Log of land price	log(yen/m^2)	1.9902E-01	6.76
Log of developable land	log(m^2)	3.8944E-01	15.70
Potential (f2) = Household ÷ Travel time	household /min	5.1480E-06	2.38
Potential (f3) = Employee ÷ Travel time^2	person/min^2	7.5821E-06	2.95
Dummy for commercial land category	-	2.6175E-01	6.27

Table 4 Single-household family

Explanatory Variable	*Unit*	*Parameter*	*t-value*
Minimum travel time to nearest station	min	-2.8991E-02	-10.36
Potential (f1) = Employee ÷ Travel time	person/min	1.6676E-05	13.21
Log of land price	log(yen/m^2)	3.1585E-01	12.99
Log of developable land	log(m^2)	5.6499E-01	37.65
Dummy for low-rise house	-	-4.2305E-01	-12.40
Dummy for middle/high-rise housing/condominium	-	2.7051E-01	8.98
Dummy for other types of house	-	2.6872E-01	8.60

Table 5 Married-household family

Explanatory Variable	Unit	Parameter	t-value
Minimum travel time to Sapporo station	min	-2.6134E-03	-4.67
Minimum travel time to nearest station	min	-1.4829E-02	-8.57
Dummy of facing to the main road	-	-1.7454E-02	-1.13
Percent of road surface in zone	%	1.7413E-06	1.84
Floor area ratio	%	3.4782E-04	2.25
Log of land price	log(yen/m^2)	1.7751E-01	11.42
Log of developable land	log(m^2)	6.9601E-01	52.60
Dummy for low-rise house	-	1.9698E-01	6.33
Dummy for middle/high-rise housing/condominium	-	3.3689E-01	14.16
Dummy for other types of house	-	2.6846E-01	12.34

Table 6 Two-or-more-household family

Explanatory Variable	Unit	Parameter	t-value
Minimum travel time to Sapporo station	min	-4.5279E-03	-8.03
Minimum travel time to nearest station	min	-9.9158E-03	-5.64
Dummy of facing to the main road	-	-2.6981E-02	-1.78
Percent of road surface in zone	%	6.9049E-06	6.99
Floor area ratio	%	1.3261E-04	0.84
Log of land price	log(yen/m^2)	1.1852E-01	7.63
Log of developable land	log(m^2)	7.0920E-01	52.83
Dummy for low-rise house	-	3.5269E-01	11.45
Dummy for middle/high-rise housing/condominium	-	3.8554E-01	16.51
Dummy for other types of house	-	2.8848E-01	13.54

In addition, the parameters for specific locator group are also estimated, the result of which is shown in Table 7. Eventually, the estimated parameters are used for the model calibration, i.e., the residual of the model is determined and compensated accordingly.

Table 7 Specific Parameters for Each Locator

Locator Type	γ_I	β_I
Manufacturing Industry	0.297	0.472
Business	0.321	0.152
Retail/Restaurant	0.389	0.190
Single Family	0.565	0.249
Married Couple Family	0.696	0.519
Two or More-Generation Family	0.709	0.591

7 INTEGRATION WITH A TRANSPORT MODEL

After the newly estimated RURBAN model is validated by observing the base forecast of land use and land price, it is integrated with an existing transport model in order to form up an integrated urban model. In this regard, a set of interface is equipped to the model so that the interaction between land use and transport models can be effectively executed. It is designed to be universal such that any kind of models dealing with any urban sub-system, including land use, transport, or the

Environment model, can be connected. This idea of universal interface may be illustrated as in Figure 9.

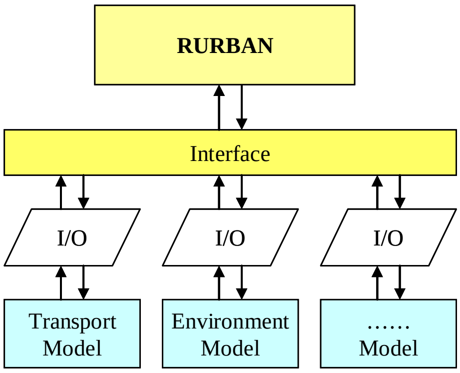

Figure 9 Interface Module

In particular, RURBAN currently uses the interzonal travel time (both the travel time by auto and the composite travel time) from the travel model of Sapporo to capture the effects of transportation policy changes on land price and household location. It is, however, possible to incorporate other means of transport effects such as composite travel utility by demand category or accessibility measure by using additional module with the appropriate interface.

8 APPLICATIONS

The RURBAN Sapporo system allows a range of policy to be analyzed and tested, both land use and transport-related policy in Sapporo Metropolitan Area. Various transport development have been proposed in the area. This includes road network development such as ring road construction, highway connection to the inner urban area (shown in Figure 10) or subway line extension (shown in Figure 11).

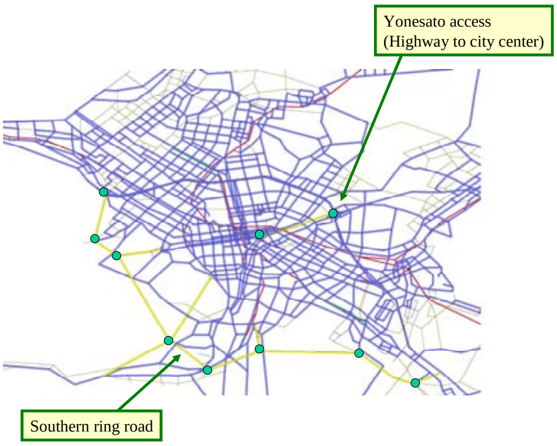

Figure 10 Road Construction

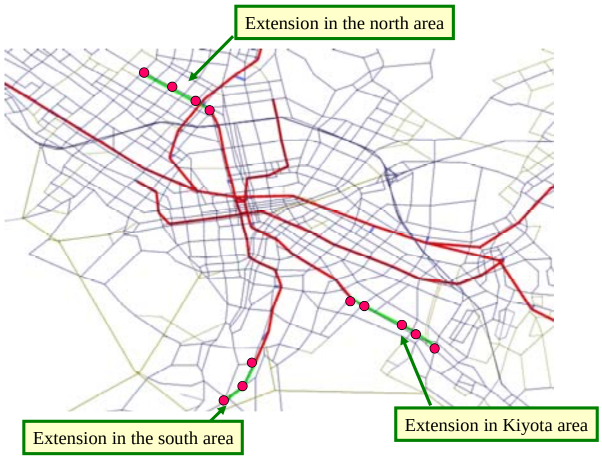

Figure 11 Subway Extension

By using the RURBAN system, the effect of transport change to urban development is analyzed and forecasted. For example, in case the subway line is extended to the Kiyota area (south-eastern end), the travel time to the city center is shown to be substantially reduced, as shown in Figure 12.

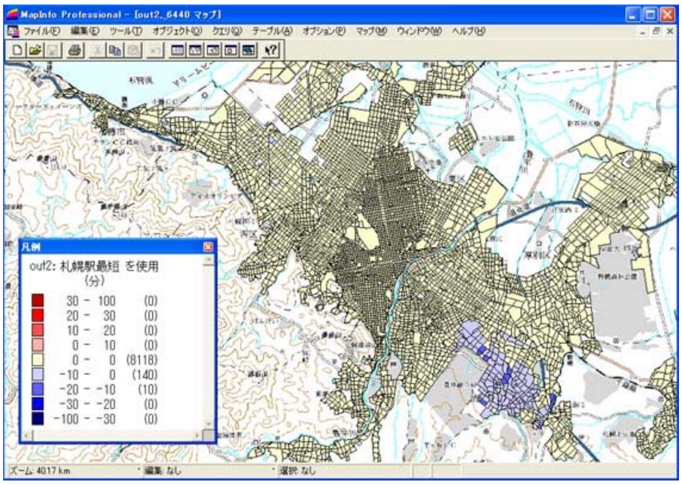

Figure 12 Change of Travel Time to City Center

Morever, the accessibility improvement to the south-eastern area brought by the new subway section has raised up the land price, meaning the development, and have accordingly attracted more residents, as shown in Figure 13 and Figure 14.

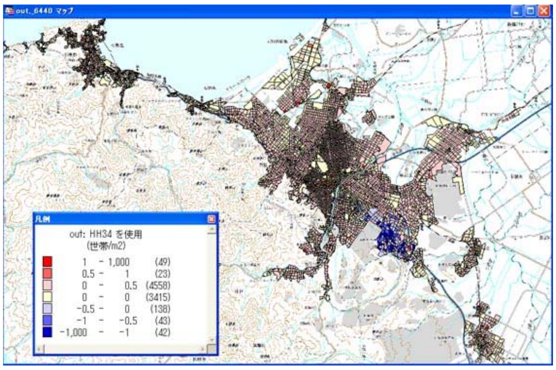

Figure 13 Change of Land Price

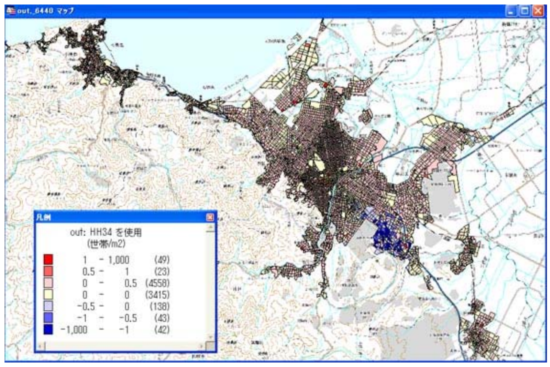

Figure 14 Change of (3+) Household

9 CONCLUDING REMARKS

This paper presented the newly improved RURBAN model, from both theoretical and operational viewpoints. The model interpretation is now theoretical consistent while the software is fully operational and user-friendly. Within the GIS environment, the system for Sapporo employs very detail spatial unit and has produced high resolution results, which are demanded for the more advanced analysis such as the microsimulation or the environmental modeling. The parameter estimation gave us enough numbers of explanatory variables with the expected signs. The validated system is being used for various policy analyses in Sapporo, both land use and transport related. The program has been developed to be universal to connect to the other urban modeling components as may be required in the future.

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REFERENCES

Miyamoto, K., Udomsri, R. (1996) An analysis system for integrated policy measures regarding land use, transport and the environment in a metropolis. In Hayashi, Y., Roy., J. (eds.) **Transport, Land Use and the Environment**. Kluwer, Dordrecht, 259-280.

Wegener, M. (2003) **Overview of Land-Use Transport Models**, Invited Paper of the 8th International Conference on Computers in Urban Planning and Urban Management (CD-Rom)