THE BENEFIT EVALUATION OF URBAN TRANSPORTATION IMPROVEMENTS WITH COMPUTABLE URBAN ECONOMIC MODEL

Akiyoshi TAKAGI
Department of Planning, Nakanihon Engineering Consultants Co., Ltd.
Nishiki 1-8-6, Naka-ku, Nagoya, Aichi 460-0003, JAPAN

Shinichi MUTO
Department of Civil Engineering, Gifu University
Yanagido 1-1, Gifu 501-1193, JAPAN

and

Taka UEDA
Department of International Development Engineering, Tokyo Institute of Technology
Ookayama 2-12-1, Meguro-ku, Tokyo 152-8552, JAPAN

Abstract – Recently, the environmental problems and external diseconomy issues caused by the automobile in urban transportation are intensifying. Although the improvement projects to solve such problems for the transport system are proposed, the policies exert influences not only on the transportation system but also the location system. In this paper, we propose the socioeconomic model based on the urban economics, called for the computable urban economic (CUE) model, in which the mechanism of the demand and supply in the land market is modeled clearly and the mutual relation between the transport and locating behavior is considered. An application to the Japanese City with the CUE model is shown, and the usefulness of the model is expressed for the actual analysis.

1. INTRODUCTION

Recently, the environmental problems such as the air pollution or noise, and external diseconomy issues such as traffic accident or road congestion caused by the automobile in the urban transportation are intensifying. The improvement projects to solve such problems for the transport system are proposed, for example the improvement of road traffic networks, introduction of the light rail transit and the inflow regulation. Although these policies only exert influences on the transport system in short term, it is conceivable that they also give the impacts to the locating pattern through the change of their economic activities in the long run.

There are some studies that treat the interaction between the transportation and location. However, in those studies, the theoretical adjustability between the transportation and location is not necessarily kept. The reason is that the transportation and location are thought to be different activities fundamentally. For example, Miyagi (1989) constructed the transportation equilibrium model in that the population was decided endogenously and predicted changes not only of the transport system but also the locating pattern when the policy was carried out. But, in that model, the behavior principle for the location was not explained sufficiently. On the other hand, in the field of the economics, the evaluation of transport improvements has been conducted by using the urban economic model in that the locating behavior is formulated in full [Henderson(1985)]. However the transport behavior model was not exact enough for the actual analysis.

In this paper, we construct the spatial economic model based on the urban economics. It is the reason of adopting the urban economic model that the mechanism of the demand and supply in the land market is modeled clearly, because the land market plays an important role in Japan that is narrow country. Furthermore the transport behavior is also formulated based on the economic behavior principle. So, in this model, the interaction between the transport and locating behavior is considered to be consistent.

We try to apply the spatial economic model that we built for actual analysis. In this meaning, this model also should be correspond to the simulation analysis, so we make to call this model a computable urban economic model, in other words CUE model. By showing the example applied the CUE model to the Japanese City, we express the usefulness of the model for the actual analysis.

2. STRUCTURE OF THE CUE MODEL

2.1. Assumption

This model has the following major assumptions.

1) The society consists of the area (a) where the transport improvement is carried out emphatically, and the area (b) that is other, and the area (a) is divided in the zone of i pieces.
2) Four agents exist in the area i : household, firm defined by one person of employee, developer and absentee landowner (Fig.1).

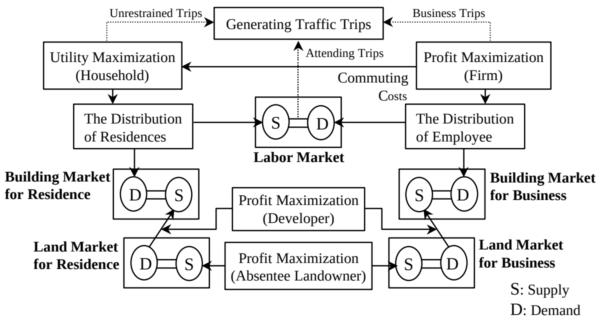

Fig.1 Mutual relation of the agents in the zone i of the area (a)

3) The land and building are dealt to a different piece, they compose of the residence type and business type individually.

2.2 The Behavior of Agents

The locating and transport behavior of each agent (household and employee) is made formality. Although the transport behavior model is possible formalization similarly for both of the household and employee, the location model is not possible. So, on the location model, the formalization for the household and the employee are shown.

2.2.1 Location Equilibrium Model

Household

At first, the household chooses the area (a) or (b), and, next, the household who chooses the area (a) decides the selection of zones i for the residence. This behavior model can be expressed as a mathematical optimization problem like the following.

$$S^{HA} = \max_{\Phi_{a,i}^{HZ}, P_l^{HA}} \left[Z^{HZ}\left(\Phi_{a,i}^{HZ}, P_l^{HA}\right) + P_b^{HA} \cdot S_b^{HA} - \frac{1}{q^{HA}} \sum_l \left\{ P_l^{HA} \cdot \ln P_l^{HA} \right\} \right] \quad (1a)$$

$$\text{s.t.} \ \sum_l P_l^{HA} = 1 \ , \quad \sum_i \Phi_{a,i}^{HZ} = P_a^{HA} \quad (1b)$$

$$Z^{HZ} = \sum_i \Phi_{a,i}^{HZ} \cdot V_{a,i}^{Z} - \frac{1}{q^{HZ}} \sum_i \left[\Phi_{a,i}^{HZ} \cdot \ln \frac{\Phi_{a,i}^{HZ}}{P_l^{HA}} \right] \quad (1c)$$

Where, S^{HA} : inclusive expected utility on the location behavior for the residence, P_l^{HA} : probability of locating in the area l ($= a$ or b), S_b^{HA} : utility level of the household locating in the area b (constant), i : a label for zone, $\Phi_{a,i}^{HZ} : = P_a^{HA} \cdot P_{a,i}^{HZ}$, $P_{a,i}^{HZ}$: probability of locating in the zone i of the area a , $V_{a,i}^{Z}$: utility level of the household locating in the zone i of the area a and q^{HA}, q^{HZ} : logit parameter.

The objective function of (1) is the entropy on the locating selection of the area, and Z^{HZ} is the entropy on the locating selection of the zone. The programming in (1) yields to the each probability of locating.

The probability of locating in the area l *:* P_l^{HA}

$$P_a^{HA} = \frac{1}{1 + \exp q^{HA} \left[S_b^{HA} - \frac{1}{q^{HZ}} \ln \sum_i \exp q^{HZ} V_{a,i}^{Z} \right]} \quad (2a)$$

The probability of locating on the zone i *:* $P_{a,i}^{HZ}$

$$P_{a,i}^{HZ} = \frac{\exp q^{HZ} V_{a,i}^{Z}}{\sum_i \exp q^{HZ} V_{a,i}^{Z}} \quad (2b)$$

Substituting the equation (2) into (1a), the inclusive expected utility on the stage of choosing the zone S_a^{HZ} and the one on the stage of choosing the area S^{HA} are obtained as follow.

$$S_a^{HZ} = \frac{1}{q^{HZ}} \ln \sum_i \exp q^{HZ} V_{a,i}^{Z} \quad (3a)$$

$$S^{HA} = \frac{1}{q^{HA}} \ln\left[\exp q^{HA} S_b^{HA} + \exp q^{HA} S_a^{HZ} \right] \quad (3b)$$

$V_{a,i}^{Z}$ of equation (2b) is guided from the formulation of the household's consuming behavior. Here, it is assumed that the household takes the utility maximization behavior under the budget constraint, and the formulation is conducted as follows.

$$V_{a,i}^{Z} = \max_{z_i, a_i, x_i, s_i} \left[U_{a,i}^{Z}\left(z_i, a_i, x_i, s_i\right) + m \cdot g\left(f_i\right) \right] \quad (4a)$$

$$\text{s.t.} \ z_i + r_i a_i + q_i x_i + w s_i = w \left[T_i - \frac{\sum_{j \in I} n_{ij} t_{ij}}{N_i} \right] + y_i \quad (4b)$$

Where, $U_{a,i}^{Z}$: direct utility of the household locating in the zone i of the area a , z_i : consumption of the composite commodity, a_i : consumption of housing service, x_i : consumption of unrestraint trip, s_i : consumption of leisure, $g\left(f_i\right)$: external diseconomies level which is dependent on traffic flow f_i , r_i : residential housing lent, q_i : generalized price of unrestraint trip, w : wage (constant), T_i : total available time, y_i : property income, n_{ij} : number of household who lives in zone i and works in zone j , t_{ij} : transport time between zone i and j , N_i : number of household in zone i .

It is considered that the household's total income is expressed with the total value of the total wage income, the property income and the average commuting time loss.

Solving (4), we obtain the consuming volume for z_i, a_i, x_i and s_i.

$$z_i = z_i\left(r_i, q_i, y_i\right) \tag{5a}$$

$$a_i = a_i\left(r_i, q_i, y_i\right) \tag{5b}$$

$$x_i = x_i\left(r_i, q_i, y_i\right) \tag{5c}$$

$$s_i = s_i\left(r_i, q_i, y_i\right) \tag{5d}$$

And we also obtain the utility level $V_{a,i}^Z$ by substituting (5) into (4a).

$$V_{a,i}^Z = V_{a,i}^Z\left(r_i, q_i, y_i, g\right) \tag{6}$$

Furthermore, when we substitute equation (6) into (2) and (3), each probability of locating is obtained. The generalized price of unrestraint trip q_i is decided through the later transport behavior model.

Firm (Employee)

It is possible to formulate even the locating behavior of the firm similar to household's one. But, we should formulate by the profit maximization behavior in the firm's formulization, comparing with the part done by the utility maximization behavior in household's formulization. Therefore, it should be replaced $V_{a,i}^Z$ in formulation (1) to the firm profit $\Pi_{a,i}^Z$, and the each probability of locating of the firm is requested as follows.

The probability of locating in the area l: P_l^{FA}

$$P_a^{FA} = \frac{1}{1+\exp q^{FA}\left[S_b^{FA} - \dfrac{1}{q^{FZ}}\ln\sum_i \exp q^{FZ}\Pi_{a,i}^Z\right]} \tag{7a}$$

The probability of locating on the zone i: $P_{a,i}^{FZ}$

$$P_{a,i}^{FZ} = \frac{\exp q^{FZ}\Pi_{a,i}^Z}{\sum_i \exp q^{FZ}\Pi_{a,i}^Z} \tag{7b}$$

Where, P_l^{FA}: probability of locating in the area l ($=a$ or b), S_b^{FA}: profit of the firm locating in the area b (constant), $\Phi_{a,i}^{FZ}$: $= P_a^{FA}\cdot P_{a,i}^{FZ}$, $P_{a,i}^{FZ}$: probability of locating in the zone i of the area a, $\Pi_{a,i}^Z$: profit of the firm locating in the zone i of the area a and q^{FA}, q^{FZ}: logit parameter.

$\Pi_{a,i}^Z$ of equation (7) is introduced through the formulation of the firm's producing behavior. That is, it is assumed that the firm takes the profit maximization behavior under the producing technology constraint, and this is formulated as follows.

$$\Pi_{a,i}^Z = \max_{A_i, X_i}\left[Z_i - R_i A_i - Q_i X_i - wL_i - \frac{\sum_{j\in I} n_{ij}p_{ij}}{E_i}\right] \tag{8a}$$

$$\text{s.t.}\quad Z_i = Z_i\left(A_i, X_i\right) \tag{8b}$$

Where, $\Pi_{a,i}^Z$: profit of the firm locating in the zone i of the area a, Z_i: supply volume of the composite commodity, A_i : input volume of building for products, X_i: input volume of business trip, L_i: input time of labor, R_i: building lent for products, Q_i : generalized price of business trip, p_{ij} : commuting cost between zone i and j, E_i: number of employee in zone i.

In equation (8), it is considered the commuting cost as shared by the firm.

The solution of the programming (8) gives supply volume for Z_i, and input volumes for A_i, X_i.

$$Z_i = Z_i\left(R_i, Q_i\right) \tag{9a}$$

$$A_i = A_i\left(R_i, Q_i\right) \tag{9b}$$

$$X_i = X_i\left(R_i, Q_i\right) \tag{9c}$$

And firm profit is obtained.

$$\Pi_{a,i}^Z = \Pi_{a,i}^Z\left(R_i, Q_i\right) \tag{10}$$

Substituting equation (10) into (7), we obtain the each probability of locating of the firm.

The distribution of commuter trip

The number of household N_i who lives in zone i and the number of employee of firm E_i who works in zone i are obtained from the equation (3) and (8) in the location behavior model, respectively.

$$N_i = P_{a,i}^{HZ}\cdot P_a^{HA}N^T \tag{11}$$

Where, H: a label of household, N^T: total number of household (constant).

$$E_j = P_{a,j}^{FZ}\cdot P_a^{FA}E^T \tag{12}$$

Where, F: a label of firm, E^T: total number of employee (constant).

As for the commuter trip, it is considered the number of household N_i as the generating trip, and the number of employee E_i as the attracting trip. And by using the gravity model with double constraint, the distribution of commuter trip as follow,

$$N_i = P_{a,i}^{HZ}\cdot P_a^{HA}N^T \tag{13a}$$

$$m_i = \frac{1}{\sum_j n_j E_j\cdot\left(q'_{ij}\right)^{-r}},\quad n_j = \frac{1}{\sum_i m_i N_i\cdot\left(q'_{ij}\right)^{-r}} \tag{13b}$$

Where, q'_{ij}: average generalized price between zone i and j, m_i, n_j: parameters for adjustment, r : parameter.

2.2.2 Transportation Equilibrium Model

The transportation equilibrium model is conceivable as the programming that requests each selection probability for the destined zone, mode choice or route choice, to unrestrained trips guided in (5c) and business trips guided in (9c). This is expressed as the mathematical programming like the following.

$$S^D = \max_{\Phi_{ij,k,r}^K,\Phi_{ij,k}^S,P_{ij}^D} \left[\sum_j ZH_j^D\left(\Phi_{ij,k,r}^K,\Phi_{ij,k}^S,P_{ij}^D\right) - \frac{1}{q^D}\sum_j \left\{P_{ij}^D \cdot \ln P_{ij}^D\right\} \right] \quad (14a)$$

$$\text{s.t.} \sum_j P_{ij}^D = 1,\ \sum_k \Phi_{ij,k}^S = P_{ij}^D,\ \sum_r \Phi_{ij,C,r}^K = \Phi_{ij,C}^S,$$

$$\Phi_{ij,C,r}^K \geq 0,\ x_a = \sum_j \sum_r X_{ij,C}\Phi_{ij,C,r}^K d_{ij,ar} \quad (14b)$$

$$ZV_j^D = \sum_k ZH_k^S - \frac{1}{q^S}\sum_k \left\{\Phi_{ij,k}^S \cdot \ln \frac{\Phi_{ij,k}^S}{P_{ij}^D}\right\} \quad (14c)$$

$$ZV_k^S = \sum_r ZH_r^K - \frac{1}{q^K}\sum_r \left\{\Phi_{ij,k,r}^K \cdot \ln \frac{\Phi_{ij,k,r}^K}{\Phi_{ij,k}^S}\right\} \quad (14d)$$

$$ZH_r^K = -\Phi_{ij,C,r}^K\, p_{ij,C} - w\sum_a \int_0^{x_a} t_a(w)dw \quad (14e)$$

Where, ij : a label of OD pair, k : a label of transport mode ($k = k'$: the public transportation, $k = C$: automobile transportation), r : a label of path, P_{ij}^D : probability of choosing the destined zone j, $\Phi_{ij,k}^S$: probability of choosing the mode k, $\Phi_{ij,C,r}^K$: probability of choosing the path r for automobile transportation C, x_a : traffic volume of link a, $X_{ij,C}$: automobile trip between the zone i and j, $d_{ij,ar}$: link-path incidence matrix, $p_{ij,C}$: automobile cost, t_a : automobile time of link a, q^D, q^S, q^K : logit parameter.

The objective function of (14) is the entropy on choosing the destined zone, and ZV_j^D, ZV_k^S is the entropy on choosing the mode and path, respectively. And the first part of ZH_r^K is expected users' cost of automobiles, and the second is the integration form of link-cost function in the user equilibrium model. The solution of the programming (14) yields to the probability at each stage for P_{ij}^D, $P_{ij,k}^S$ and $P_{ij,C,r}^K$, respectively.

$$P_{ij}^D = \frac{\exp\left[q^D \cdot S_{ij}^S\right]}{\sum_j \exp\left[q^D \cdot S_{ij}^S\right]} \quad (15a)$$

Where, $S_{ij}^S = \frac{1}{q^S}\ln\sum_k \exp\left[q^S \cdot S_{ij,k}^K\right]$ (15b)

$$S_{ij,k'}^K = -q_{ij,k'}^K,\ S_{ij,C}^K = \frac{1}{q^K}\ln\sum_r \exp\left[q^K q_{ij,C,r}^K\right] \quad (15c)$$

$$q_{ij,C,(r)}^K = p_{ij,C} + w \cdot t_{ij,C,(r)} \quad (15d)$$

$$P_{ij,k}^S = \frac{\exp\left[q^S \cdot S_{ij,k}^K\right]}{\sum_k \exp\left[q^S \cdot S_{ij,k}^K\right]} \quad (16)$$

$$P_{ij,C,r}^K = \frac{\exp\left[-q^K \cdot q_{ij,C,r}^K\right]}{\sum_r \exp\left[-q^K \cdot q_{ij,C,r}^K\right]} \quad (17)$$

Where, S_{ij}^S is the inclusive expected utility on the stage of choosing mode. As for $S_{ij,k}^K$, in the public transportation sector, it is defined with its generalized cost, and in the automobile transportation, it defined by the inclusive expected utility on the stage of choosing path. Where, $q_{ij,k,(r)}^K$ is meaning the generalized cost of mode k.

The above programming also yields to the generalized cost for the unrestrained trip q_i.

$$q_i = \sum_j q_{ij}^D \exp\left(S_{ij}^S - S_i^D\right) \quad (18a)$$

Where, $q_i = \sum_j q_{ij}^D \exp\left(S_{ij}^S - S_i^D\right)$ (18b)

$$q_{ij,k}^S = \sum_r q_{ij,C,r}^K \exp\left(-q_{ij,C,r}^K - S_{ij,C}^K\right). \quad (18c)$$

The generalized cost for the business trip Q_i is guided similarly.

2.3 The Behavior of the Developer

The developer supplies the buildings for the residence or for the business through the profit maximization behavior by inputting the capital k_i and the land l_i. The behavior is formulated like a follow mathematical programming.

$$p_i = \max_{as_i}\left[r_i as_i - c(as_i)\right] \quad (19a)$$

$$\text{s.t.}\quad c(as_i) = \min\left(r_i^L\, l_i + h\, k_i\right) \quad (19b)$$

$$as_i = as_i(l_i, k_i) \quad (19c)$$

Where, p_i : profit of developer, as_i : supplied volume of buildings for the residence, $c(as_i)$: cost of supply buildings for the residence, r_i^L : rent of buildings for the residence, h : price of capital.

The solution of the profit maximization in (19) leads to the supplied volume, input volume of land and profit function for as_i, l_i and p_i.

$$as_i = as_i\left(r_i, r_i^L\right) \quad (20a)$$

$$l_i = l_i\left(r_i, r_i^L\right) \quad (20b)$$

$$p_i = p_i\left(r_i, r_i^L\right) \quad (20c)$$

The supplying behavior of buildings for the business is also formulated similarly.

2.4 The Behavior of the Absentee Landowner

The absentee landowner supplies the land for the developer under the land supply function like the following.

$$l_i^S = \overline{l_i^S}\left(1 - \frac{s_i}{r_i^L}\right) \quad (21)$$

Where, l_i^S : supplied volume of land for the residence, $\overline{l_i^S}$: Supply capacity of land for the residence, s_i : parameter.

As for the land for the business, it is formulated with one for the residence similarly.

2.5 Equilibrium Conditions

2.5.1 Location Equilibrium Condition

We have expressed the probabilities of locating selection of households in equation (2). So the location equilibrium condition is shown as follow.

$$N^T = \sum_i N_i^a + N^b \tag{22a}$$

Where, $N_i^a = N^T \cdot P_a^{HA} \cdot P_{a,i}^{HZ}$ (22b)

$$N^b = N^T \cdot P_b^{HA} . \tag{22c}$$

As for firms, by using equation (7), the location equilibrium condition is also shown as follow.

$$E^T = \sum_i E_i^a + E^b \tag{23a}$$

Where, $E_i^a = E^T \cdot P_a^{FA} \cdot P_{a,i}^{FZ}$ (23b)

$$E^b = E^T \cdot P_b^{FA} . \tag{23c}$$

2.5.2 Market Equilibrium Conditions

The markets that we treat clearly are the building market and land market in this model. Because we have modeled distinguishing for the residence and the business, the market equilibrium conditions are also expressed individually, like a follow.

For the Residence

$$as_i\left(r_i, r_i^L\right) = N_i^a a_i\left(r_i\right) \tag{24a}$$

$$l_i^S\left(r_i^L\right) = l_i\left(r_i, r_i^L\right) \tag{24b}$$

For the Business

$$AS_i\left(R_i, R_i^L\right) = E_i^a A_i\left(R_i\right) \tag{25a}$$

$$L_i^S\left(R_i^L\right) = L_i\left(R_i, R_i^L\right) \tag{25b}$$

Where, AS_i : supplied volume of buildings for the business, R_i^L : rent of buildings for the business, L_i^S : supplied volume of land for the business, L_i : demands of land for the business.

As for the labor market, this model doesn't have the structure where the wage is determined by the market equilibrium condition, because the wage is given constant. But, here, the distribution of commuter trips has been formulated by the gravity model with double constraint, and it allow the household to alter the zone to live or to attend. So we are interpreting that the equilibrium in the labor market is satisfied substitutively with this formulation.

3. DEFINITION OF BENEFITS AND BENEFIT INCIDENCE TABLE

3.1 Definition of Benefits

In this paper, it is considered that the urban transport improvement project is carried out. The benefits of the project are defined by EV that means equivalent variation. The EV is interpreted as the value evaluating an increase of the household's utility by the project in monetary terms.

We have obtained the utility level of the household for each zone of area (a), in equation (6). In addition to it, We have introduced the inclusive expected utility in equation (4a) that means the average utility level of every household locating in area (a). So EV becomes possible to be defined by two types corresponding with each utility level.

Zone Contingent EV (ZCEV)

EV defined by the utility level of the household for each zone is being called the zone contingent EV with the meaning that is defined for each zone. It is shown as follows.

$$V_{a,i}^{Z\,B} = V_{a,i}^{Z}\left(r_i^A, q_i^A, y_i^A + ZCEV_i, g^A\right) \tag{26}$$

Non Contingent EV (NCEV)

EV depending on the inclusive expected utility is called the non contingent EV with the meaning that is not limited the zone. We obtain the defined equation as follows.

$$S_a^{HZ} = \frac{1}{q^{HZ}} \ln \sum_i \exp\left\{q^{HZ} V_{a,i}^Z\left(r_i^A, q_i^A, y_i^A + NCEV, g^A\right)\right\} \tag{27}$$

3.2 Benefit Incidence Table

3.2.1 Differentiation Forms of Utility and Profit Function

Before making the benefit incidence table, we should introduce the total differentiation forms of the utility and the profit function.

Utility Function

The inclusive expected utility S^{HZ} obtained in (3) is able to be interpreted the utility level of households, in this model. The infinitesimal change of S^{HZ} is guided as follows.

$$dS^{HZ} = \frac{\partial S^{HZ}}{\partial V_{a,i}^Z} dV_{a,i}^Z = P_{a,i}^{HZ} dV_{a,i}^Z . \tag{28}$$

Where, we utilized the relation of $\partial S^{HZ} / \partial V_{a,i}^Z = P_{a,i}^{HZ}$ to this transformation.

The indirect utility function $V_{a,i}^Z$ in equation (28) is shown in (7), so its infinitesimal change form is introduced from the envelope theorem as follow.

$$dV_{a,i}^Z = \left[l^{HZ} \left\{ -a_i dr_i - x_i dq_i - w \cdot d\left(\frac{\sum_{j \in I} n_{ij} t_{ij}}{N_i} \right) + dy_i \right\} + \frac{\partial V_{a,i}^Z}{\partial g} dg \right] \tag{29}$$

Where, l^{HZ} : lagrangian multiplier on the utility maximization programming.

$-l^{HZ} x_i dq_i$ in equation (29) means the change of household's utility level on the stage of consuming the

Table 1.　Benefit Incidence Table

	Transport Firm	Zone i			Total
		Household	Firm	Landowner	
Investment into Infrastructure	$-dC$				$-dC$
Transport Revenue	$\sum_i \left[\Phi^{HZ}_{a,i} N^T \sum_j \left\{\Phi^{HK}_{ij,k'} d\left(x_i p_{ij,k'}\right)\right\}\right]$ $+\sum_i \left[\Phi^{FZ}_{a,i} E^T \sum_j \left\{\Phi^{FK}_{ij,k'} d\left(X_i p_{ij,k'}\right)\right\}\right]$				$\sum_i \left[\Phi^{HZ}_{a,i} N^T \sum_j \left\{\Phi^{HK}_{ij,k'} d\left(x_i p_{ij,k'}\right)\right\}\right]$ $+\sum_i \left[\Phi^{FZ}_{a,i} E^T \sum_j \left\{\Phi^{FK}_{ij,k'} d\left(X_i p_{ij,k'}\right)\right.\right.$
User Benefit of mode k'		$-\Phi^{HZ}_{a,i} N^T \cdot \sum_j \left(\Phi^{HK}_{ij,k'} x_i dp_{ij,k'}\right)$	$-\Phi^{FZ}_{a,i} E^T \cdot \sum_j \left(\Phi^{FK}_{ij,k'} X_i dp_{ij,k'}\right)$		$-\sum_i \left\{\Phi^{HZ}_{a,i} N^T \sum_j \left(\Phi^{HK}_{ij,k'} x_i dp_{ij,k'}\right)\right\}$ $-\sum_i \left\{\Phi^{FZ}_{a,i} E^T \sum_j \left(\Phi^{FK}_{ij,k'} X_i dp_{ij,k'}\right)\right]$
Time Saving Benefit of mode k'		$-\Phi^{HZ}_{a,i} N^T \cdot \sum_j \left(\Phi^{HS}_{ij,k'} x_i wdt_{ij,k'}\right)$	$-\Phi^{FZ}_{a,i} E^T \cdot \sum_j \left(\Phi^{FS}_{ij,k'} X_i wdt_{ij,k'}\right)$		$\sum_i \sum_j \left(\Phi^{HK}_{ij,C,r} x_i wdt_{ij,C,r}\right)$ $+\sum_i \sum_j \left(\Phi^{FK}_{ij,C,r} X_i wdt_{ij,C,r}\right)$
Time Saving Benefit of Automobile		$-\Phi^{HZ}_{a,i} N^T \cdot \sum_j \left(\Phi^{HK}_{ij,C,r} x_i wdt_{ij,C,r}\right)$	$-\Phi^{FZ}_{a,i} E^T \cdot \sum_j \left(\Phi^{FK}_{ij,C,r} X_i wdt_{ij,C,r}\right)$		$\sum_i \sum_j \left(\Phi^{HK}_{ij,C,r} x_i wdt_{ij,C,r}\right)$ $+\sum_i \sum_j \left(\Phi^{FK}_{ij,C,r} X_i wdt_{ij,C,r}\right)$
Average Commuter Cost Saving Benefit	$\sum_i \left[\Phi^{FZ}_{a,i} E^T \cdot d\left(\frac{\sum_j n_{ij} p_{ij}}{E_i}\right)\right]$		$-\Phi^{FZ}_{a,i} E^T \cdot d\left(\frac{\sum_j n_{ij} p_{ij}}{E_i}\right)$		0
Average Commuter Time Saving Benefit		$-\Phi^{HZ}_{a,i} N^T \cdot wd\left(\frac{\sum_j n_{ij} t_{ij}}{N_i}\right)$			$-\sum_i \left[\Phi^{HZ}_{a,i} N^T \cdot d\left(\frac{\sum_j n_{ij} t_{ij}}{N_i}\right)\right]$
Change of land rent		$-\Phi^{HZ}_{a,i} N^T \cdot a_i dr_i$	$-\Phi^{FZ}_{a,i} E^T \cdot A_i dR_i$	$\Phi^{HZ}_{a,i} N^T \cdot a_i dr_i$ $+\Phi^{FZ}_{a,i} E^T A_i dR_i$	0
Change of Externalities		$\frac{\partial V^Z_{a,i}}{\partial g} dg$			$\frac{\partial V^Z_{a,i}}{\partial g} dg$
Total	$-dC$ $+\sum_i \left[\Phi^{HZ}_{a,i} N^T \sum_j \left\{\Phi^{HK}_{ij,k'} d\left(x_i p_{ij,k'}\right)\right\}\right.$ $+\Phi^{FZ}_{a,i} E^T \sum_j \left\{\Phi^{FK}_{ij,k'} d\left(X_i p_{ij,k'}\right)\right\}$ $\left.+\Phi^{FZ}_{a,i} E^T \cdot d\left(\sum_j n_{ij} p_{ij} / E_i\right)\right]$	$-\Phi^{HZ}_{a,i} N^T \cdot$ $\left[\sum_j \sum_{k'} \left(\Phi^{HK}_{ij,k'} x_i dp_{ij,k'}\right)\right.$ $-wd\left(\sum_j n_{ij} t_{ij} / N_i\right)$ $+\sum_j \sum_k \left(\Phi^{HK}_{ij,k,(r)} x_i wdt_{ij,k,(r)}\right)$ $\left.-a_i dr_i\right] + \partial V^Z_{a,i} / \partial g \cdot dg$	$-\Phi^{FZ}_{a,i} E^T \cdot$ $\left[\sum_j \sum_{k'} \left(\Phi^{FK}_{ij,k'} X_i dp_{ij,k'}\right)\right.$ $-d\left(\sum_j n_{ij} p_{ij} / E_i\right)$ $+\sum_j \sum_k \left(\Phi^{FK}_{ij,k,(r)} X_i wdt_{ij,k,(r)}\right)$ $\left.-A_i dR_i\right]$	$\Phi^{HZ}_{a,i} N^T \cdot a_i dr_i$ $+\Phi^{FZ}_{a,i} E^T A_i dR_i$	***SNB***

unrestraint trip. And we are able to transform this part by using the inclusive expected utility S^{HD} obtained from the consuming behavior model of unrestraint trips.

$$
\begin{aligned}
-x_i dq_i &= dS^{HD} \\
&= \sum_j x_i \frac{\partial S^{HD}}{\partial S^{HS}_{ij}} \frac{\partial S^{HS}_{ij}}{\partial S^{HK}_{ij,C}} \frac{\partial S^{HK}_{ij,C}}{\partial v^{HK}_{ij,C,r}} \left\{-wdt_{ij,C,r}\right\} \\
&\quad + \sum_j \sum_{k'} x_i \frac{\partial S^{HD}}{\partial S^{HS}_{ij}} \frac{\partial S^{HS}_{ij}}{\partial v^{HS}_{ij,k'}} \left\{-dp_{ij,k'} - wdt_{ij,k'}\right\} \\
&= \sum_j x_i \cdot \Phi^{HK}_{ij,C,r} \left\{-wdt_{ij,C,r}\right\} \\
&\qquad + \sum_j \sum_{k'} x_i \cdot \Phi^{HS}_{ij,k'} \left\{-dp_{ij,k'} - wdt_{ij,k'}\right\} \qquad (30)
\end{aligned}
$$

Profit Function

The total differentiation form of the profit function is requested like follow, such as the case of the utility function.

$$dS^{FZ} = \frac{\partial S^{FZ}}{\partial \Pi^Z_{a,i}} d\Pi^Z_{a,i} = P^{FZ}_{a,i} d\Pi^Z_{a,i} \qquad (31a)$$

Where,

$$d\Pi^Z_{a,i} = l^{FZ} \left\{ -A_i dR_i - X_i dQ_i - d\left(\frac{\sum_{j \in I} n_{ij} p_{ij}}{N_i} \right) \right\} \qquad (31b)$$

$$
\begin{aligned}
-X_i dQ_i &= dS^{FD} \\
&= \sum_j x_i \cdot \Phi^{HK}_{ij,C,r} \left\{-wdt_{ij,C,r}\right\} \\
&\qquad + \sum_j \sum_{k'} x_i \cdot \Phi^{HS}_{ij,k'} \left\{-dp_{ij,k'} - wdt_{ij,k'}\right\} \qquad (31c)
\end{aligned}
$$

Where, l^{HZ} : lagrangian multiplier on the profit maximization programming.

3.2.2 Benefit Incidence Table

Utilizing equations (28 through 31), the benefit incidence table of Table.1 is completed. The agent of developer is made an exception due to the simplification in Table.1.

4. MEASURING THE BENEFITS

4.1 Setting of the Application

We will apply the CUE model for measuring the benefits of the urban transport improvement project in a Japanese city. It is intended for Gifu City at Chukyo Area in Japan, that is, we pick up the whole area of Gifu City as the area (a) where the transport improvement is carried out emphatically, and the zone division of the area (a) makes 9 zones, shown in figure-2. We will evaluate the benefit of the case, in that the light rail transit (LRT) is introduced in order to reduce the various problems caused by automobile transportation. Yet, due to the simplification, the area (b) makes to not consider, and regarding the agents, the developer makes to think as the unit with the absentee landowner.

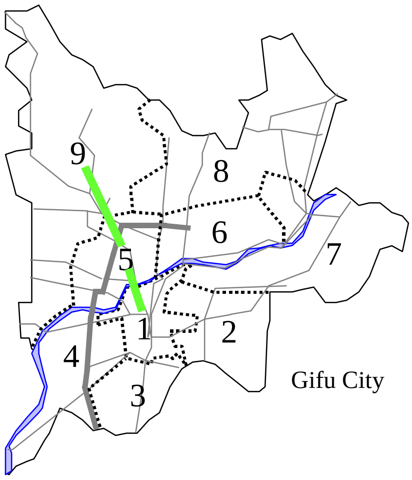

Fig. 2 Gifu City and project line of LRT

4.2 Specification of the function and parameter setting

We should decide the form of each function that introduced in previous section and set up their parameters, to apply the CUE model to measure the benefits actually. Here, we have only to do the specification of utility function, production function and land supply function of the absentee landowner, because the developer makes to not consider. As for the land supply function shown in (22), we formulate under the assumption that all of the possessing land are loaned. And the utility function and production function are conducted the specification by Cobb-Douglas form, shown in Table. 2.

Table. 2 Specification of functions

Function	The form of function
Utility function (5.a)	$U_{a,i}^{Z} = z_i^{a_z} a_i^{a_a} x_i^{a_x} s_i^{a_s} + mg\left(f_i\right)$ Where, a_z, a_a, a_x, a_s : share parameter ($a_z + a_a + a_x + a_s = 1$).
Production function (10.b)	$Z_i = m A_i^{b_A} X_i^{b_X}$ Where, m : scale parameter, b_A, b_X : share parameter.
Land supply function Of absentee landowner	$l_i^S = \overline{l_i^S}$

The parameters are set by calibration method that determines parameters corresponding with the data set of a benchmark year.

In this model, each parameter is independent on the zone, that is possible to set up the parameters for a representative household in the whole Gifu City. The parameters set up like this way, is regarded as ones for the household of each zone.

It is set the benchmark year in 1993, and the data set is made out on the basis of "Gifu-shi statistics book" or "Person trip survey". The parameter values requested as above results are shown in Table. 3.

Table. 3 Setting result of main parameters

Utility function	a_z	0.467	Production function	m	1,838,064
	a_a	0.023		a_A	0.158
	a_x	0.027		a_X	0.031
	a_s	0.484			

4.3 Result of Simulation

4.3.1 Setting of the Project

It is assumed that the project is the introduction of the LRT to zone 1-5-9, shown in the Fig. 2. We simulate the project under the transportation generalized price as shown in Table. 4, gained from the result that the required times of public transportation are reduced.

Table. 4 Setting of the generalized price

Transportation Generalized Price (Unrestrained Trip)

Zone	Without	With	Rate
1	573	541	-5.70%
2	602	602	0%
3	639	639	0%
4	619	619	0%
5	580	552	-4.79%
6	608	608	0%
7	725	725	0%
8	767	767	0%
9	705	669	-5.11%

Transportation Generalized Price (Besiness Trip)

Zone	Without	With	Rate
1	462	433	-6.20%
2	524	524	0%
3	497	497	0%
4	490	490	0%
5	541	461	-14.87%
6	545	545	0%
7	723	723	0%
8	765	765	0%
9	705	665	-5.79%

4.3.2 Result of Simulation

Under the aforementioned setting, the change of each transportation trip and the household number and employee population are shown in Table. 5. And the change of the land rent and the land demand are shown in Table. 5.

Table. 5 The Results of Simulation

Unrestrained Trip (Trips/year)

Zone	Without	With	Rate
1	30,820,946	33,264,857	7.929%
2	4,784,026	4,698,243	-1.793%
3	4,791,084	4,704,148	-1.815%
4	10,659,996	10,479,608	-1.692%
5	4,710,683	4,976,289	5.638%
6	2,830,095	2,779,063	-1.803%
7	2,714,631	2,667,357	-1.741%
8	5,627,194	5,538,115	-1.583%
9	2,826,364	3,013,040	6.605%

Business Trip (Trips/year)

Zone	Without	With	Rate
1	5,220,337	5,591,535	7.111%
2	555,235	553,086	-0.387%
3	595,081	591,981	-0.521%
4	1,187,972	1,189,619	0.139%
5	678,135	786,735	16.014%
6	483,169	480,829	-0.484%
7	468,986	468,733	-0.054%
8	964,487	968,620	0.428%
9	316,591	338,121	6.801%

Number of Household (family)

Zone	Without	With	Rate
1	84,963	86,472	1.78%
2	13,859	13,610	-1.79%
3	14,717	14,450	-1.81%
4	31,745	31,208	-1.69%
5	13,131	13,208	0.58%
6	8,280	8,131	-1.80%
7	9,483	9,318	-1.74%
8	20,814	20,485	-1.58%
9	9,601	9,712	1.16%

Number of Employee (person)

Zone	Without	With	Rate
1	11,668	11,704	0.307%
2	1,508	1,501	-0.462%
3	1,511	1,502	-0.622%
4	2,697	2,702	0.166%
5	1,814	1,776	-2.087%
6	1,403	1,395	-0.579%
7	1,726	1,725	-0.065%
8	3,286	3,303	0.512%
9	1,267	1,273	0.505%

Land rent for residence (yen/m^2)

Zone	Without	With	Rate
1	2,102	2,139	1.776%
2	2,221	2,181	-1.793%
3	1,942	1,907	-1.815%
4	1,061	1,043	-1.692%
5	2,632	2,647	0.579%
6	3,796	3,728	-1.803%
7	2,658	2,612	-1.741%
8	1,323	1,302	-1.583%
9	2,518	2,547	1.162%

Land rent for business (yen/m^2)

Zone	Without	With	Rate
1	1,123	1,128	0.465%
2	1,489	1,483	-0.387%
3	1,537	1,529	-0.521%
4	877	878	0.139%
5	1,117	1,103	-1.234%
6	1,602	1,594	-0.484%
7	1,202	1,202	-0.054%
8	619	622	0.428%
9	2,102	2,115	0.617%

Land demand for residence (m^2)

Zone	Without	With	Rate
1	85	84	-1.745%
2	80	82	1.826%
3	92	94	1.848%
4	168	171	1.721%
5	68	67	-0.576%
6	47	48	1.836%
7	67	68	1.772%
8	135	137	1.608%
9	71	70	-1.149%

Land demand for business (m^2)

Zone	Without	With	Rate
1	927	924	-0.306%
2	652	655	0.465%
3	641	645	0.626%
4	1,238	1,236	-0.165%
5	911	931	2.132%
6	590	593	0.582%
7	822	823	0.065%
8	1,823	1,814	-0.510%
9	422	420	-0.503%

Table-7 The Result of Benefits Measurement

(100million yen/year)

	Zone	1	2	3	4	5	6	7	8	9
Household	ZCEV	7.70	0.45	0.48	0.97	1.21	0.27	0.30	0.59	0.85
	NCEV	10.16								
Firm	Benfit	1.68	-0.05	-0.08	0.06	0.12	-0.05	-0.01	0.24	0.14
	Total Benfit	1.86								
Landowner	Benfit	3.26	-0.50	-0.55	-0.92	0.36	-0.33	-0.30	-0.43	0.27
	Total Benfit	0.86								
Regulatory benefit of external diseconomies		0.08	0.00	0.00	0.04	-0.00	0.00	0.00	-0.04	-0.02
		0.05								
Social Net Benfit		12.93								

We showed that traffic trips have increased in the upgrading line 1-5-9, and it is considered that the attractiveness of zones is going up. The inflow of the household and employee to the improved area was occurred along with and even the land rents are going up.

4.3.3 Measuring the Benefits

The result of measuring the benefits of this project is shown in Table. 7. At first, we consider the Zone Contingent EV (ZCEV) and the profits change of the absentee landowner, which are defined for each zone.

The ZCEV that households enjoy in the upgrading zone 1-5-9 of LRT are larger than the one of unupgrading zones. The changes of profits of firm and land rent incomes of the absentee landowner in upgrading zones are almost positive. This results express that households and firms who locate in the upgrading area are enjoying the benefit by increasing the each trip through the decrease of transportation generalized price. The inflow of households and firms to the upgrading zone from the unupgrading zone is occurred along with. So because the land rents are rising in the upgrading zone, the land rent incomes of landowners increase.

In the unupgrading area, the volumes of ZCEV that household enjoys and one of the decreases of rent income of landowner are almost same amount. It is conceivable that households obtain benefits as a result of the migration to the upgrading area, on the other hand, the rent income of landowners decreased. Because those amount are almost same and cancel out, they do not exert the influence to social benefit.

5. CONCLUSION

We propose the computable urban economic (CUE) model, to evaluate the indirect influence to location change as well as the direct influence to the transportation system of the improvement projects to solve the various problems in the urban transportation. Also, by using the CUE model, we simulate the project for Gifu City in Japan. We showed that the influences of both of the transportation system change and location change of the project are measured, and the regulatory benefits of external diseconomies are evaluated.

Acknowledgement - We wish to thank Mr. Tomita and Mr. Kanazawa for their help. They made many contributions for the simulation analysis in the study.

REFERENCES

Anas, A. (1984) Discrete choice theory and the general equilibrium of employment, housing, and travel networks in a Lowry-type model of the urban economy, *Environment and Planning A*, **16**, 1489-1502.

Henderson, J. V. (1985) *Economic theory and the cities*, Academic Press.

Kanemoto, Y. and Mera, K. (1985) General equilibrium analysis of the benefits of large transportation improvement, *Regional Science and Urban Economics*, 15, 343-363.

Miyagi, T. (1989) A combined residential-location and transportation network equilibrium model, *Selected Proceedings of the 5th WCTR*, **IV**, 123-137.

Morisugi, H. and Ohno, E. (1992) A benefit incidence matrix for urban transport improvement, *the Journal of the RSAI*, **71**(1), 53-70.

Ueda, T., Hiratani, K. and Tsutsumi, M. (1993) Land use model based on the general equilibrium of land and building market, *Proceedings of International conference on Land Problem and Urban Policy*, Kyoto.

Ueda, T., Morisugi, H. and Takagi, A. (1996) On the economic evaluation of natural disaster prevention projects, *the Proceedings of the Memorial Conference on the Hanshin Great Earthquake*, Japan Society of Civil Engineers (in Japanese).