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

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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).
3) The land and building are dealt to a different piece, and, next, the household who chooses the area \((=a, b)\) or \((a, b)\) is made formally.
The locating and transport behavior of each agent (household and employee) is made formally.
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. The Behavior of Agents
The locating and transport behavior of each agent (household and employee) is made formally. 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.

\[
S_{HA}^{HA} = \max_{\Phi_{HZ}^{HA}, \Phi_{HZ}^{HA}} \left[ Z_{HA}^{HZ} \left( \Phi_{HZ}^{HA}, P_{HA}^{HA} \right) \right]
+ P_{HA}^{HA} \cdot S_{b}^{HA} - \frac{1}{\theta_{HA}} \sum_{i} \left( P_{HA}^{HA} \cdot \ln P_{HA}^{HA} \right) \quad (1a)
\]

s.t. \( \sum_{i} P_{HA}^{HA} = 1 \), \( \sum_{i} \Phi_{HZ}^{HA} = P_{HA}^{HA} \) \( (1b) \)

\[
Z_{HA}^{HZ} = \sum_{i} \Phi_{HZ}^{HA} \cdot V_{a,j}^{HZ} - \frac{1}{\theta_{HA}} \sum_{i} \left( \Phi_{HZ}^{HA} \cdot \ln P_{HA}^{HA} \right) \quad (1c)
\]

Where, \( S_{HA}^{HA} \): inclusive expected utility on the stage of choosing the zone \(i\) for the residence, \( P_{HA}^{HA} \): probability of locating in the area \(i\) \((=a, b)\), \( S_{b}^{HA} \): utility level of the household locating in the area \(b\) (constant), \( i \): a label for zone, \( \Phi_{HZ}^{HA} = P_{a,i}^{HA} \cdot P_{a,i}^{HA} \cdot P_{HZ}^{HA} \), \( P_{HZ}^{HA} \): probability of locating in the zone \(i\) of the area \(a\), \( V_{a,j}^{HZ} \): utility level of the household locating in the zone \(i\) of the area \(a\) and \( \theta_{HA}, \theta_{HZ} \): logit parameter.

The objective function of \((1)\) is the entropy on the locating selection of the area, and \( Z_{HA}^{HZ} \) 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 \(i\): \( P_{HA}^{HA} \)

\[
P_{a}^{HA} = \frac{1}{1 + \exp \frac{\theta_{HA}^{HZ} \sum_{i} \exp \theta_{HZ}^{HZ} V_{a,j}^{HZ}}{\theta_{HA}^{HZ}}} \quad (2a)
\]

The probability of locating on the zone \(i\): \( P_{HZ}^{HA} \)

\[
P_{a,j}^{HZ} = \frac{\exp \theta_{HZ}^{HZ} V_{a,j}^{HZ}}{\sum_{j} \exp \theta_{HZ}^{HZ} V_{a,j}^{HZ}} \quad (2b)
\]

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

\[
S_{a,j}^{HZ} = \frac{1}{\theta_{HZ}^{HZ}} \ln \sum_{i} \exp \theta_{HZ}^{HZ} V_{a,j}^{HZ} \quad (3a)
\]

\[
S_{HA}^{HZ} = \frac{1}{\theta_{HA}^{HZ}} \ln \left[ \sum_{i} \exp \theta_{HZ}^{HZ} S_{a,j}^{HZ} + \exp \theta_{HA}^{HZ} S_{b}^{HA} \right] \quad (3b)
\]

\( V_{a,j}^{HZ} \) 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.

\[
V_{a,j}^{HZ} = \max_{z_{i}, a_{i}} \left[ U_{a,j}^{HZ}(z_{i}, a_{i}, x_{i}, s_{i}) + \mu \cdot \gamma(f_{i}) \right] \quad (4a)
\]

s.t. \( z_{i} + r_{i} \cdot a_{i} + g_{i} \cdot x_{i} + w_{i} = w_{i} \left[ T_{i} - \frac{\sum_{j} n_{ij} \cdot y_{i}}{N_{i}} \right] + y_{i} \quad (4b)\)

Where, \( U_{a,j}^{HZ} \): 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, \( \gamma(f_{i}) \): 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 $s_i$.

\[ z_i = z_i(r_i, q_i, y_i) \quad (5a) \]
\[ a_i = a_i(r_i, q_i, y_i) \quad (5b) \]
\[ x_i = x_i(r_i, q_i, y_i) \quad (5c) \]
\[ s_i = s_i(r_i, q_i, y_i) \quad (5d) \]

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

\[ V^Z_{a,i} = V^Z_{a,i}(r_i, q_i, y_i, y) \quad (6) \]

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 $V^Z_{a,i}$ in formulation (1) to the firm profit $\Pi^Z_{a,i}$, and the each probability of locating of the firm is requested as follows.

The probability of locating in the area $l$: $P^F_{a,l}$

\[ P^F_{a,l} = \frac{1}{1 + \exp \theta^F_S \exp \frac{1}{\Phi^F_S} \exp \frac{\exp \theta^F_{Z_a} \Pi^Z_{a,i}}{\sum_i \exp \theta^F_{Z_a} \Pi^Z_{a,i}}} \quad (7a) \]

The probability of locating on the zone $i$: $P^F_{a,i}$

\[ P^F_{a,i} = \frac{\exp \theta^F_{Z_a} \Pi^Z_{a,i}}{\sum_i \exp \theta^F_{Z_a} \Pi^Z_{a,i}} \quad (7b) \]

Where, $P^F_{a,l}$: probability of locating in the area $l$ (= $a$ or $b$), $S^F_{a,b}$: profit of the firm locating in the area $b$ (constant), $\Phi^F_{a,b}$ : $= P^F_{a,b} \cdot P^F_{a,i}$, $P^F_{a,i}$ : probability of locating in the zone $i$ of the area $a$, $\Pi^Z_{a,i}$ : profit of the firm locating in the zone $i$ of the area $a$ and $\theta^F_{a,b}, \theta^F_{Z_a}$ : logit parameter.

$\Pi^Z_{a,i}$ of equation (7) is introduced through the formulization 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.

\[ \Pi^Z_{a,i} = \max_{A_i, X_i} \left[ Z_i - R_i A_i - Q_i X_i - wL_i - \sum_{j} n_{ij} p_{ij} \right] \quad (8a) \]

s.t. $Z_i = Z_i(A_i, X_i) \quad (8b)$

Where, $\Pi^Z_{a,i}$ : 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 building 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 $A_i$, $X_i$.

\[ Z_i = Z_i(R_i, Q_i) \quad (9a) \]
\[ A_i = A_i(R_i, Q_i) \quad (9b) \]
\[ X_i = X_i(R_i, Q_i) \quad (9c) \]

And firm profit is obtained.

\[ \Pi^Z_{a,i} = \Pi^Z_{a,i}(R_i, Q_i) \quad (10) \]

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.

\[ N_i = P^H_{a,i} \cdot P^H_{a,i} N^T \quad (11) \]

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

\[ E_i = P^F_{a,i} \cdot P^F_{a,i} E^T \quad (12) \]

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,

\[ N_i = P^H_{a,i} \cdot P^H_{a,i} N^T \quad (13a) \]
\[ \mu_{ij} = \frac{1}{\sum_j E_i \cdot (q_{ij})^{-\rho}} \cdot V_{ij} = \frac{1}{\sum_j \mu_{ij} N_i \cdot (q_{ij})^{-\rho}} \quad (13b) \]

Where, $q_{ij}$: average generalized price between zone $i$ and $j$, $\mu_{ij}$, $\nu_{ij}$: parameters for adjustment, $\rho$: 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.

\[ \pi^Z_{a,i} \]

\[ \text{s.t. } Z_i = Z_i(A_i, X_i) \]
\[ S^D = \max_{\phi_{k,r}, \phi_{k,r}, a_{r,k}} \left[ \sum_j ZH^D_j (\Phi_{k,r,k}, \Phi_{k,r,k}, P^D_{y,j}) \right. \]
\[ \left. - \frac{1}{\theta^s} \sum_j \left\{ P^D_{y,j} \cdot \ln P^D_{y,j} \right\} \right] \quad (14a) \]
\[ \text{s.t.} \quad \sum_j P^D_{y,j} = 1, \quad \sum_j \Phi_{k,r,k} = P^D_{y,j}, \quad \sum_j \Phi_{k,r,k} = \Phi_{k,r}, \quad \Phi_{k,r,k} \geq 0, \quad \alpha = \sum_j X_{k,c} \Phi_{k,r,k} \delta_{k,aw} \quad (14b) \]
\[ ZV^D_j = \sum_k ZH^D_j - \frac{1}{\theta^s} \sum_k \left\{ \Phi_{k,r,k} \cdot \ln \frac{\Phi_{k,r,k}}{P^D_{y,j}} \right\} \quad (14c) \]
\[ ZV^s_j = \sum_k ZH^s_k - \frac{1}{\theta^s} \sum_k \left\{ \Phi_{k,r,k} \cdot \ln \frac{\Phi_{k,r,k}}{P^D_{y,j}} \right\} \quad (14d) \]
\[ ZH^s_k = -\Phi_{k,r,c,k} P_{y,c} - w \sum_j \int_0^{\infty} t_a (\omega) d\omega \quad (14e) \]

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, \( P^D_{y,j} \) : probability of choosing the destined zone \( j \), \( \Phi_{k,r,k} \) : probability of choosing the mode \( k \), \( \Phi_{k,r,k} \) : probability of choosing the path \( r \) for automobile transportation \( C \), \( x_j \) : traffic volume of link \( a \), \( X_{k,c} \) : automobile trip between the zone \( i \) and \( j \), \( \delta_{k,aw} \) : link-path incidence matrix, \( P_{y,c} \) : automobile cost, \( t_a \) : automobile time of link \( a \), \( \theta^s, \theta^s, \theta^s \) : logit parameter.

The objective function of (14) is the entropy on choosing the destined zone, and \( ZV^D_j, ZV^s_j \) is the entropy on choosing the mode and path, respectively. And the first part of \( ZH^s_k \) 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 \( P^D_{y,j} \), \( P^D_{k,r,k} \) and \( P^D_{k,r,k} \), respectively.

\[ P^D_{y,j} = \frac{\exp \left[ \theta^D \cdot S^D_{y,j} \right]}{\sum_j \exp \left[ \theta^D \cdot S^D_{y,j} \right]} \quad (15a) \]

\[ S^D_{y,j} = \frac{1}{\theta^D} \ln \left( \sum_k \exp \left[ \theta^S \cdot S^D_{y,k} \right] \right) \quad (15b) \]

\[ S^D_{k,r,k} = -q^D_{k,r,k}, S^D_{k,r,k} = \frac{1}{\theta^D} e^{\ln \left( \sum_k \exp \left[ \theta^S \cdot q^D_{y,k} \right] \right)} \quad (15c) \]

\[ q^D_{k,r,k} = p_{y,c} + w \cdot t_{a,c,r} \quad (15d) \]

\[ P^S_{y,j} = \frac{\exp \left[ \theta^S \cdot S^S_{y,j} \right]}{\sum_j \exp \left[ \theta^S \cdot S^S_{y,j} \right]} \quad (16) \]

\[ P^S_{y,k} = \frac{\exp \left[ \theta^S \cdot S^S_{y,k} \right]}{\sum_j \exp \left[ \theta^S \cdot S^S_{y,k} \right]} \quad (17) \]

Where, \( S^D_{y,j} \) is the inclusive expected utility on the stage of choosing mode. As for \( S^D_{y,k} \), 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, \( q^D_{y,k} \) is meaning the generalized cost of mode \( k \).

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

\[ q_i = \sum_j q^D_{y,j} \exp \left( S^D_{y,j} - S^D_{y,j} \right) \quad (18a) \]

Where, \( q_i = \sum_j q^D_{y,j} \exp \left( S^D_{y,j} - S^D_{y,j} \right) \)

\[ q^S_{y,k} = \sum_j q^S_{y,k} \exp \left( -q^S_{y,k} \right) \quad (18c) \]

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.

\[ \pi_i = \max_{a_i} \left[ r_i a_i - c(a_s) \right] \quad (19a) \]

\[ \text{s.t.} \quad c(a_s) = \min \left( r_i l_i + h k_i \right) \quad (19b) \]

\[ a_s = a_i(l_i, k_i) \quad (19c) \]

Where, \( \pi_i \) : profit of developer, \( a_s \) : supplied volume of buildings for the residence, \( c(a_s) \) : cost of supply buildings for the residence, \( r_i \) : 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 \( a_s \), \( l_i \) and \( \pi_i \).

\[ a_s = a_i(r_i, r_i) \quad (20a) \]

\[ l_i = l_i(r_i, r_i) \quad (20b) \]

\[ \pi_i = \pi_i(r_i, r_i) \quad (20c) \]

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.

\[ l_i = \bar{l} \left( 1 - \frac{\sigma}{r_i} \right) \quad (21) \]

Where, \( l_i \) : supplied volume of land for the residence, \( l_i \) : Supply capacity of land for the residence, \( \sigma_i \) : 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.

\[ N^T = \sum N_i^a + N_i^b \]  
(22a)

Where, \( N_i^a = N_i - P_{fa} \cdot P_{ja} \)  
(22b)

\[ N_i^b = N_i - P_{fb} \cdot P_{ja} \]  
(22c)

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

\[ E^T = \sum E_i^a + E_i^b \]  
(23a)

Where, \( E_i^a = E_i - P_{fa} \cdot P_{ja} \)  
(23b)

\[ E_i^b = E_i - P_{fb} \cdot P_{ja} \]  
(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 made distinguished for the residence and the business, the market equilibrium conditions are also expressed individually, like a follow.

For the Residence

\[ as(r_i, r_i^s) = N_i^a(r_i) \]  
(24a)

\[ l_i^s(r_i, r_i^s) = l_i^s(r_i) \]  
(24b)

For the Business

\[ AS(R, R_i^f) = E_i^a(R) \]  
(25a)

\[ L_i^f(R_i, R_i^f) = L_i(R_i) \]  
(25b)

Where, \( AS \) : supplied volume of the business, \( R_i^f \) : rent of buildings for the business, \( L_i^f \) : 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.

\[ V_{a,j}^Z = V_{a,j}^Z(r_i, q_i, y_i^A, ZCEV, y^A) \]  
(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.

\[ S_{a,j}^IZ = \frac{1}{6} \sum \exp\{6 \cdot V_{a,j}^Z(r_i^A, q_i, y_i, ZCEV, y^A)\} \]  
(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 \( S_{a,j}^IZ \) obtained in (3) is able to be interpreted the utility level of households, in this model. The infinitesimal change of \( S_{a,j}^IZ \) is guided as follows.

\[ dS_{a,j}^IZ = \frac{\partial S_{a,j}^IZ}{\partial V_{a,j}^Z} \cdot dV_{a,j}^Z = P_{a,j}^IZ \cdot dV_{a,j}^Z. \]  
(28)

Where, we utilized the relation of \( \frac{\partial S_{a,j}^IZ}{\partial V_{a,j}^Z} = P_{a,j}^IZ \) to this transformation.

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

\[ dV_{a,j}^Z = \left[ \lambda_{a,j}^IZ \cdot \left( -a_i \cdot dR_i - x_i \cdot dq_i - w \cdot \frac{\sum N_i q_i}{N_i} \right) \right] \]  
\[ + d\gamma_i + \frac{\partial V_{a,j}^Z}{\partial \gamma} \cdot d\gamma \]  
(29)

Where, \( \lambda_{a,j}^IZ \) : lagrangian multiplier on the utility maximization programming.

\( -\lambda_{a,j}^IZ \cdot x_i \cdot dq_i \) in equation (29) means the change of household’s utility level on the stage of consuming the
unrestraint trip. And we are able to transform this part by using the inclusive expected utility obtained from the consuming behavior model of unrestraint trips.

\[-x_i d_q_i = dS^{HD}\]

\[= \sum_j x_i \frac{\partial S^{HD}}{\partial S^{0}_{ij}} \frac{\partial S^{HS}}{\partial S^{0}_{ij}} \frac{\partial S^{HK}}{\partial S^{0}_{ij}} - w d t_{0,i,c} \]

\[+ \sum_j x_i \frac{\partial S^{H0}}{\partial S^{0}_{ij}} \frac{\partial S^{HS}}{\partial S^{0}_{ij}} \frac{\partial S^{HK}}{\partial S^{0}_{ij}} - d p_{0,i,c} - w d t_{0,i,c} \]

\[= \sum_j x_i \Phi^{HK}_{0,i,c} \{- w d t_{0,i,c} \}

\[+ \sum_j \sum_k x_i \Phi^{HS}_{0,i,c,k} \{- d p_{0,i,c} - w d t_{0,i,c} \} \]

\[\text{(30)}\]

**Profit Function**

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

\[dS^{FD} = \frac{\partial S^{FD}}{\partial \Pi_{a,i}} d \Pi_{a,i} = P_{a,i}^{FD} d \Pi_{a,i} \]

Where,

\[d \Pi_{a,i} = \lambda^{FD} \left\{ - \Lambda_i d R_i - x_i d Q_i - d \left( \sum_{j} \frac{N_j P_{ij}}{N_i} \right) \right \} \]

\[\text{(31b)}\]

\[X_i d Q_i = dS^{FD} \]

\[= \sum_j x_i \cdot \Phi^{HK}_{0,i,c,j} \{- w d t_{0,i,c} \}

\[+ \sum_j \sum_k x_i \cdot \Phi^{HS}_{0,i,c,j,k} \{- d p_{0,i,c} - w d t_{0,i,c} \} \]

\[\text{(31c)}\]

Where, \(\lambda^{FD}\) : 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.

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

<table>
<thead>
<tr>
<th>Function</th>
<th>The form of function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility function</td>
<td>$U_{z a} = \alpha_u a_u x_i^{\alpha_u} + \mu_i(f)$</td>
</tr>
<tr>
<td>Production function</td>
<td>$Z_i = m A_{\beta_x} X_i^{\beta_x}$</td>
</tr>
<tr>
<td>Land supply function</td>
<td>$I_{z a} = I_{z a}$</td>
</tr>
</tbody>
</table>

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.

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

<table>
<thead>
<tr>
<th>Zone</th>
<th>Without</th>
<th>With</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>579</td>
<td>541</td>
<td>-5.70%</td>
</tr>
<tr>
<td>2</td>
<td>602</td>
<td>602</td>
<td>0%</td>
</tr>
<tr>
<td>3</td>
<td>639</td>
<td>639</td>
<td>0%</td>
</tr>
<tr>
<td>4</td>
<td>619</td>
<td>619</td>
<td>0%</td>
</tr>
<tr>
<td>5</td>
<td>580</td>
<td>552</td>
<td>-4.79%</td>
</tr>
<tr>
<td>6</td>
<td>608</td>
<td>608</td>
<td>0%</td>
</tr>
<tr>
<td>7</td>
<td>725</td>
<td>725</td>
<td>0%</td>
</tr>
<tr>
<td>8</td>
<td>767</td>
<td>767</td>
<td>0%</td>
</tr>
<tr>
<td>9</td>
<td>705</td>
<td>669</td>
<td>-5.11%</td>
</tr>
</tbody>
</table>

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

The numbers of the result are shown in the Table 5.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Without</th>
<th>With</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2,779,063</td>
<td>3,013,040</td>
<td>9.29%</td>
</tr>
<tr>
<td>2</td>
<td>2,632</td>
<td>47</td>
<td>-1.149%</td>
</tr>
<tr>
<td>3</td>
<td>5,591,535</td>
<td>6,131,531</td>
<td>10.28%</td>
</tr>
<tr>
<td>4</td>
<td>4,791,084</td>
<td>6,605,084</td>
<td>38.70%</td>
</tr>
<tr>
<td>5</td>
<td>669</td>
<td>639</td>
<td>-4.79%</td>
</tr>
<tr>
<td>6</td>
<td>725</td>
<td>725</td>
<td>0%</td>
</tr>
<tr>
<td>7</td>
<td>767</td>
<td>767</td>
<td>0%</td>
</tr>
<tr>
<td>8</td>
<td>705</td>
<td>669</td>
<td>-5.11%</td>
</tr>
</tbody>
</table>

The numbers of the result are shown in the Table 5.
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.

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REFERENCES


