# An Example of Visualization for Urban Economic Scenery and Urban Modeling using GIS

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ABSTRACT

This paper presents a zone-based urban model to forecast population distribution and land use transition. A GIS model has been suggested for urban economic scenery forecasting by using data related to an urban environment like Tokyo in Japan. The model has structural simplicity, visibility and applicability of policy analysis.

## 1 INTRODUCTION

In mega cities, there have been many complex problems related to the centering and the overcrowded phenomena. To solve the problem for a proper city, estimating the future status of the city area and controlling each city function are needed.

Therefore, that the basic structure of city can be described and to show the model which it is easily understood and is wealthy in the operate-ability are desired.
In this paper, with such a point of view, we will firstly present a method for estimation of basic model, which describes residential location model. Secondly examine techniques which show us economic scenery caused by human activities, which is the land-use, to experiment in the verification with metropolitan area of Japan. Those techniques aimed in here are ways to show economic scenery of cities and to more promote to reach to the consensus using GIS by getting easy to understand.

In the present study a concrete method has been proposed for the forecasting of the urbanization. First, in concrete method, we will propose the handy method for estimating the resident population distribution of urban area by setting employment in every area as given condition to the base of the planning frame. That the spatial scale of former urban models divided a city into some zones on the presupposition that it would generally have a uniform spatial characteristic in the zone. Therefore, for example, a spatial interaction among the zones was analyzed based on the traffic network characteristic among the zone centers, it has been treating handily by aggregating of a continuously changing spatial interaction originally. On the other hand, the handy method mentioned has difficulty to imagine a city condition concretely because of an aggregation of an estimated result in the zone, so the process of getting a consensus has difficulty too. And, secondly by using a GIS we will divide the amount of value in every zone into the cell and examine the technique that it makes easy to understand and to show the economic scenery made with land use. In this report we will show a statistical significant result and enough facility that are gotten after applying the mentioned model to National Capital Region.

## 2. POPULATION DISTRIBUTION MODEL

It contains two sub-models to estimate resident population of each zone. In the following sections we describe these sub-models.

### 2.1 **General Concept**

When setting employment frame as the given condition, the basic flow that simply estimates resident population of the urban region is as shown in figure 1. The concept is that if the distribution of working population and non-working population explain the distribution of resident population, the working population distribution is dependent on the choice of its residential location. The choice of residential location can be explained by location utility that contains commuting time, cost ratio of residence, area of plot and the number of stations as its variables in the residential location model. Here, an assumption has been made on the cost of residence (land

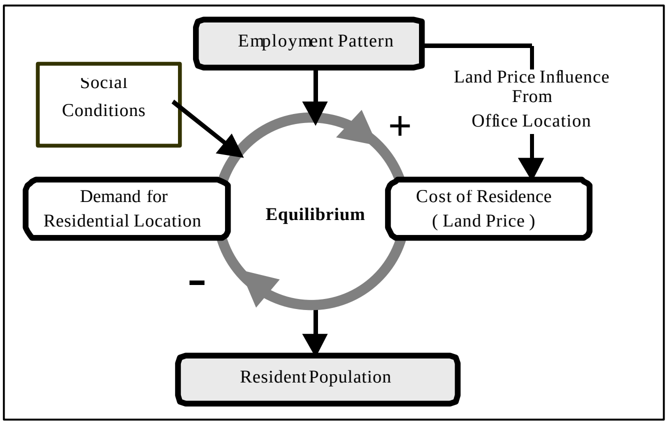


Figure 1: **The Flow of the Estimate for Resident Population Distribution**

price) as in equilibrium, and the working population distribution is fixed by the market equilibrium. The land price is explained land price sub-model. As for the non-working, its amount is decided from the number of non-working per working person based on the ratio of being at work.

### 2.2 **Residential Location Sub-Model**

The distribution pattern of resident population is supposed to be formed with choice of residential location for each worker to maximize the utility of the individual and with total of the result. According to random utility theory, by setting the workplace zone *j* with each worker as the given condition for this model, the following formula can show the probability $P(i \mid j)$ for choice residential place zone *i* and the deterministic part $V_{ij}$ of residential location utility in zone *i*.

$$P(i \mid j) = \frac{\delta_{ij} \exp[V_{ij}]}{\sum_k \delta_{kj} \exp[V_{jk}]} . \qquad (1)$$

Where $\delta_{ij}$ is the characteristic function of the alternative set, it means determination for valid alternative set.

Also, for description of utility function $V_{ij}$ the explanatory variables as follows,

$$V_{ij} = (\ln NS_i + \alpha_1 \ln \frac{RA_i}{NS_i}) + \alpha_2 \frac{LV_i}{INC_t} + \alpha_3 TTM_{ij} . \qquad (2)$$

Where

| | |
|---|---|
| $NS_i$ | : the number of stations in zone *i* |
| $RA_i$ | : total area of lots for residential / commercial in zone *i* |
| $LV_i$ | : land price of residential location in zone *i* |
| $INC_t$ | : annual income of individual *t*, depending working in zone *j* |
| $TTM_{ij}$ | : travel cost using train from zone *i* to zone *j*. |

The first member means zone capacity, second is the ratio of load and third is commuting time. The utility of living in residential zone *i* for an individual who works in zone *j* is mainly decided by the balance between residence cost (which is the ratio of the land price and the annual income of the individual) and the commuting time. The zone capacity that shows a zone scale is obtained from the total number of stations in each zone and from attraction degree of stations. The parameter, attraction degree of stations is obtained from division of the resident possible area in zone *i* by the number of the stations as the auxiliary variable that shows appeal with the increase of one.

### 2.3 **Land Price Sub-Model**

For estimating the residence cost, it substitutes it for the land price. The land price is supposed to be explained by the account deoxidization (present land use). It thought of the explanation variable that can show the present situation handily as far as it is possible as the explanation variable with Land Price Model.

In other words, the explanation variable is described at the distributed income and the production income for every unit area and other factors and it formulates those variables by the line -shaped multiple regression. The average land price of the resident place in zone $i$ denoted by $LV_i$ is obtained as follows;

$$LV_i = \beta_0 + \beta_1 AIN_i \frac{POP_i}{A_i} + \beta_2 GDP_i \frac{EMP_i}{A_i} + \varepsilon \quad . \qquad (3)$$

Where

$AIN_i$ : income per capita (resident population) in zone $i$
$POP_i$ : resident population in zone $i$
$GDP_i$ : production per capita (employed population) in zone $i$
$EMP_i$ : employed population in zone $i$
$A_i$ : built up area in zone $i$
$\varepsilon$ : random part.

## 2.4 **Stochastic User Equilibrium**

The stochastic user equilibrium assumes that the resident distribution function (the demand model) and the land price function (the service function) are in the user equilibrium.  Therefore, equilibrium point can be obtained by solving non-linear simultaneous equations (2), (3). As for solving of this equilibrium point, it uses Method of Successive Average (MSA) method.

# 3. LAND USE TRANSITION MODEL

The land use transition model suggested here estimates the position of new urban land use. That is, it sets total populations of each zone that are obtained in precedingchapter and conventional land use change patterns of each zone as given condition to decide points of new habitable place.

## 3.1 **Outline Of Model**

The variation in the population density $\Delta A$ can be related to the degree of change in the land use. For example, more $\Delta A$, there will be much change in the land use pattern. Therefore, it suggests that the land use transition model be based on many assumptions as explained in the following:

- Only in the city planning area, the urban land use will expand.
- Comparatively only on the edge of the low density built up area, the urban land use will expand.

- Not expand into non-habitable area.
- As for the built up area, in the same land use category, it supposes that it has the same population density.
- Supposes that the population density every land use doesn't change in future.
- Supposes that it is the previous natural land use to change newly to urban land use.

### 3.2 **Approaches**

To map the urban areas the ARC/Info GIS was used and model has been built in the same environment. The approaches employed to execute the models are shown below:

Step I; calculates the previous average of resident population density in every urban land use with a 1-km cell. The average population density *r* in a 1-km cell is obtained from the ratio between population and total area of the built up sites.

Step II; calculates the area *b*, which is new built up area expanded. It is estimated from the increment $\Delta A$ of the population divided by average population density *r*.

Step III; decides the point at which the build up land use has changed. Eventually, it evaluates the rate of land use transition. To follow these above steps the following three conditions were made.

*(i) Type Weight ($W_U$):*

Some types of land use are more susceptible to development than others. This can be seen in the results from previous land use studies. Transition percentage of urban use denoted $t_u$ could be estimated from processing every zone. Using the transition percentage, type weight can be calculated by using the equation:

$$W_u = \frac{t_u - t_{\min}}{t_{\max} - t_{\min}} \quad (4)$$

Where

$t_u$ : percentage of land use transition from natural land use *u* to urban

$t_{\min}$ : the minimum of $t_u$

$t_{\max}$ : the maximum of $t_u$

*(ii) Distance Weight (Wl)*:

Distance weight can be computed by using the existing urban areas. This evaluates advantage of the location among the same land use type. In this study, we proposed that the susceptibility could have an inverse logarithmic relationship to the data, so the susceptibility decreases as distance l increases.

$$W_l = \exp[-\gamma l] \quad (5)$$

, $\gamma$ is positive constance.

Where, *l* is distance.

*(iii) Size Weight (Ws)*:

Supposing that the size of the development is influenced from the size of nearest urban area in the zone. Size weight is obtained from

$$W_s = \frac{s - s_{\min}}{s_{\max} - s_{\min}} \quad (6)$$

Where

$s$ : total area of nearest urban land use continuous.

$s_{\min}$ : the minimum of $s$

$s_{\max}$ : the maximum of $s$

It gets final transition weight $W$ from line-shaped summation with three above pieces of weight,

$$W = W_u + W_l + W_s \quad (7)$$

According to this $W$, the order of priority in transition facility is fixed, so we can select the spots that change into urban land use.

## 4. CASE STUDY

The model, wide area urban model, is tested in Tokyo, Japan (figure 2).

### 4.1 **Wide Area Urban Model**

The whole study area is divided into eighty-one zones including many Municipalities. The division is made considering the regional contiguities, traffic network conditions, population scales and other urban structures.

We estimate resident population with application residential location model to these eighty-one zones. As for the reappear-ability with two functions that were estimated residence choice function and the land price function, it confirmed a sufficiently height.

### 4.2 **Distribution of New Urban Land Use**

To estimate the urban land use expansion, data of National Land and Census have been utilized. Figure 3 illustrates the population density distribution of Saitama Prefecture during 1985. The urban land use pattern of two dates (1985 and 2010) in the same area is shown in figure 4. According to this figure, we are able to see the linear shape of urban land use and able to grasp easily distribution of new urbanized area. It seems that newly urbanized area locates in middle east area of Saitama. It means the possibility of development in the area. Based on this result, the people lived in there not only officer be able to understand the future of area where they live in.

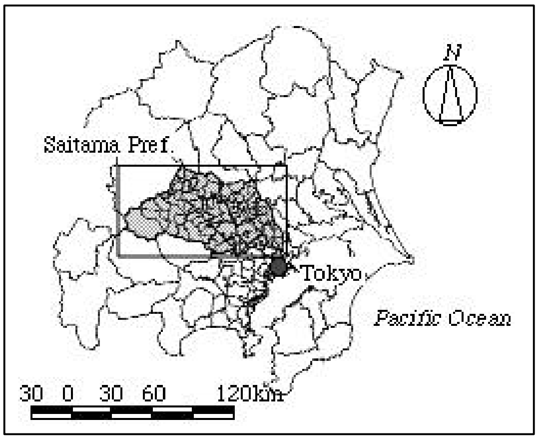


Figure 2: **Study Area**

## 5 CONCLUSION

GIS to express in gradually by modeling the real world visually to carry forward getting more consensus while grasping the estimate result of the city activity quantity and the spatial information as it showed in this study is necessary. The improvement of user interface of models and other techniques are demanded in the future to develop the arguments with the seamless from the micro influence of the city environment to the urban structure using GIS which is free from scale.

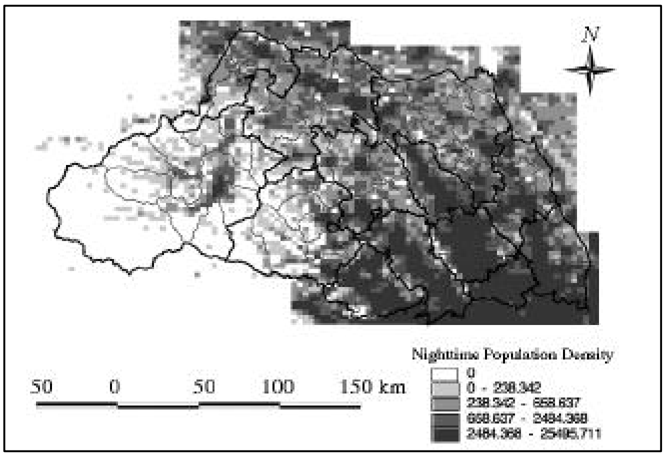


Figure 3: **The Distribution of Population Density (1985)**

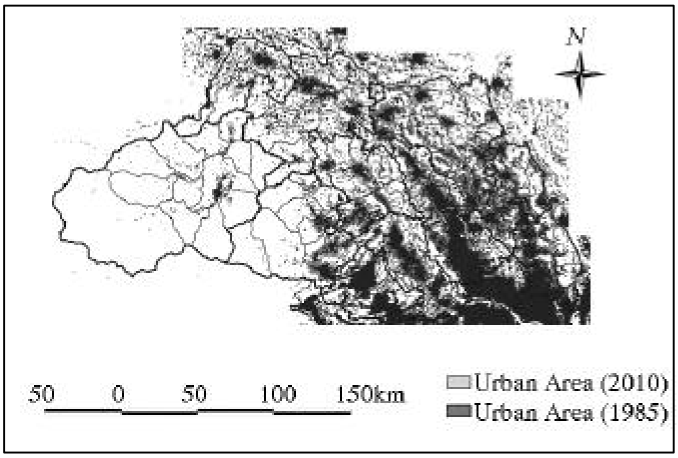


Figure 4: **Result of Estimation for Urban Land Use Expansion**

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