韓國地形空間情報學會論文集 第8卷 第1號 2000年 3月 pp. 27-42

사회기반시설 정비효과계측을 위한 GIS지원시스템

GIS-Supported System for Measuring the Effect of Social Infrastructure Improvements

표 명 영*
Pior, Myoung-Young

要 旨

본 연구에서는 사회기반시설의 정비효과계측을 위한 GIS지원시스템을 구축하였다. 정비효과를 계측하기 위한 평가수법으로써는 간이헤도닉접근법과 로젠의 2단계접근법을 동시에 적용함으로써 평가결과의 객관성을 확보하고자 하였다. 두 접근법에 필요한 각종의 토지속성데이타는 GIS지원환경속에서 보다 효율적으로 수집 또는 자동생성할 수 있었다. 또한 GIS를 이용함으로써 보다 객관적이고 정확한 데이타를 제공할 수 있었으며, 사회기반시설의 정비에 따른 편익을 실제위치상에서 계측할 수 있었다. 본 연구에서 개발한 시스템을 활용하여 동경도시권내에 현재 계획중인 죠반신선(瀏晨竊猜)의 정비효과계측에 적용함으로써, 본 시스템의 실용성을 확인할 수 있었다. 사회기반시설의 편익계측작업을 GIS와 통합시킴으로써, 본 개발시스템은 사회기반시설계획등의 평가에 유용한 툴(tool)이 될 수 있을 것이다.

ABSTRACT

In this study, a GIS-supported system is used to measure the effect of social infrastructure improvements. Benefit evaluation approach is based on two types of approaches -the simple hedonic approach and Rosen's two step approach. The land attribute data for both approaches are efficiently collected and generated in a GIS-supported environment. Moreover, it conveys more objective and correct data. The benefits are estimated on real locations by using GIS. The potentiality of the developed system for practical application has been verified by its application to Joban New Line in Tokyo metropolitan area. By incorporating benefit evaluation routines into GIS, the proposed system will be a useful tool for decision making on the improvements of social infrastructure.

1. INTRODUCTION

1.1 Background

There are several different practical approaches in measuring the benefits of infrastructure improvements. This study specifically focuses on the hedonic approach in evaluating the effect of infrastructure improvements. Since Riker and Henning's pioneering study of 1967 on the relationship between property value and air pollution, a vast research literature has appeared on the hedonic approach to obtain information on the benefits expected from public programs and infrastructure improvements.

In the hedonic approach, there are many advantages. The concept of hedonic approach is relatively clear and benefits can be directly estimated in terms of money. Total benefits are estimated, including indirect effects. There is no

* 일본 명해대학교 부동산학과 조교수

possibility of double counting of benefits. The places where benefits are yielded can be known precisely.

In spite of these advantages, there are some practical difficulties. In this approach, analysts must first collect information regarding all the factors determining land price or housing price. The most expensive and time-consuming aspects of the approach are about the collecting and coding of the required data.

Under these circumstances, a more convenient tool is needed for avoiding these difficulties. A more efficient tool would be indispensable, when we apply the hedonic approach for the benefit evaluation of the project.

When developing a more convenient tool, GIS (geographic information system) is focused in this study. The main characteristics of GIS is the use of geo-reference information in data collecting, analyzing, decision making and problem solving. By exploiting the geographical dimensions, GIS has made useful contributions to diverse application in different fields and promises much more success.

A wide range of spatial data characterizing a study area is required in the hedonic approach. These data are intimately related to geographical locations. In a GIS-aided environment, the data necessary for the benefit evaluation processes can be directly collected at any site of the study area. Some information can be also generated within the system.

Moreover, the benefits estimated by the hedonic approach can be more accurately calculated on real locations. The areas affected by infrastructure improvements can be pinpointed more concretely and objectively. In this way, the GIS-aided environment will offer a useful tool for more reasonable evaluation of infrastructure improvements.

Concerning with the difficulty of financially estimating the value of non-market goods, comprehensive evaluation, based on multiple evaluation approaches, is required for more reasonable and objective decision. In this spirits, two approaches in the hedonic approach -the simple hedonic approach and Rosen's two step approach- are adopted in the developed system.

In the simple hedonic approach, the estimated hedonic price function itself is used for benefit estimation. The hedonic price function is an upper bound of bid price functions. The use of the hedonic price function itself leads to benefit overestimation. Many studies (Harrison and Rubinfeld, 1978; Kanemoto, 1988; etc.) have pointed out that the simple hedonic approach has the possibility of benefit overestimation. Kanemoto (1988) proposed that in order to obtain correct benefit estimates, appropriate measures such as CV (compensating variation) and EV (equivalent variation) must be calculated. Following these circumstances, Rosen's two step approach is also focused on in this study. In Rosen's two step approach, benefits can be estimated as WTP (willingness to pay) -CV and EV- by using the two step approach.

In this study, the author tries to develop a GIS-aided benefit evaluation system for infrastructure improvements, focusing on the simple hedonic and Rosen's two step approaches.

1.2 Advantages of the GIS-supported system

There are several advantages in incorporating the benefit evaluation procedure into GIS framework. Although some of the advantages have already been explained in the background, they are briefly described below :

1) In the GIS-aided environment, the necessary information can be directly collected and generated in the proposed system by reducing the burden of collecting and coding spatial information.

2) A homogenous conditions unit is generated by the overlay function of GIS, which prepares the basic unit of census tract for the benefit estimation. Such basic units are very useful for the statistical analysis necessary for the benefit evaluation.

3) The benefits can be estimated more concretely and objectively on real locations undertaking improvement gains. This is an important advantage as the theoretical base is set up for the benefits to society as well as for the balance of regional developments.

4) The spatial distribution of changing situations can be displayed as a computer-drawn map by linking benefit evaluation routines into display with any variety of spatially detailed or zone specific data. These functions make interpretations and explanations easier for affected residents or public representatives.

1.3 Objectives

The main objectives of this study are as follows :

1) By developing a GIS-supported benefit evaluation system as a useful tool, it is possible to support benefit evaluation processes and prepare effective materials for explanation.

2) By applying the proposed system to a new urban railway system, the Joban New Line project, the potential of the proposed system can be verified practically.

3) From empirical study results, using two approaches -the simple hedonic approach and Rosens two step approach-, we get more reasonable and objective evaluation indicators, comparing the both results.

2. REVIEW OF THE HEDONIC APPROACH

2.1 Theoretical basis of the simple hedonic approach and Rosen's two step approach

There are generally two ways for evaluating benefits of infrastructure improvements. The first one is a direct method. Contingent valuation method (CVM) is its example. It directly elicits the valuations of infrastructure improvements from the respondents. The second is indirect method that infers an implicit value for public goods from observable prices of private goods. The keys for the estimation of the value of any public goods can be found in private market goods. Using the relationship between the infrastructure improvement level and land or housing price offers an example of indirect method. Improvements in infrastructure level are expected to shift the demand schedules for the land or housing affected by infrastructure improvements. From the extent of these shifts, implicit prices of improvements can be inferred from the affected land or housing price data. This approach is usually called the hedonic approach.

The hedonic approach is further classified into two different approaches -the simple hedonic approach and Rosen's two step approach. In the simple hedonic approach, the demand parameters are inferred directly from the coefficients of the estimated hedonic function. The hedonic price function itself is used for benefit estimation. The hedonic price function estimated from observed market data is an upper bound of bid price functions. This follows from the nature of the bid price, which states that the price of a site exceeds the bid or willingness to pay of the people who do not live there. Therefore, the use of the hedonic price function itself leads to benefit overestimation and the estimated results can be assumed to be the maximum bound of the benefits of studied projects.

To overcome the overestimation problem, an alternative approach was suggested by Rosen (1974). This method for the estimation of demand functions for land or housing attributes uses a two step process. In the first step, the hedonic price function is estimated. In the second step, the bid price function, a household's willingness to pay for a given product can be estimated. By using this household's bid price function, the WTP for a particular land or housing attribute can be estimated. Based on this concept, the bid price function can be identified and the benefit estimated.

2.2 Benefit estimation

2.2.1 Benefit estimation by the simple hedonic approach

In the simple hedonic approach, the best hedonic price function for the studied area is determined by relating land or housing price to its attributes before improvements. New land or housing prices are calculated by the determined hedonic price function, under the assumption that the structure of the hedonic prices is identical before and after infrastructure improvements. While calculating new land or housing prices, the changed attribute values resulting from improvements are used as inputs.

If LP is denoted as new land or housing price before infrastructure improvements, and LP^* is denoted as new land or housing price after infrastructure improvements, then, in the simple hedonic approach, the benefit of infrastructure improvements is specified as follows:

$$Benefit = LP^*_{with\ infrastructure\ improvement} - LP_{without\ infrastructure\ improvement} \qquad (2\text{-}1)$$

2.2.2 Benefit estimation by Rosen's two step approach

According to some studies (Scotchmer, 1985; 1986), the housing stock and the distribution of people in a space are not affected by any improvements in the short term. However in the long term, there will be a new dispersion of housing and population reflecting the change in land attributes by any improvements. In particular, large transport-related infrastructure improvements, such as the construction of urban railway systems, affect the area over a long period of time. Urban development projects for a new dispersion of population are usually accompanied by such an urban railway system. The assumption of fixed housing stocks is problematic. The viewpoint of the long term is more reasonable for urban railway improvements. In this study, the benefits of a new urban railway system are evaluated for the long-term, taking into consideration of the above point of view.

Quigley's methodology (1982) of Rosen's two-step approach (1974), in which the demand for land and house attributes is calculated by estimating the parameters of an explicit utility function, is modified in this study. The parameters estimated by the modified method are then used to measure willingness to pay for the change of land and house attributes with infrastructure improvements.

According to the equilibrium condition, each household consumes a vector of housing attributes H_0 and composite goods X_0 the price of which is unity. A household chooses its consumption bundle subject to a budget constraint where income Y is exhausted by their purchases of X_0 and one unit of type-H_0 housing bundle (land and house). The prices of the housing attributes that form the housing bundle are not directly observed. Only the hedonic market price $P_0(H_0)$, which is the amount paid for the entire bundle, is observed. Furthermore, the attributes are jointly and non-linearly priced. The budget constraint is thus similar to the relation given below.

$$Y = X_0 + P_0(H_0) \qquad (2\text{-}2)$$

where X_0 represents composite private good and $P_0(H_0)$ is the hedonic price for housing.

In the long run, a house is a manufactured private good like any other private goods and one can think of house and land as separate items in the consumption bundle (Scotchmer, 1985; 1986). Land attributes here may include various local public goods, environmental quality and infrastructure capital. Unlike house attributes such as construction materials and room numbers, the land attributes are exogenous to a consumer's decision problem even in the long run. From the long-term viewpoint, the consumer's budget constraint (2-2) can be rewritten as:

$$Y = X_0 + s \cdot P(H) + P^*(H^*) \qquad (2\text{-}3)$$

where : s = lot size,

$P(H)$ = land price function per unit area with a vector of land attributes H.

$P^*(H^*)$ = house price of type-H^* house.

The consumer's budget constraint (2-3) can be interpreted as follows. The consumer chooses one lot of land with a vector of land attributes H and a type-H^* house. The vector H can include time-distance to CBD(Central Business Districts), school facilities, road maintenance condition, air quality and so on; in short, any attributes which are attached to the location, and the consumer cannot change them. H^* represents house attributes which in the long run can be chosen by a consumer at any location. In the long run, we assume that each house type can be built at every location at the same cost $P^*(H^*)$. Thus we can include a constructed house in composite private goods, and end up with the budget constraint given below.

$$Y = X + s \cdot P(H) \qquad (2\text{-}4)$$

where : $X = X_0 + P^*(H^*)$

A generalized constant elasticity of substitution (GCES) utility function, which provides enough restrictions actually enable us to ensure that the observed bundles of X and H will certainly identify points along the indifference curve assumed in the study.

$$U=\left[\sum_{i=1}^{m} a_i h_i^{\gamma_i} + a_s s^{\gamma_s} + X^{\varepsilon}\right]^{\phi} \quad (2\text{-}5)$$

where : $a_i, a_s, \gamma_i, \gamma_s, \varepsilon$ and ϕ are parameters, h_i is land attribute which is one component of H, s is lot size and X is a composite goods item that is numeraire.

The representative household must choose its consumption bundle (X, H) by solving the following constrained maximization problem:

$$\Psi=\left[\sum_{i=1}^{m} a_i h_i^{\gamma_i} + a_s s^{\gamma_s} + X^{\varepsilon}\right]^{\phi} + \lambda[Y - sP(H) - X] \quad (2\text{-}6)$$

where : λ is a Lagrange multiplier, Y is income, $P(H)$ is the hedonic land price function per unit area and X is a composite goods item that is numeraire.

The first order maximization condition yield:

$$\partial\Psi/\partial h_i = 0$$

$$\phi\left[\sum_{i=1}^{m} a_i h_i^{\gamma_i} + a_s s^{\gamma_s} + X^{\varepsilon}\right]^{\phi-1}\left(\gamma_i a_i h_i^{\gamma_i-1}\right) = \lambda(s\,\partial P/\partial h_i)$$

for $i=1,2,\ldots m$ (2-7)

$$\partial\Psi/\partial s = 0$$

$$\phi\left[\sum_{i=1}^{m} a_i h_i^{\gamma_i} + a_s s^{\gamma_s} + X^{\varepsilon}\right]^{\phi-1}\left(\gamma_s a_s s^{\gamma_s-1}\right) = \lambda(P(H)) \quad (2\text{-}8)$$

$$\partial\Psi/\partial X = 0$$

$$\phi\left[\sum_{i=1}^{m} a_i h_i^{\gamma_i} + a_s s^{\gamma_s} + X^{\varepsilon}\right]^{\phi-1} \varepsilon X^{\varepsilon-1} = \lambda \quad (2\text{-}9)$$

By using the relation of (2-9), two functional forms, (2-7) and (2-8) can be simplified into (2-10) and (2-11).

$$(\partial P/\partial h_i) = (s^{-1}\gamma_i a_i \varepsilon^{-1})\, h_i^{\gamma_i-1} X^{1-\varepsilon}, \quad i=1,\ldots,m \quad (2\text{-}10)$$

$$P(H) = (\gamma_S a_S \varepsilon^{-1})\, s^{\gamma_S-1} X^{1-\varepsilon} \quad (2\text{-}11)$$

The right-hand side of (2-10) and (2-11) are the marginal rate of substitution(MRS) in consumption between h_i and X or s and X. They indicate the amount of consumption of all other goods (X) that an individual is willing to pay for another unit of the i^{th} land attribute or lot size. In household equilibrium condition, they must equal the unobserved marginal price of those attributes $(\partial P/\partial h_i)$ or $P(H)$. The $(\partial P/\partial h_i)$ and $P(H)$ can be calculated from the hedonic price function which is estimated by market-observed data.

For the two step approach, in the first step, the hedonic price function is estimated by market observed data and the derivatives are calculated from the estimated hedonic price function. In the second step, using the derivatives in (2-12) and (2-13), which are the log-linear estimation of (2-10) and (2-11), we can estimate the parameters of utility function by linear regression techniques.

$$\ln(\partial P/\partial h_i) = \ln(s^{-1}\gamma_i a_i \varepsilon^{-1}) + (\gamma_i - 1)\ln h_i + (1-\varepsilon)\ln X$$

for $i=1,\ldots,m$ 2-12)

$$\ln(P(H)) = \ln(\gamma_S \alpha_S \varepsilon^{-1}) + (\gamma_s - 1)\ln s + (1-\varepsilon)\ln X \quad (2\text{-}13)$$

Kanemoto and Nakamura (1986) have pointed out that there is the possibility of multi-collinearity while estimating the parameters of (2-12) and (2-13). If there is multi-collinearity, the ridge regression techniques can be used to calculate point estimates that are "closer" to the true values of model parameters as compared with the usual least square point estimates (Hoerl and Kennard, 1970 a; b). In this study, the ridge regression technique has been used for decreasing the multi-collinearity in estimating the parameters of (2-12) and (2-13).

After estimating the coefficients of (2-12) and (2-13), we can identify the parameters (α_i , α_s , γ_i , γ_s , ε) of the utility function. ϕ is arbitrary and is usually assumed to be as 1 (Quigley, 1982). By using the estimated utility function and assuming $\phi = 1$, we can estimate benefit as CV and EV for infrastructure improvements :

$$CV = X_0 - \left[\sum_{i=1}^{m} \alpha_i h_{i0}^{\gamma_i} + \alpha_s s_0^{\gamma_s} - \sum_{i=1}^{m} \alpha_i h_{i1}^{\gamma_i} - \alpha_s s_1^{\gamma_s} + X_0^{\varepsilon} \right]^{1/\varepsilon} \quad (2\text{-}14)$$

$$EV = \left[\sum_{i=1}^{m} \alpha_i h_{i0}^{\gamma_i} + \alpha_s s_0^{\gamma_s} - \sum_{i=1}^{m} \alpha_i h_{i2}^{\gamma_i} - \alpha_s s_2^{\gamma_s} + X_0^{\varepsilon} \right]^{1/\varepsilon} - X_0 \quad (2\text{-}15)$$

3. ROLES OF GIS IN THE PROPOSED SYSTEM

3.1 Collecting and generating land attributes in GIS

For benefit evaluation in the hedonic approach, various types of land attributes are needed. In this section, the method of collecting and generating such land attributes in the GIS environment is to be explained concretely.

3.1.1 Time distance to CBD

1) Deciding time distance to CBD

By using the network function in GIS, some data containing vectors and nodes are transferred into an arc cost table. The arc cost table contains vector length as cost. Time distance to CBD is calculated by dividing the vector length by the train speed. In this study, vector length has been converted into time distance between a previous node (station) and a subsequent node (next station). By the shortest path function, a spanning tree can be decided; which contains the information of the shortest path from CBD.

2) Deciding the station domain of each station

A method of constructing polygons from data points involves the function of creating Voronoi or Thiessen polygons in GIS (Peuquet and Marble, 1990). A fundamental property of these polygons is that the area within any polygon is closer to the data point, where polygon is formed as compared with any other data point. Each Voronoi map has a special attribute (e.g., time distance to CBD in this study).

3.1.2 Distance to the nearest station or road

With the buffer function in GIS, we can determine an area extendable to user's specification distance in all directions from a station, or on either side of a road. The distance from the nearest station or road can also be calculated at any site.

3.1.3 Slope and direction of ground

The slope and direction of ground can be calculated by DEM (digital elevation model) data. DEM is the file of terrain elevations for the intersections on a very fine-grained grid.

3.1.4 Residential infrastructure conditions

Gas service, water service, and sewer service conditions can be managed as polygons with attributes (e.g., such service facilities do or do not exist in this study). Accessibility to neighborhood facilities (e.g., park, cultural and educational facilities, etc.) can also be calculated as Euclidean distances or time distances.

3.1.5 Land use conditions

Land use conditions can be managed as polygons with their attributes (e.g., zoning types in this study). The administration boundary can also be defined as a polygon with a certain attribute (e.g., inside or outside the city of Tokyo in this study).

3.2 Generating homogenous conditions unit

For estimating benefits, land attribute data must be aggregated into meaningful statistical areas. In the case of non-GIS, the mesh method is used in aggregating land attributes into defined small areas, which is an arduous task for analyzers. In the case of GIS, homogenous conditions units with a table are easily and more accurately generated at their real locations by the help of overlay function of GIS. A homogenous conditions unit provides the basic unit, which is a kind of census tract for benefit estimation. These units are very useful in the statistical analysis for the benefit estimation.

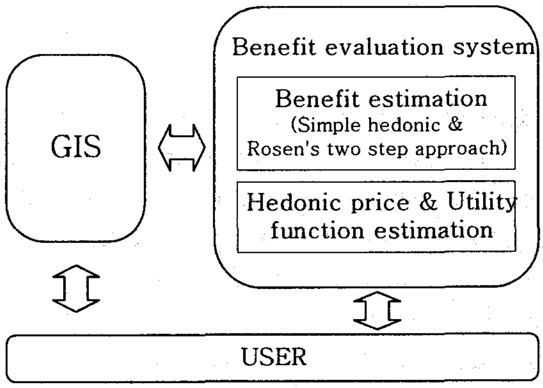

figure 1 Overview of the GIS-supported system

3.3 Overview of the proposed system

The design of the GIS-supported benefit evaluation system is shown in figure 1. The system consists of GIS and the benefit evaluation system, which are essentially required in the GIS-supported environment. The benefit evaluation system is organized into two sub-systems: 1) the hedonic price and utility function estimation sub-system; 2) the benefit estimation sub-system. In the GIS-supported environment, the hedonic price function can be estimated for the studied area by transferring data with GIS. By using an estimated hedonic price function, the parameters of the GCES utility function, explicitly assumed as a utility function, are estimated. After estimating these two functions, the process of benefit evaluation is carried out for estimating the benefits of the studied infrastructure improvements.

In GIS, the land attribute data are collected and generated for sub-systems. The updating, storing, and retrieving of the land attribute data are processed by the DBMS (database management system) in GIS. The outputs are also reported, displayed, and plotted through GIS. The main functions of the proposed system in this study are based on GIS.

4. APPLICATION OF THE PROPOSED SYSTEM

4.1 The case study area

4.1.1 Study project : the Joban New Line and urban area development projects

The Joban New Line in the metropolitan Tokyo is proposed to be built from Akihabara to Tsukuba, with 19 stations and total length of 58.3 kilometers. The implementation of the project would reduce the travel time of Akihabara to Tsukuba from 85 to 45 minutes. Various urban development projects are also proposed along the new line.

4.1.2 Areas affected by the Joban New Line

The new stations domains are decided by using Voronoi diagram for the Joban New Line. In this study, they are defined as the areas directly affected by the Joban New Line. In figure 2, the affected areas decided by Voronoi diagram are shown. These areas are actually used as the objective areas for the benefit estimation. In this study, we have assumed that

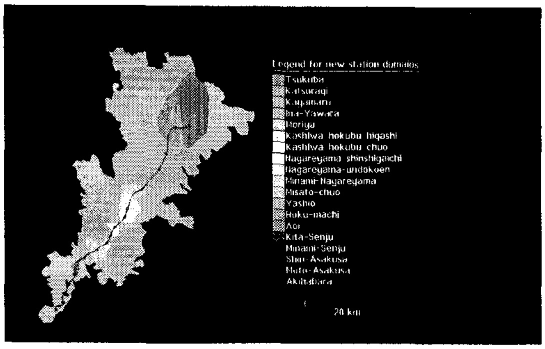

figure 2 Areas affected by the Joban New Line

the benefits would occur inside the new station domains of the Joban New Line.

4.2 Application into the case study area

4.2.1 Data set used for parameter estimation

In this study, the officially assessed land price data set of the National Land Agency of Japan (land price, zoning, sewer service, gas service, *etc.*) and the income data of the Annual Report on the Family Income and Expenditure Survey of Statistics Bureau, Prime Minister's Office of Japan were used for the estimation of the hedonic land price function and utility function.

4.2.2 Assumption for application into the case study

For benefit evaluation, the assumption conditions are as follows :

1) Assumption on land price
  (1) All households living in the present locations are the highest bidders.
  (2) Officially assessed land price is the highest bid price respectively.

2) Assumption on Time distance to CBD
  (1) The origin of CBD is assumed as Tokyo Station.
  (2) Waiting time is zero at the boarding station.
  (3) Transfer time is average waiting time for transfer.

3) Assumption on the areas affected by the Joban New Line
  (1) The areas affected by the Joban New Line are assumed to be the station domains of the new stations on the Joban

New Line. figure 2 shows the areas affected by the Joban New Line.

4.2.3 Sub-dividing data group

In this study, for estimating land price functions, the data are grouped into three parts by zoning types.

1) Data group 1 : the data of the 1st exclusively residential, the 2nd exclusively residential, residential districts and urbanization control areas.

2) Data group 2 : the data of commercial and neighborhood commercial districts.

3) Data group 3 : the data of industrial and quasi-industrial districts

4.2.4 Functional form of the hedonic function

Land price can be described as function of one or more explanatory variables. Actually, we do not know the appropriate functional form for the land price function. If the functional form is not correctly specified, then, the second step estimation may be seriously biased. In view of this, Halvorsen and Pollakowski (1981) recommended the Box-Cox flexible functional form (Box and Cox, 1964) for the hedonic analysis and for measuring the best performance with a goodness of fit test. Since we do not have any prior notions about the shape of the hedonic land price function, we use the Box-Cox functional form because many familiar forms such as linear, semi-log, log linear, and trans-log are subsets of the Box-Cox functional form. The functional form of the Box-Cox transformation function is written as follows.

$$P^{(\lambda_0)} = a_1 + \sum_{i=1}^{m} a_i h_i^{(\lambda_i)} + \varepsilon \qquad (4\text{-}1)$$

where :

$$P^{(\lambda_0)} = \begin{cases} (P^{\lambda_0} - 1)/\lambda_0 & \lambda_0 \neq 0 \\ \ln(P) & \lambda_0 = 0 \end{cases}$$

$$h_i^{(\lambda_i)} = \begin{cases} (h^{\lambda_i} - 1)/\lambda_i & \lambda_i \neq 0 \\ \ln(h_i) & \lambda_i = 0 \end{cases}$$

In (4-1), F is a dependent variable, h_i is a set of independent variables, λ_0 , λ_i , a_1 and a_i are parameters of the function and ε is a normal random error. In this study, the land price corresponds to F and the land attributes correspond to h_i' s.

4.2.5 Selecting appropriate independent variables for the hedonic land price function

The hedonic price function using a somewhat ad hoc process was extensively tested for selecting appropriate independent variables. This variable-reduction process focused on eliminating high variable correlation by the inspection of the correlation matrix and increasing the adjusted coefficient of determination. The signs of the coefficients were checked and the significant levels of the coefficients were also checked by the t values of the coefficients.

A reduced variable function that appeared most robust was finally determined through the variable-reduction process. Finally, the selected variables for the hedonic land price function were "Time distance to the CBD", "Distance to the nearest station", "Urban gas and sewer service conditions", "Zoning types", and "Administration boundary". The selected variables were collected and generated in GIS.

4.3 Collecting and generating land attributes in GIS

4.3.1 Time distance to the CBD

There are two maps for "Time distance to the CBD" : without the Joban New Line and with the Joban New Line. The map in figure 3 is the Voronoi map which includes time distance to the CBD without Joban New Line and the map in figure 4 with the Joban New Line.

4.3.2 Distance to the nearest station

There are two maps for "Distance to the nearest station" : without the Joban New Line and with the Joban New Line. In figure 5, the map includes distances to the nearest station without the Joban New Line and figure 6 contains distances to the nearest station with the Joban New Line.

4.3.3 Urban gas and sewer service conditions

The urban gas and sewer service conditions are managed by polygons with attributes (whether such services exist or not) in GIS. The map including urban gas and sewer service conditions is not shown in this paper.

4.3.4 Zoning types

Zoning types are managed by polygons including the attributes of zoning types in GIS. In this study, there are eight zoning types : the 1st exclusively residential; the 2nd exclusively residential; residential; commercial; neighborhood commercial; quasi-industrial; industrial; and exclusive industrial districts in the urbanization promotion area. The urbanization control area is

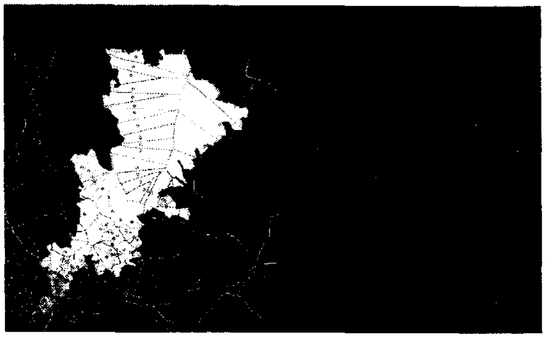

figure 3 Voronoi map without Joban New Line

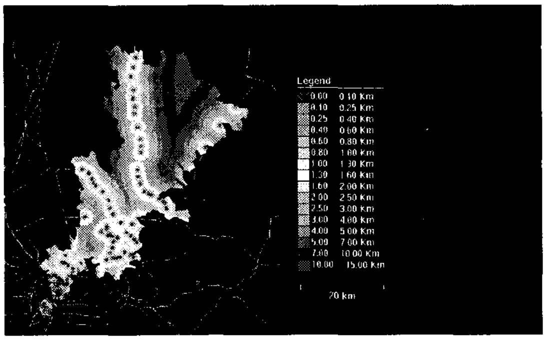

figure 5 Buffer map without the Joban New Line

figure 4 Voronoi map with the Joban New Line.

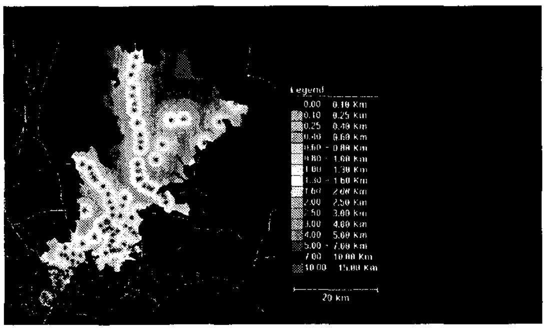

figure 6 Buffer map with the Joban New Line

also taken into consideration in this study. The map including zoning types is not shown in this paper.

4.3.5 Administration boundary

The administration boundaries are managed as polygons in GIS. In this study, there are two administration division attributes : inside and outside the city of Tokyo. The map including administration boundaries is not shown in this paper.

4.4 Homogenous conditions unit for statistical analysis

In the GIS-supported environment, homogenous conditions units with a table are easily and more accurately generated in their real locations by the GIS overlay function. In figure 7, the generating process of homogenous conditions units is shown.

4.5 Parameter values of the hedonic land price function

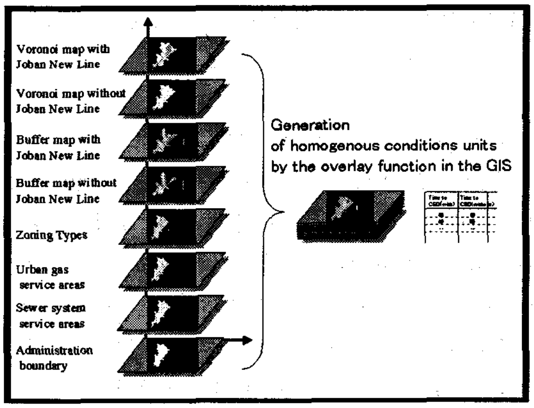

figure 7 Generating homogenous conditions units

In the Box-Cox functional form, there are two main ways of estimating parameter λ. One is to use the method of maximum likelihood for the proper choice of λ. By a grid search method, the maximum likelihood against several values of λ is calculated in the selected range (we look at λ's in the range (-2, 2) at first, and extend the range later as necessary). After calculating maximum likelihood estimators against several λ, the value of λ that corresponds

Table 1 Box-Cox transformed multi-linear function for data group 1

Parameter	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10
Parameter value	1.45	-5.93×10^{-2}	-4.04×10^{-1}	3.29×10^{-1}	6.10×10^{-1}	1.12	1.02	1.22	-3.14×10^{-1}	4.24×10^{-1}
t-value	15.6	-15.4	-12.9	2.99	0.91	15.7	6.84	10.3	-1.97	1.25
Coefficient of determination				0.773						
$\lambda_0=0.3$ $\lambda_2=1.0$ $\lambda_3=0.2$										
Functional form				$\frac{y^{\lambda_0}-1}{\lambda_0}=a_1+\sum_{i=2}^{3}a_i\frac{h_i^{\lambda_i}-1}{\lambda_i}+\sum_{i=4}^{10}a_i h_i$						

where :

y = Land price per square meter (10 thousand yen)

h1 =Constant value

h2 = Time distance to the CBD (minutes)

h3 = Distance to the nearest station (meters)

h4 = Gas service (Yes;e, No; 1)

h5 = Sewer system (Yes;e, No;1)

h6 = 1st Exclusive Residential districts (Yes;e, No;1)

h7 = 2nd Exclusively Residential districts (Yes;e, No;1)

h8 = Residential districts (Yes;e, No;1)

h9 = Urbanization control area (Yes;e, No;1)

h10 = Inside the city of Tokyo (Yes;e, No;1) to the peak value of the maximum likelihood estimator is selected. An alternative calculation is to select λ that maximizes the value of the coefficient of determination. It is conceptually simpler and easier to understand. Our study was carried out by the second method. In this study, 0.1 was used as the incremental interval value of λ for input. Concretely, -2.0, -1.9, -1.8, ⋯,1.8, 1.9, and 2.0 were used in the sequence. While determining the parameter λ , the other parameters of linear parts in the hedonic land price function were also determined simultaneously at the maximum point of the value of the coefficient of determination.

The estimated results of parameters for data group 1 are shown in Table 1. The estimated results of parameters for data group 2 and 3 are excluded in this paper. The signs of all estimated parameters have the expected sign and the coefficients of determination are considered to be significant for establishing the hedonic price function. Following the *t* values in Table 1, most of the coefficients are significant at the 5% level. Especially, in the case of the coefficient of "sewer system", the relatively low level of significance is acceptable. Actually, the condition of "sewer service" will have no significant effect in determining land prices in the metropolitan Tokyo.

4.6 Parameter values of the utility function

To estimate utility function in this study, we assumed an explicit utility function for households GCES (generalized constant elasticity of substitution) form (see (2-5))

Table 2 reports the estimated parameters of GCES utility function for data group 1. The

Table 2 GCES Utility Function Parameters for data group 1

Parameter	$\alpha 1$	$\alpha 2$	$\alpha 3$	$\alpha 4$	$\alpha 5$	$\alpha 6$	$\alpha 7$	$\alpha 8$	$\alpha 9$	$\alpha 10$	α_S
Parameter value	0.453	-0.008	-0.148	0.022	0.003	0.084	0.079	0.092	-0.020	0.030	0.032
t-value	3.025	-1.425	-1.721	2.671	2.423	2.546	2.459	2.581	-2.211	2.197	1.653

Parameter	$\gamma 1$	$\gamma 2$	$\gamma 3$	$\gamma 4$	$\gamma 5$	$\gamma 6$	$\gamma 7$	$\gamma 8$	$\gamma 9$	$\gamma 10$	γ_S
Parameter value	0.419	0.881	0.197	1.013	1.011	0.926	0.913	0.928	1.072	1.009	1.036
t-value	3.487	2.722	1.603	4.245	3.504	3.620	3.316	3.712	2.834	2.801	1.935

Parameter	$\varepsilon 1$										
Pparameter value	0.358										
t-value	77.797										
Coefficient of determination			0.9934								
Functional Form			$U=\sum_{i=1}^{10}\alpha_i h_i^{\gamma_i}+\alpha_S s^{\gamma_S}+X^{\varepsilon}$								

where :

h1 = Constant value

h2 = Time distance to the CBD (minutes)

h3 = Distance to the nearest station (meters)

h4 = Gas service (Yes;e, No;1)

h5 = Sewer system (Yes;e, No;1)

h6 = 1st Exclusive Residential districts (Yes;e, No;1)

h7 = 2nd Exclusive Residential districts (Yes;e, No;1)

h8 = Residential districts (Yes;e, No;1)

h9 = Urbanization control areas (Yes;e, No;1)

h10 = Inside the cityof Tokyo (Yes;e, No;1)

s = lot size (square meters)

X = Composite goods (10 thousands yen)

signs of all estimated parameters of GCES function have the expected sign. The adjusted coefficients of determination are also thought to be significant in establishing GCES function. Following the t values in Tables 2, most of the coefficients are significant at the 5 % level.

By using the estimated utility function, we can estimate benefit as CV and EV in establishing the Joban New Line project (see (2-14) and (2-15)).

4.7 Estimation of aggregate benefits

The aggregate benefits of the Joban New Line as a new urban railway system have been estimated by using the estimated hedonic price function and utility function. The benefits of each site on the studied areas have also been estimated at their respective locations. The benefits estimated by the proposed system have been expressed as both numerical outputs and graphical outputs in the form of map. (see Table 3 and figure 8 and 9).

The aggregate benefits in terms of money price over all the areas affected by the Joban New Line are about 25 trillion yen by the simple hedonic approach (see Table 3 and figure 8), while by Rosens approach, the benefits of the same railway project are estimated as CV and EV (see Table 3, figure 9. The map for EV is not shown in this paper.). The aggregate benefits as CV and EV over all the affected areas are about 17 trillion yen.

Considering the fact that the simple hedonic approach will overestimate the benefits, the amount of estimated benefits is considered to be the maximum bound of the benefit of the new urban railway system project. The amount of CV and EV of Rosen's two step approach isconsidered to be the minimum bound in the proposed system.

Table 3 Benefit estimated by the simple hedonic and Rosen two step approaches

Types	Concrete types	Increased land price (Unit : trillion yen)	CV (Unit : trillion yen)	EV (Unit : trillion yen)	Average land price per m² (Unit : 10,000 yen)	Area (ha)
Urbanization Promotion area	The 1st exclusively residential district	1.95	1.420	1.443	12.9	2782.29
	The 2nd exclusively residential district	2.15	1.611	1.632	13.2	3533.61
	Residential district	3.52	2.782	2.847	10.8	6109.15
	Commercial district	3.28	2.864	2.433	136.2	546.62
	Neighborhood commercial district	1.03	0.807	0.850	41.9	479.93
	Industrial district	2.46	1.887	2.002	15.2	2567.84
	Quasi-industrial district					
Urbanization control area		10.20	5.465	6.077	1.4	53313.36
Total		24.59	16.863	17.283	-	69332.80

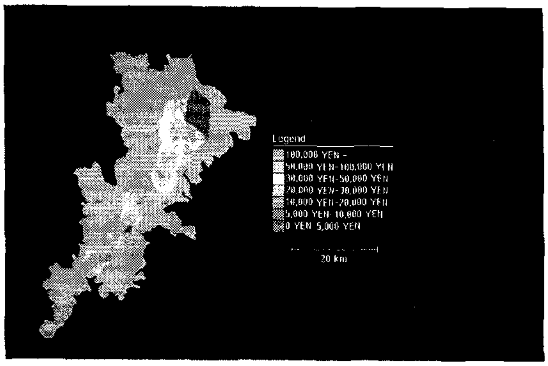

figure 8 Map for increased land price estimated by the simple hedonic approach

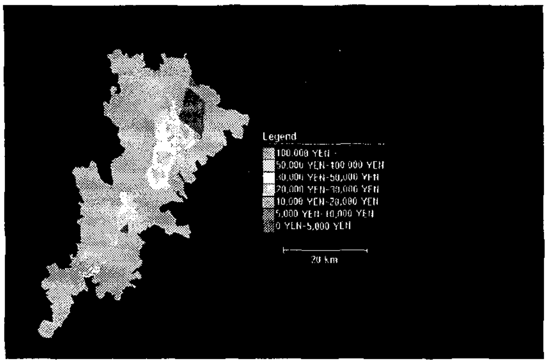

figure 9 Map for CV estimated by the Rosen's two step approach

5. CONCLUSIONS

By incorporating benefit evaluation routines into GIS, the proposed system provides a useful tool within one environment for the benefit evaluation of infrastructure improvements. The information on land attributes necessary for the benefit evaluation approaches was efficiently collected and generated in the GIS-supported environment. The burden of collecting and coding spatial information was considerably reduced in the developed system.

The aggregate benefits of the Joban New Line were estimated and the benefit of each site was concretely pinpointed and objectively estimated at a real location.

In the proposed system, the benefits of the studied infrastructure are estimated by two approaches. The project is evaluated by the minimum bound and maximum bound of its improvement gains. Consequently, the proposed system can suggest appropriate evaluation indications for more reasonable and objective evaluation of the studied project.

Considering the difficulty of financially estimating the benefits of infrastructure improvements, the proposed system has indeed done the job reasonably well. The benefits of the new urban railway system project, as a case study, have been efficiently estimated in the GIS-aided environment.

However, the important point to be emphasized here is not only that the benefits of the Joban New Line have been efficiently estimated but the proposed system holds the potential for wider practical applications. This result also suggests the intrinsic usefulness of GIS for high-level applications.

ACKNOWLEDGEMENTS

The author wishes to thank anonymous referees for their helpful comments on an earlier draft. The author, however, are solely responsible for remaining shortcomings.

REFERENCES

1. Box, G. and D. Cox, (1964) An analysis of transformations, J. Roy. Statist. Soc. Ser. B, 26, pp. 211-243.

2. Ellickson, B., (1981) An alternative test of the hedonic theory of housing markets, J. Urban Economics, 9, 56-79.
3. Halvorsen, R. and Pollakowski, H. O. (1981) Choice of functional form for hedonic price equations, J. Urban Economics, 10, 37-49.
4. Harrison, D., and D.Rubinfeld (1978) Hedonic housing prices and the demand for clean air, Environ. Econo. and Management, 5, pp.81-102.
5. Hoerl, A.E. and R. W. Kennard, (1970 a) Ridge regression: biased estimation for nonorthogonal problems, Techrometrics, 12, pp. 55-67.
6. Hoerl, A.E. and R. W. Kennard, (1970 b) Ridge regression : application to nonorthogonal problems, Techrometrics, 12, pp. 69-82.
7. Kanemoto, Y. (1988). Hedonic prices and the benefits of public projects, Econometrica, 56/4, pp.981-989.
8. Kanemoto,Y. and R. Nakamura (1986) A new approach to the estimation of structural equations in hedonic models, Department of Business and Economics, Kinki Univ.,Academic Press.
9. Mittermayer, E. (1972) A generalization of the least squares method for the adjustment of freenetworks, Bull. of Geodesique, 104, 139-157.
10. Peuquet, D. J. and D. F. Marble (1990) Introductory readings in geographic information systems, Taylor & Francis ltd.
11. Quigley, J. M. (1982) Nonlinear budget constrains and consumer demand: An application to public programs for residential housing, J. Urban Econ., 12, pp.177-210.
12. Ridker, R. G. and J. A. Henning, (1967) The determinants of residential property value with special references to air pollution, Review of Economics and Statistics, 64, pp. 246-255.
13. Rosen, J. (1974) Hedonic prices and implicit markets : product differentiation in pure competition, J. Polit. Econo., 82, pp.34-55.
14. Scotchmer, S., (1985) Hedonic prices and cost/benefit analysis, J. Economic Theory, 37, pp.55-75.
15. Scotchmer, S., (1986) The short-run and long-run benefits of environmental improvement, J. Pub. Econo., 30, pp.61-81.