A GIS BASED LAND-USE MODEL DEALING WITH BUILDING TYPES BY SMALL UNIT OF LAND IN A METROPOLITAN AREA

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abstract: Although a number of land-use models have been developed to evaluate alternative policy measures for a metropolitan area, their functions are limited to estimate urban activities only by fair-sized zones. In the present study, an integrated land-use analysis system is built based on a two-level land-use model which is capable of taking detailed land conditions by block level into account and a Geographical Information System to provide necessary data for the analysis.

1. INTRODUCTION

Although various land use models have been developed for the purpose of analyzing impacts of transportation projects, their functions are limited only to the distribution of urban activities in a metropolitan area; for example, population and employment by fair-size zone. Few models are capable of describing the building patterns by detailed unit of analysis like block level. Almost all existing land use models, in spite of their name, have not dealt directly with "land use" which can be represented on a map.

There are some problems for the fact that detailed land use information is not estimated in the course of transportation planning and analysis as follows;

(1)It is impossible to substantially analyze the environmental impacts, noise and air pollution, caused by transportation projects, since environmental impacts assessment should be made at most in block level.
(2)It is difficult to present effective information regarding development benefits or betterment caused by transportation projects, since they are closely related to building or physical development patterns.
(3)It is impossible to verify the validity of estimates given by conventional land use models which deal a large-size unit of analysis, since they don't take detailed land conditions, which are very complex and various particular in Eastern Asia, into account.

In order to relief the above-mentioned problems with respect to existing land use models, the present study intends to develop an "operational" land use model which can describe the distribution of urban activities with building patterns by small unit of land based on detailed land conditions which are provided by a Geographical Information System (GIS).

In the present paper, the basic idea, model equations and the way of parameter estimation of the detailed land use model are mainly described with some empirical results in the case of Sendai city, Japan.

2. A TWO-LEVEL LAND-USE MODEL BASED ON DETAILED INFORMATION

2.1 Fundamentals

Many land use models, designed to support analysis of planning, have surged that use urban economic theories such as utility theory or bid-rent theory as the basis for their urban activities allocation criteria. However, most among these allocate activities to regions that are constructed from grids at least 1 sq. km in size, and in general ignore detailed land conditions below this level. In the case of most Asian countries, with its land constrained capital cities, this kind of models do not correspond with certainty to actual land use conditions, and although referred to as land use models, they actually fall at a distance of what is in reality happening with land. For this reason, allocation values resulting from the forecasting do not become accurate representations of the physical and systematic development of land along with spatial resources and constraints; this in turn can be said to have acted as a deterrent for the use of models in every day decision making practice.

Parting from here, this study constructs a model with a two level structure that makes uses one of such existing models in the upper level, in which allocation values for activities by zones are calculated, and then builds a lower level model wherein these values are reallocated to buildings on block units, this time considering land constraints and specific lots of land. Although there are some existing models which deal with housing or building types (e.g. Anas, 1982, and Echenique, 1985), their units of analysis are fair-sized zone. In addition, their data are not corresponding to actual building types by small unit of land. Consequently, the outputs of the models are hardly applicable to environmental assessment. One of the, unique points of the present model is to represent variety patterns of building distribution by small unit of land, which is indispensable in the case of transport related environmental assessment in a city in Eastern Asia.

However, some limitations arise in the acquisition of data to conduct this kind of detailed analysis, and as a matter of fact, this point is thought to be one of the reasons that have kept land use analysis from being a routine practice. Accordingly, it is important when doing this kind of analysis, that one of the model system's functions be data providing. In this study, a plan to produce a model for practical uses is devised making use of the GIS efficient displaying and analysis functions for detailed spatial data. In this way, the model presented here can be said to have deepened the applicability of a practical GIS.

2.2 Structure of the Model

The outline of the model put forward hereby is shown in Figure 1. The model has a structure of two-level allocation: the upper level conforms to the kind of models currently available, that allocate 'activities' such as population and employment to 'zones'. The lower model is meant to reallocate, in the interior of the zones and conforming to detailed information of specific locations and constraints, the zone-based allocated 'activity values' (population and employment) calculated by the top level model.

It is difficult to keep statistical stability when detailed land units are dealt with. However, environmental evaluation of the project should be done from a micro-viewpoint, based on block units at most. So, on the condition that activities are allocated to large zones by the upper model, statistical analysis of the possibility that activity values could be allocated to buildings in detailed block units is done. The model has a structure of two-level allocation in order to make allocation in each of the appropriate levels of analysis, based on a regression model derived from the bit-rent theory.

As for the upper level, initial values and conditions of the various zones are obtained from the GIS, and then processed, estimated, and totalized to become the input for the zone-based allocation model. The physical and systematic considerations of land constraints in the lower model are made based on the GIS detailed database. Following the characteristics of the model, the main conversions that can be operated over data include acquisition of zone data from detailed data, representative values, average values, and logsum function values.

2.2.1 Outline of the Upper Model

The upper model makes use of an existing land use model to forecast and evaluate, benefits or disbenefits brought, for instance, by a new transportation infrastructure project, or locational variations caused by new land use regulations. As for the model, although there exist a number of land use models (e.g. Wegener, 1994) that make use of utility functions, bid rent functions, or a combination of the two, this study relies for the allocation of activities on a model named RURBAN (Miyamoto, 1989), which is based on random utility theory and rent-bid theory.

2.2.2 Outline of the Lower Model

The lower model reallocates in the interior of the zones, using GIS detailed data, land prices and other variables, the allocated activity values assigned to each zone by the upper model. The allocation due to the lower model, rather than being a forecast, is meant to be a visualization aid that presupposes the values given by the upper model and shows how the actual physical arrangement of the locations will be; the main purpose of the model is to provide physical structure to begin with building types at block level with environmental

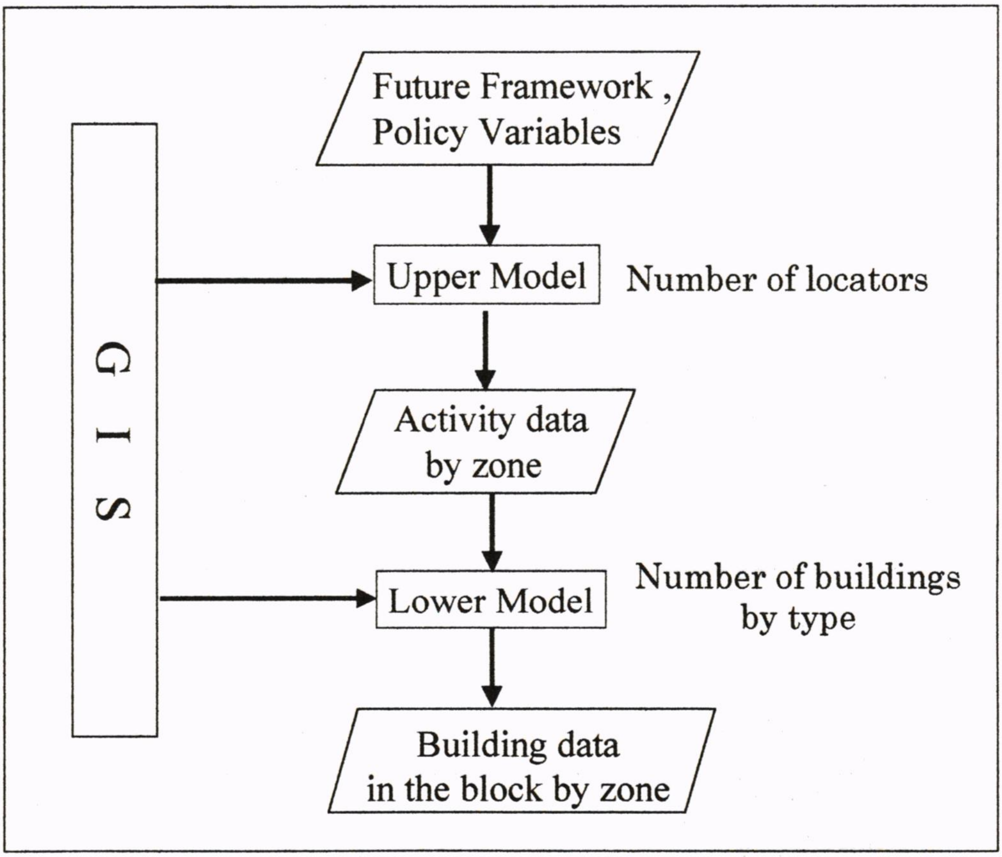


Figure 1. Outline of a Model with Detailed Information

evaluation of a transportation project at the block level, and to better represent the correspondence between actual land use conditions and a verified adequacy of the allocation of activities to zones. Also examination of proposed framework, and evaluation of allocation methods of the upper model are possible. Concretely, before allocation is done, the zone allocation function expressing the rates at which zone allocation values are assigned to individual sites, is prepared with allocation indexes based on detailed information. Following, the most likely distribution under the zone characteristic allotment and constraints is sought for the corresponding maximization of the joint probability function.

Table 1 Urban activities and corresponding building types

URBAN ACTIVITIES	BUILDING TYPES: Vacant	Detached Commercial House	Middle Size Shopping Complex	Shopping Street House	Middle-high Size Office Building	Shops & Business Complex Building	Detached House	Small Size Apartment House	Concrete Apartment House	Condominium	Detached House with Commercial Use	Small Size Apartment House with Commercial Use	Shops & Housing Complex Building	Office & Housing Complex Building	Heavy and Chemical Industry	Light Industry	Farm House	Public
Commercial																		
Neighborhood		○	○	○		○												
Central			○		○	○												
Business					○	○												
Residential																		
Family							○	○	○	○	○	○	○	○				
Single								○	○			○	○	○				
Industrial																		
Small Size																○		
Urban																○		
Manufacturing															○	○		
Agriculture																	○	
Official																		○
Transportation																		○
None	○																	

3. LOWER MODEL.

3.1 Allocation Method

The lower model's primary objective is to allocate values number of locators N_{IS} for activity I in zone S to building type i in lot l. In order to allocate urban activities into buildings, the latter are
classified into a number of groups i according to type of structure, as shown in Table 1.

The allocation of land uses is done in the lower model based on the above classification of groups. The groups are transformed for activity locator I given by the upper model, by an operator of the form:

$$I = \Gamma(i) \tag{1}$$

that checks building types per urban activities as displayed in Table 1. In this way, the activity values produced by the upper model are inversely transformed by the lower model to the metrics of buildings before reallocation is conducted. Moreover, the set of i that satisfies equation (1) is defined as follows:

$$u_I = \{i | \Gamma(i) = I\} \tag{2}$$

As for the region under analysis, analysis unit in the upper model or zone S is considered to be made up of a number of blocks k_S regarded as having each uniform land conditions. Furthermore, blocks are considered to consist of a number of lots l (l=1,...,L_{ks}) that are the physical units on which buildings are located. These ideas are summarized in Figure 2.

Allocation of land uses in the lower model is done after locational probability is obtained for each building in individual lots using bid rent analysis. In other words, whether or not the lot l supplies land to the building type i, is assumed to depend on the building's bid rent value b_{il}. Usually, when thinking of the per floor area bid rent function b'_{il} for building type i in lot l, the detailed land conditions for the lot, X_l, and the parameters $\boldsymbol{a}_i$ for each

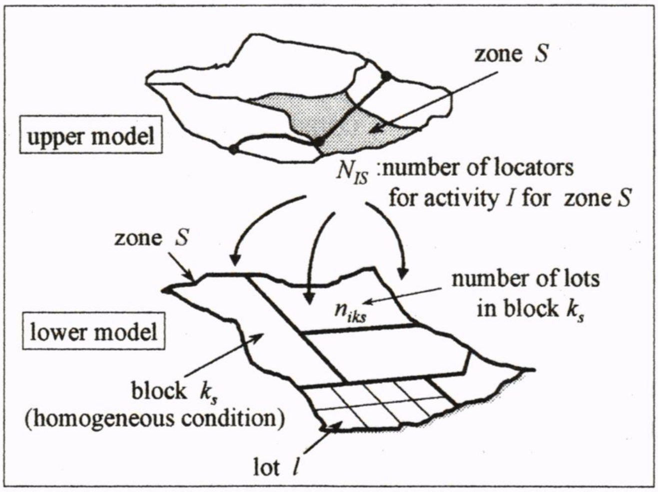


Figure 2. Outline of Zoning

building type, can be expressed as follows:

$$b'_{il} = \boldsymbol{a}_i \boldsymbol{X}_l \qquad (3)$$

$$\mathbf{a}_i = \{\alpha_{im}\} \qquad (m = 1, \cdots, M)$$

$$\mathbf{X}_l = \{X_{lm}\}'$$

The detailed land conditions for this case are thought to be spatial locational resources, road side conditions and others.

However, as shown in figure 3, when thinking of the bid rent per land area, b_{il}, it becomes necessary to include demolition costs and new construction costs in the bid rent value of buildings that differ from actual land uses. Accordingly, the bid rent per land area for building type i that is locating in such conditions is expressed as follow:

$$b_{il} = \boldsymbol{a}_i \boldsymbol{X}_l V(b_{il}) - (h^r_{i'} V_{i'l} + h^c_i V(b_{il}))\delta(i, i') \qquad (4)$$

$h^r_{i'}$: parameters for the demolition costs of existing building i' per unit floor area

h^c_i : parameters for the construction costs of new building i per unit floor area

$V_{i'l}$: Existing building observed floor-area ratio.

$V(b_{il})$:locational density function

$$\delta(i, i') = \begin{cases} 1 : i \neq i' \\ 0 : i = i' \end{cases}$$

The second term in the right-hand side of the equation (4) represents the resistance of the

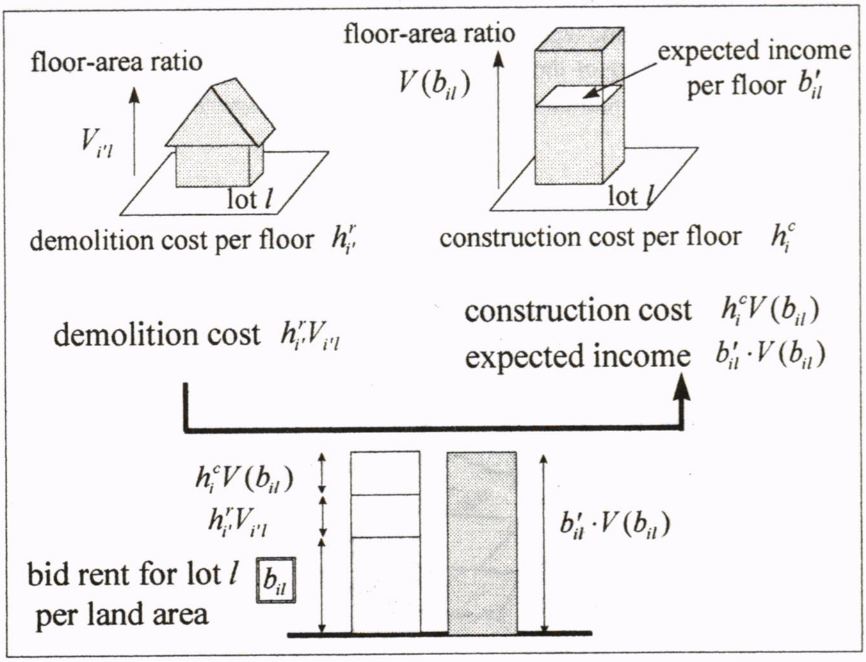


Figure 3. Outline of the bid rent function

lot to change from its current land use to a different one, with exogenously given h_i^r and h_i^c representing the demolition and construction costs per unit floor area, respectively. Moreover, to obtain a high correlation between locational density and land prices, the equation includes in the land price term the building's own bid rent value for $V(b_{il})$, the density function that expresses the degree of intensity of uses for the building. This means that the highest bid rent value in equation (4) is actualized as the land price, and since the locational density function $V(b_{il})$ is given exogenously by the land price function, then the bid price b_{il} can be considered unique.

Assuming IIGD(Independently Identical Gumbel Distribution) for the bid rent function in equation (4), and using a logit model, the maximum bid probability for i in l is given by

$$p_{il} = \frac{\exp \mu_i b_{il}}{\sum_{j \in u_l} \exp \mu_j b_{jl}} \qquad (5)$$

$$s.t. V(b_{jl}) \le V_l^{cap} \qquad \forall j \in u_l$$

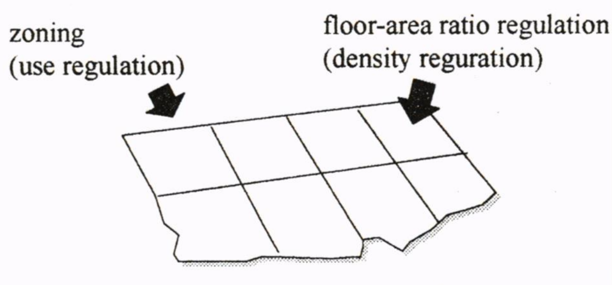
V_l^{cap} :Floor area ratio regulations in lot l

Constraints in equation (5) are the Floor-area ratio regulations that constrain the locational density function. This constraints differ from use regulation, as shown in Figure 4, and mean that the locators unable to meet the conditions, can not take part in the bid process.

A block consists of lots is regarded as having uniform land conditions, and suffix in equation (5) can be changed from l to k_s. Then the allocation function that represents the share of building type i in block k_s is equation (6) below:

$$p_{ik_s} = \frac{\exp \mu_i b_{ik_s}}{\sum_{j \in u_l} \exp \mu_j b_{jk_s}} \qquad (6)$$

$$s.t. V(b_{jk_s}) \le V_{k_s}^{cap} \qquad \forall j \in u_l$$



floor-area ratio regulation $\quad V_l^{cap} = \dfrac{\text{amount of floor area}}{\text{amount of lot area}}$

locational density function $\quad V(b_{il}) = \dfrac{\text{actual amount of floor area}}{\text{actual amount of lot area}}$

Figure 4. Constraints of bid probability function

Here, the upper model locational value N_{IS} is divided into n_{ik_s} that represents number of lots on which building type i locates in block k_S inside zone S as shown in figure 2. The joint probability of the allocation pattern of $\{ n_{ik_s} \}$, P, is represented by equation (7) using allocation function in equation (6).

$$P = \prod_{k_s} \left(\frac{L_{k_s}!}{\prod_{i \in u_I} n_{ik_s}!} \prod_{i \in u_I} p_{ik_s}^{n_{ik_s}} \right) \tag{7}$$

L_{k_s} : number of lots in block k_s

Next, constraints for equation (7) are considered. As for the allocation pattern $\{ n_{ik_s} \}$, total regulation conditions for the upper model locational value N_{IS} are given by:

$$N_{IS} = \sum_{k_s} \sum_{i \in u_I} \beta_i V(b_{ik_s}) n_{ik_s} \tag{8}$$

β_i : coefficient of locator conversion

$V(b_{ik_s})$: locational density function

In the upper model, in order to allocate activities given by the number of households, stores and employees, these numbers have to be transformed to building numbers, and β_i represents then activities allocated per unit floor area, which are provided exogenously. Similar to the same item in equation (4), $V(b_{ik_s})$ is a locational density function that expresses the degree of intensity of uses for the building. Total regulation for lots in the interior of the block, is given by equation (9).

$$L_{k_s} = \sum_{i \in u_I} n_{ik_s} \tag{9}$$

Physical and/or systematic constraints to allocation values resulting from conditions in each lot are expressed by several constraint function, equation (10).

$$G_r(n_{ik_s}) \le C_{k_s r} \qquad (r = 1, \cdots, R) \tag{10}$$

The joint probability for the allocation function in equation (7) is maximized under the constraints given by equations (8), (9), and (10), as shown in equation (11).

$$P = \prod_{k_s} \left(\frac{L_{k_s}!}{\prod_{i \in u_I} n_{ik_s}!} \prod_{i \in u_I} p_{ik_s}^{n_{ik_s}} \right) \rightarrow \max \tag{11}$$

$$s.t. \quad N_{IS} = \sum_{k_s} \sum_{i \in u_I} \beta_i V(b_{ik_s}) n_{ik_s}$$

$$L_{k_s} = \sum_{i \in u_I} n_{ik_s}$$

$$G_r(n_{ik_s}) \le C_{k_s r} \qquad (r = 1, \cdots, R)$$

Once the allotment of buildings in the block n_{iks} is obtained from equation (11), analysis and evaluation of the adequacy of the upper model's allocation and the environment can be conducted. Outline of allocation in the lower model is shown in Figure 5.

Here, taking logarithms of the joint probability (11), equation (12) is derived.

$$\log P = \sum_{k_{sl}} (\log L_{k_s}! - \sum_{i \in u_l} \log n_{ik_s}! + \sum_{i \in u_l} n_{ik_s} \log p_{ik_s}) \tag{12}$$

or, in terms of Sterling formulation $\log x \cong x \log x - x$ as follow:

$$\log P \cong \sum_{k_{sl}} (L_{k_s} \log L_{k_s} - \sum_{i \in u_l} n_{ik_s} \log n_{ik_s} + \sum_{i \in u_l} n_{ik_s} \log p_{ik_s}) \tag{13}$$

and accordingly, the minimization of the objective function is expressed by:

$$f(n) = \sum_{k_{sl}} \sum_{i \in u_l} n_{ik_s} \log n_{ik_s} - \sum_{k_s} \sum_{i \in u_l} n_{ik_s} \log p_{ik_s} \rightarrow \min \tag{14}$$

The Lagrangian operator in equation (15) below follows from equations (8),(9),(10) and (14):

$$\Phi(n_{ik_s}, \lambda_1, \lambda_2, \lambda_3) = \sum_{k_{sl}} \sum_{i \in u_l} n_{ik_s} \log n_{ik_s} - \sum_{k_s} \sum_{i \in u_l} n_{ik_s} \log p_{ik_s} - \lambda_1 (\sum_{k_{sl}} \sum_{i \in u_l} \beta_i V(b_{ik_s}) n_{ik_s} - N_{IS})$$
$$- \sum_{k_s} \lambda_{2k_s} (\sum_{i \in u_l} n_{ik_s} - L_{k_s}) + \sum_{m} \sum_{k_s} \lambda_{3k_s m} (G_m(n_{ik_s}) - C_{k_s m}) \tag{15}$$

λ_1 :Lagrangian multiplier

λ_2, λ_3: Lagrangian multiplier vector

while the conditions that the optimal solution should satisfy are the Kuhn-Tucker conditions:

$$\frac{\partial \Phi}{\partial n_{ik_s}} = \log n_{ik_s} + n_{ik_s} \cdot \frac{1}{n_{ik_s}} - \log p_{ik_s} - \lambda_1 \beta_i V(b_{ik_s}) - \lambda_{2k_s} + \sum_m \lambda_{3k_s m} G'_m(n_{ik_s}) = 0$$
$$(i \in u_l, k_s = 1, \cdots, K_s) \tag{16}$$

$$\frac{\partial \Phi}{\partial \lambda_1} = \sum_{ks} \sum_{i \in u_l} \beta_i V(b_{ik_s}) n_{ik_s} - N_{IS} = 0 \tag{17}$$

$$\frac{\partial \Phi}{\partial \lambda_{2k_s}} = \sum_{i \in u_l} n_{ik_s} - L_{k_s} = 0 \qquad (k_s = 1, \cdots, K_s) \tag{18}$$

$$\left.\begin{aligned} \frac{\partial \Phi}{\partial \lambda_{3k_s r}} &= G_r(n_{ik_s}) - C_{k_s r} = 0 \qquad (\lambda_{3k_s r} > 0) \\ \frac{\partial \Phi}{\partial \lambda_{3k_s r}} &= G_r(n_{ik_s}) - C_{k_s r} \le 0 \qquad (\lambda_{3k_s r} = 0) \end{aligned}\right\} \quad (k_s = 1, \cdots, K_s, r = 1, \cdots, R) \tag{19}$$

The bid rent value in equation (4) can be calculated uniquely, while the allocation function p_{ik_s} can be established from the bid rent value in equation (5). Solving the equations, allocation value n_{ik_s} can be obtained.

3.2 Parameter Estimation

Parameters are estimated sampling a number of lots from the GIS detailed information database, and then applying maximum likelihood method. The size of the sample that contains the information from which the parameters are estimated is L_Z.

At first, bid rent b'_{il_z} is initialized by observed land price in sample lot L_Z, LP_{l_z}, obtained from the GIS detailed information database, as shown in equation (20).

$$b'_{il_z} = LP_{l_z} \tag{20}$$

The bid rent function in equation (21) is given for sampled lots l_z(l_z=1,...,L_Z).

$$b_{il_z} = \mathbf{a}_i \mathbf{X}_{l_z} V(b'_{il_z}) + Const(i) \tag{21}$$

The second term in the right-hand side of equation (21) is an adjusting term, that represents demolition costs and new construction costs in the second term of equation (4) for all existing land uses. In equation (4), the detailed land conditions $\boldsymbol{X}_{l_z}$ are obtained from the GIS detailed information database, while the bid rent function is given by equation (22).

$$p_{il_z} = \frac{\exp \mu_i b_{il_z}}{\sum_j \exp \mu_i b_{jl_z}} \tag{22}$$

Since here the allocation function p_{ik_z} in equation (12) represents the allocation probability, it is necessary to consider the likelihood function that results from agreement between i in equation (23) and actual land uses i_R from the sample. Because of this consideration, the logarithm of the likelihood function in equation (23) can be taken.

$$\ln P = \sum_{l_z} \sum_{i \in u_I} \delta(i, i_R) \ln p_{il_z} \rightarrow \max \tag{23}$$

$$\delta(i, i_R) = \begin{cases} 1: i = i_R \\ 0: i \neq i_R \end{cases}$$

After substituting equations (21) and (22) in equation (23), the likelihood function of (23) is maximized and parameters $\boldsymbol{a}_i$ μ_i and *Const(i)* are estimated.

Next, the bid rent b''_{il_z} is calculated with estimated parameters using equation (24).

$$b''_{il_z} = \mathbf{a}_i \mathbf{X}_{l_z} V(b''_{il_z}) + Const(i) \tag{24}$$

Here, if b''_{il_z} is equal to b'_{il_z}, then parameters are set to $\boldsymbol{a}_i$ and μ_i, otherwise b'_{il_z} is reset by b''_{il_z}, and returned to equation (21). This repetitive operation is continued until b'_{il_z} is converged. Outline of parameter estimation is shown in Figure 6.

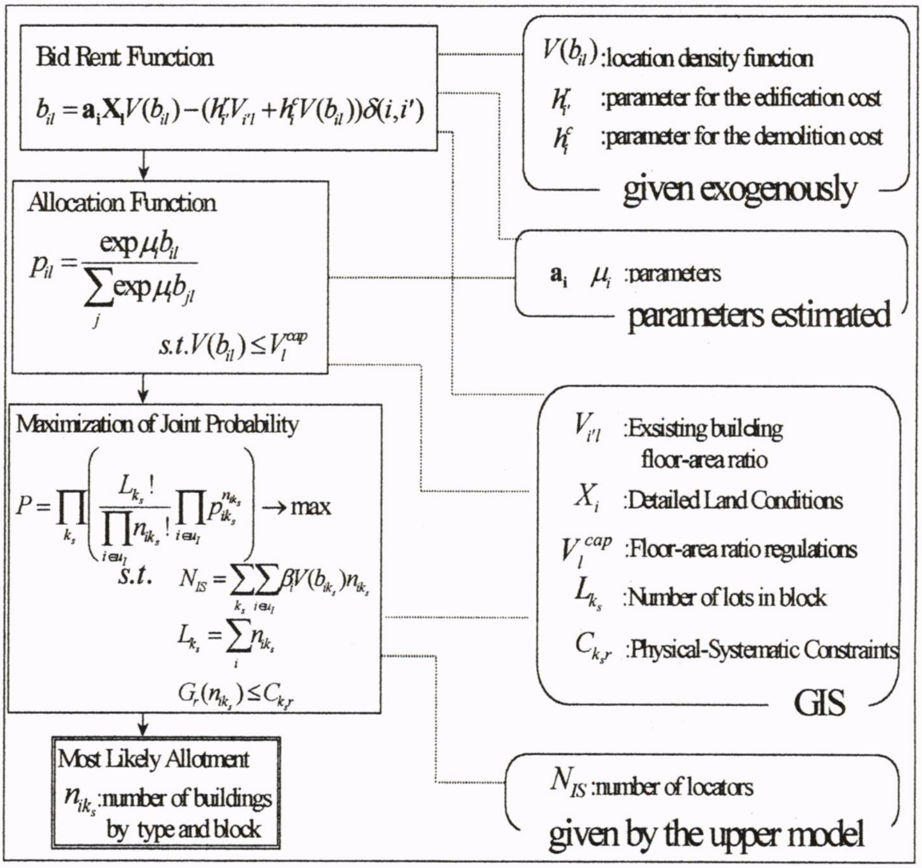


Figure 5. Outline of Allocation in the Lower Model

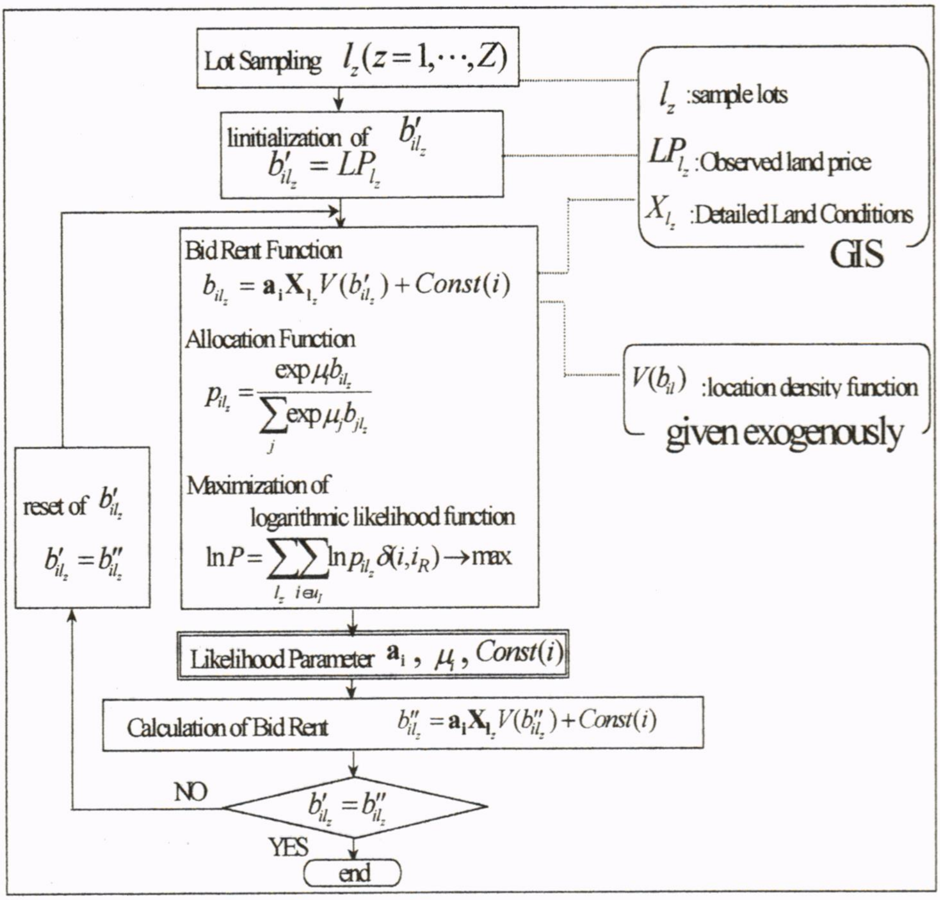


Figure 6. Outline of Parameter Estimation

4. APPLICATION

4.1 Data Base Design

The basic elements to conduct analysis, information pertaining the Sendai Metropolitan Area, were built into a GIS data base. The system structure used was the Atom GIS Engine (Asahi Aerospace Co.) now under development, that runs in a Windows 95 environment. The data used for analysis, taken from Person Trip studies and other elemental planning studies, was first processed, estimated, and totalized to convert it to the required format.

4.2 Upper Land-Use Model Construction

4.2.1 Construction of the RURBAN Analysis System

The upper model was constructed for Sendai City parting from the analysis system RURBAN. Here, a previous version made for the city of Sapporo was ameliorated introducing improvements in the system structure. Running in a personal computer under the Windows environment, the output of the model includes variations in locational patterns for given locators, effects in travel-time reductions, and changes in land prices that result from the construction of new transportation infrastructure projects and other social capital investments. The outline of the system is shown in Figure 7.

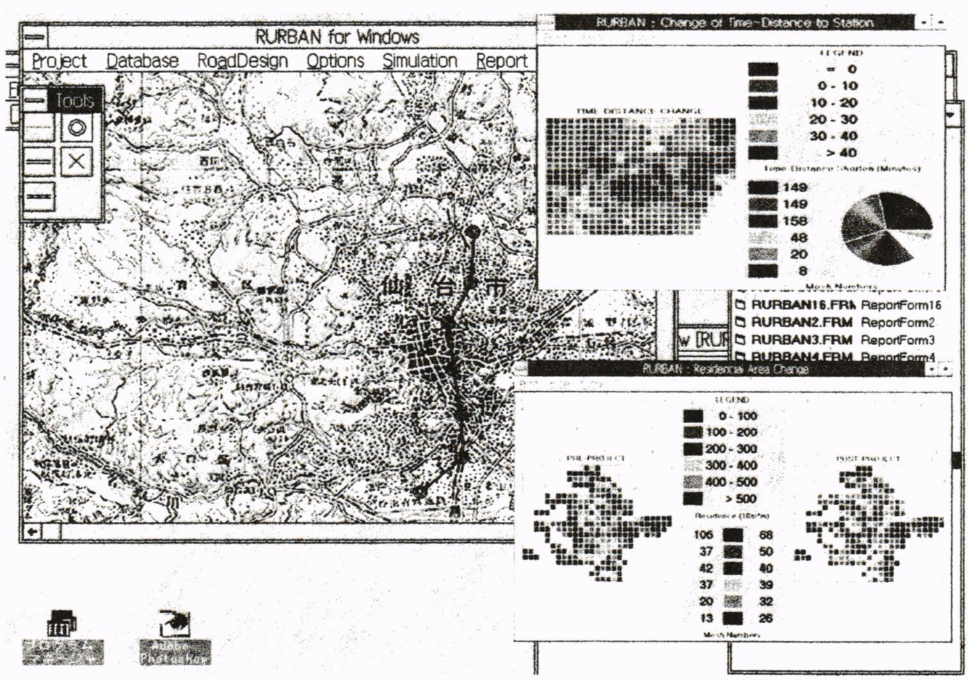


Figure 7. Outline of RURBAN/Sendai

4.2.2 Outline of the Simulation

In this study, the construction of the Subway line in Sendai city was selected as a transportation project due to its data acquisition potential. Data was collected for the years 1980 and 1990, before the subway was constructed and after it was open to the public, and model analysis was conducted on the third census tract mesh depicting changes in land uses occurring during this 10 year span in the realms of the city planning area. To begin with, the parameters were investigated under the light of total locators, individual locator land use areas, and explanatory variables corresponding to each 1980's mesh. Next, the totals for each locator as well as the explanatory variables for 1990 were obtained, and an 'afterwards' simulation was done to forecast the present year locational activity distribution. To conduct simulation at this point, the explanatory variable parameters estimated for Sapporo City were used in substitution. Moreover, due to limitations in data acquisition of totals for the commercial and industrial sector-related locators, fixed values were used before and after the simulation.

4.3 Lower Land-Use Model Construction

In relation to the location density function for computation in the lower model, a test of the potential of land prices as an index was conducted. Since locational density can very well be expressed by floor-area ratios, analysis was made on the relation between land prices and actual floor-area ratios. Regression analysis was made for actual floor-area ratios over land prices for commercial and residential locators, using floor-area ratios as given in the Sendai City Basic Planning Data Study and published data on land prices.

(a) Commerce

Relationship between floor-area ratios and land prices is shown in Figure 8. Even though land prices themselves are controlled by floor-area ratios, a strong linear relationship resulted between them.

(b) Residential

As for the relationship between residential floor-area ratios and land prices, a strong relationship didn't result from the all uses analysis, and since different distributions result from reserved use districts, analysis on variations introduced by different floor-area ratio regulations was done. As shown in Figure 9, relationship between floor-area ratios and land prices in commercial districts (floor-area ratios of 800%) was very strong. However, in the case of Category II Exclusive Residential Districts and Residential Districts (floor-area ratios of 200%) in which high class residential neighborhoods dominate and adverse topographic conditions exist, the scattergram becomes dispersed as shown in Figure 10. Also, as it can be seen in Figure 11 for Category I Exclusive Residential Districts (floor-area ratios of 60%), the existence of new development areas with exceptionally high land prices but extensive vacant areas that bring down the floor-area ratio, induce variation in the distribution. Therefore, it can be thought that land prices alone are not sufficient to explain distribution in relation to floor-area ratios, and that it is necessary to calculate the location density function based on detailed regional data analysis from the GIS, and block unit's reserved uses and actual floor-area ratios.

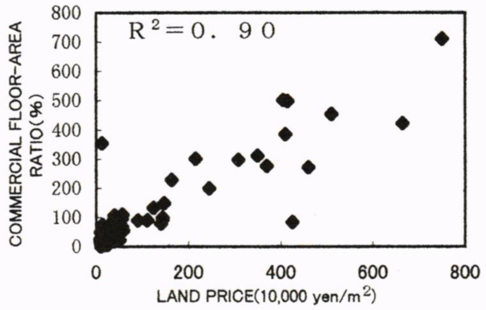


Figure 8. Commercial floor-area ratio

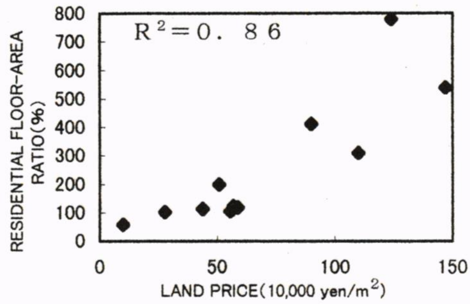


Figure 9 Residential floor-area ratio (commercial district)

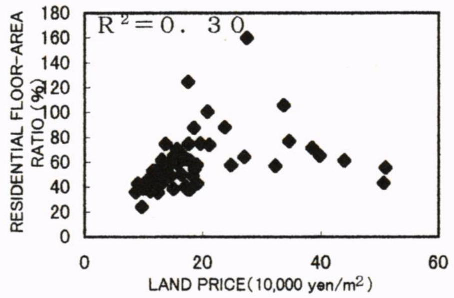


Figure 10. Residential floor-area ratio (category II exclusive residential district and residential district)

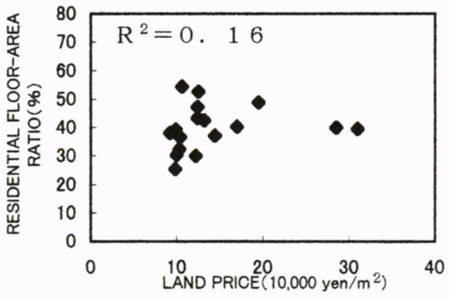


Figure 11. Residential floor-area ratio (category I exclusive residential district)

5. PROSPECTIVE ENVIRONMENTAL APPLICATIONS

It was argued above that the level of aggregation and the kind of units handled by existing models represent a shortcoming that gets reflected in the way analysis is done. Evaluation of realistic conditions and policy measures is therefore conditioned by the level of detail that the model supports, and although some efforts have been carried on to model in an integral fashion the city with its several aspects, including the environment, the characteristics of the interaction models employed inevitably have ruled the level of detail or aggregation at which the environment can be treated in a modeling approach.

In the case of air pollution, an issue that has received a great deal of attention recently, there are examples of models that deal simultaneously with land-uses, transport, and this aspect of the environment. See for instance in Wegener (1996), a model that estimates CO_2 emissions and the effect that different policies, ranging from taxation to physical rearrangement of activities have over them. In this case, however, the level of detail represented by the analysis is coarse, and since the goal is to control total emissions of a pollutant disregarding its position in space, spatially finer detail is not important. Other examples can be found that share the same peculiarity.

On the other hand, when strategic objectives give way to more operational concerns, as for instance implementation of zoning policies, building specifications or other measures, coarsely aggregated partitions of space do not stand as an appropriate solution. For example, when local air pollution, rather than urban background or regional background pollution is the object of study, interest immediately shifts from large zones and simple indicators to higher resolution and small scales. The importance of macro effects remains as high, but more focused attention can be paid to effects that would be overlooked by a coarse resolution approach. The benefits brought by a high resolution approach could be extended to the analysis of other aspects of environment, specially those that are affected by the physical characteristics of the city. Solid waste, wastewater, and perhaps urban heat island with its clearly defined spatial distribution stand as examples.

It is clear then, that there are instances in which modeling the environment might require more detailed information than that offered by most existing interaction models. Moreover, in a recent study (Miyamoto et al, 1995) that related solid waste production to land prices, it was possible to see that the ways in which physical and socioeconomic variables are related to environmental indicators confirm the necessity of having information at the micro level. The objective of the present study, producing a model capable of handling high resolution and detailed spatial information, represents a promissory start to introduce interaction modeling with environmental applications to the commonplaces of decision making.

6. CONCLUSION

In this study, for the purpose conformed land-use analysis we developed a two level land-use model composed of an upper model that allocates activities to zones and a lower model that reallocates these assigned values based on detailed land condition information; this is done in a framework that includes data acquisition based on a GIS database, and the formulation of an allocation function in the lower model. Moreover, as a case study of a prototype system, a GIS database was built for Sendai Metropolitan Area, which was used in conjunction with the RURBAN Model applied to this area..

In relation to the upper model, further study should include gathering of more sufficient data to use in constraint analysis such as substitution parameters and data in this study, as well as reconsideration of model allocation itself. As for the lower model it is needed to determine concrete allocation function including the feedback to upper model with its result, as it couldn't be mentioned. Further development of urban synthetic analysis system including a traffic model with a built-in network system, and an environment model is being planed to construct more realistic decision support systems.

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