EVALUATION OF ENVIRONMENTAL POLLUTIONS OCCURRED BY TRANSPORT INFRASTRUCTURE PROJECT AT TOKYO METROPOLITAN AREA

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Abstract

Traffic congestions both on road and railway are very serious at Tokyo Metropolitan Area. For this problem, the more projects of transport infrastructures are proposed. But the exact evaluation that is considered the interaction of transport and location should be required, when those projects are carried out. And it is also need to concern the environmental pollutions increased by those projects. We have developed the Computable Urban Economic (CUE) model that is combined model both on transport network and location choice equilibrium. In this paper, the effects and impacts of carrying out the infrastructure projects on the road and railway at the Tokyo Metropolitan Area are computed by using the CUE model. In that analysis, we measure concretely the change of the residential and business location pattern and traffic volume. And the environmental influences brought by those projects are cleared by evaluating the change of environmental pollution emissions.

Keywords: Project evaluation; Environmental impact; Computable urban economic model
Topic Area: F5 Transport and Environment: Mobility and Sustainability

1. Introduction

Traffic congestions both on road and railway are very serious at Tokyo Metropolitan Area. They are afraid to impose much burden to some socioeconomic activities. For this problem, the Ministry of Land, Infrastructure and Transport is proposing the more projects of transport infrastructures such as ring roads and ring or suburban railways (See figure 5 or 6). These projects are expected to bring the higher activity of socioeconomy through the improvement effects of transport accessibility and form the higher density of land use by being hasten the land development of objective area.

The authors have built the Computable Urban Economic (CUE) model that is the combined model both on transport network and location choice equilibrium, in order to grasp the influence to the socioeconomic activities including the relocation behavior by transport infrastructure improvements (Muto, Ueda and Takagi, 2001). The important of considering the interaction of transport and location have been from long time ago, example by Lowry (1964) and so on. The analysis model that be based on economic equilibrium principle have been proposed [e.g. (Anas, 1984), (Bertuglia, et al., 1990), (Morisugi and Ohno, 1992), (Ueda, et al., 1993)]. Though our CUE model also follows those models, it has an advanced merit that the benefits given by the development traffic as well as the induced traffic are evaluated numerically. We can make comprehension the fact easy by focusing on the transport market (Kanemoto and Mera, 1985).

In Fig. 1, the transport demand and marginal generalized cost curve are drawn. The transport infrastructure improvements shift lower the marginal generalized cost curve. By this shift, the market equilibrium point is moved from A to B and the traffic volume is increased from Q_0 to Q_1. This is called as the induced traffic.

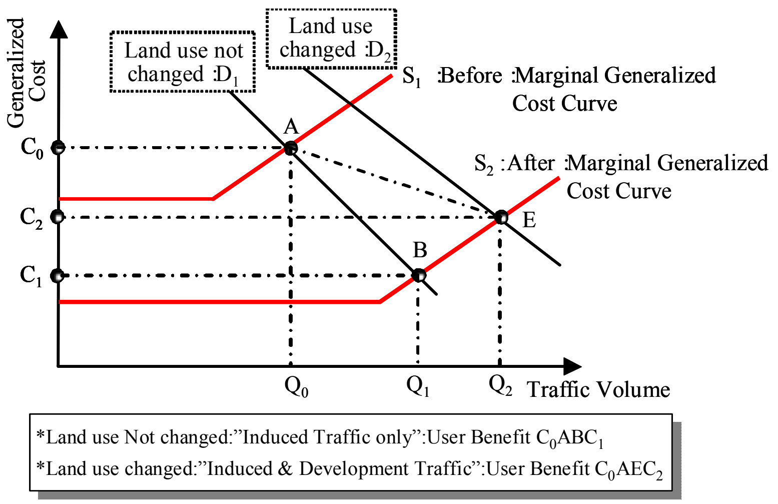


Figure 1. User benefit of considering induced traffic and development traffic

However, it is possible that the household or firm may relocate to project area for a long time. The increase of location volume shifts upper the transport demand curve. From the result, the market equilibrium point is moved from B to E, and the traffic volume is increased until Q_2. This is called as the development traffic. The user benefit for each case is expressed in Fig. 1. In the case of the development traffic, it is measured by AEC_2C_0 and , in the case of the only induced traffic, it is measured by ABC_1C_0. If the marginal generalized cost is horizon to X axis, the development traffic generates more surplus benefit of AB'E than the induced traffic. But it generally becomes to a curve upward slanting to the right by considering the congestion phenomenon. In that case, on account of the surplus loss occurred by traffic jam, it has been unknown which user benefit of development or induced traffic case is bigger. In any case, we are possible to compute rightly user benefit generated by projects through applying the CUE model, because the economic behavior including location choice and transport behavior are connected properly in that model.

It is important to grasp correctly the development traffic volume in order to evaluate how influence the projects give to environmental pollution exhausts. Even if the projects bring much economic benefit, excess burdens to environment have to be avoided. Some people have believed that the transport infrastructure improvements may decrease the environmental pollutions through the reduction of traffic jam and the rising of average velocity. But the conclusion that the pollutions are reduced is of course difficult if the induced or development traffic is generated. The efforts are due to exact analysis how the development traffic volume is generated and proper evaluation how environmental damage it brings.

In this paper, the effects and impacts of carrying out the infrastructure projects on the road and railway at the Tokyo Metropolitan Area are computed by using the CUE model. We measure concretely the changing volume of the residential and business location, or the induced and development traffic which is generated according to location pattern change. And the environmental influences brought by those projects are cleared by evaluating the change of environmental pollution emissions depend on traffic volume change.

2. Structure of cue model

2.1. Assumptions

This CUE model has the following assumptions.

a) The objective area is Tokyo Metropolitan Area that is divided in 169 zones.
b) There are households, a represent composite goods firm and absentee landowner in the each zone (see Fig. 2).
c) The only land markets are considered that treated separately the residential use and business use.
d) The prices except land rents, such as the wage and composite goods price, are constant. Total number of household and employee are also given.

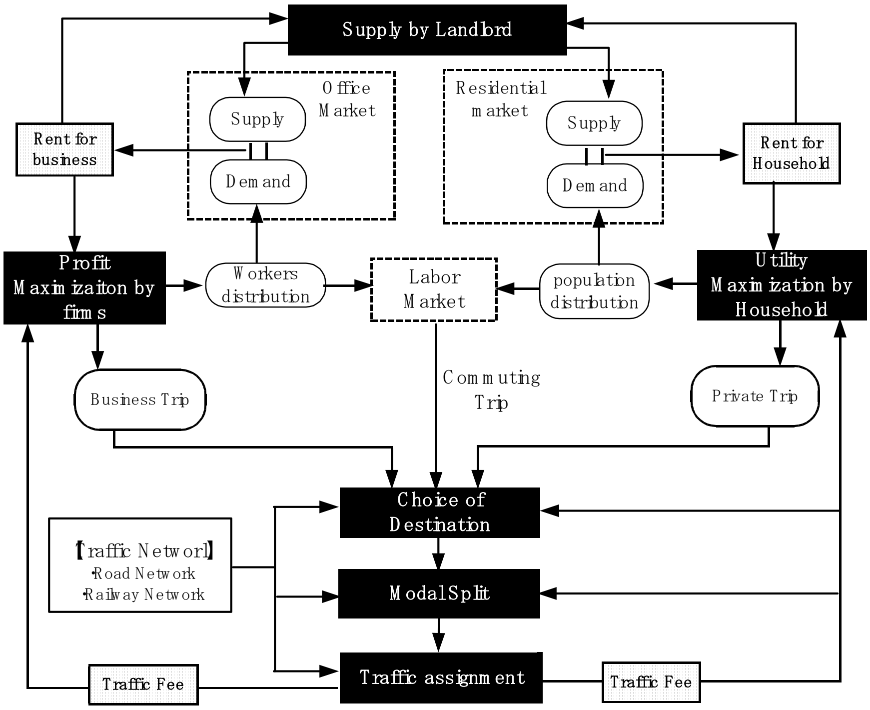


Figure 2. Outline of the CUE model for one zone

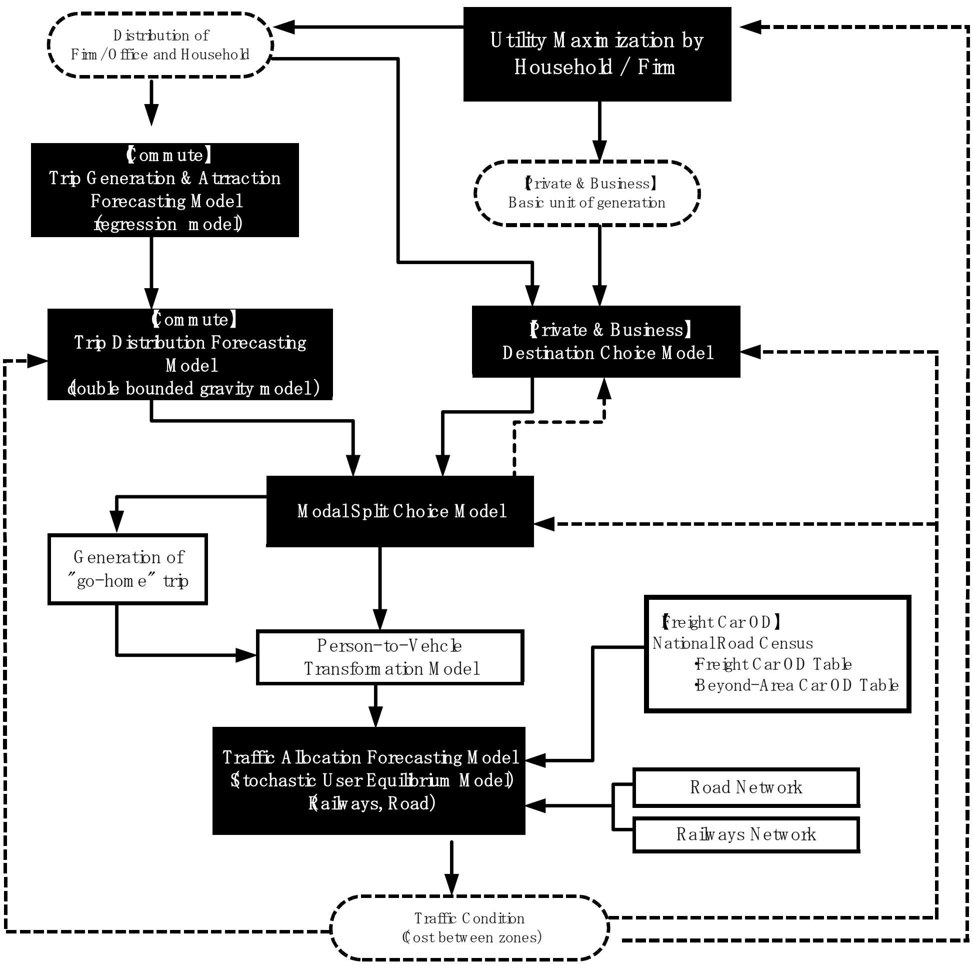


Figure 3. Outline of the transport consuming behavior model

e) Household and firm generate the trips. Household's trips consist of private trips and commuting trips which are separated business commuting and school commuting. Firm's trips consist of business trips. The consuming behavior of their trips is formulated by the destination choice model, modal choice model and traffic assignment model (See Fig. 3).

2.2. Household behavior

Household earns the income by providing labor and consumes the composite goods and land service so as to maximize his utility under his budget and time constraint. By incorporating the time constraint, consumptions of time resources for the leisure, trip or labor, can be considered in the model. In order to consume the composite goods and leisure service, the household need input the travel trips. These trips can be interpreted as the private trips. This utility maximizing behavior is formulated as follows.

$$V_i^H = \max_{z_i, a_i, x_i, s_i} \left[\alpha_z \ln z_i + \alpha_a \ln a_i + \alpha_x \ln x_i + \alpha_s \ln s_i \right] \tag{1a}$$

$$\text{s.t.} \quad z_i + r_i a_i + q_i x_i + w s_i = w \left[T - \left(\delta^B + \delta^S \right) \sum_{j \in \mathrm{I}} \frac{n_{ij}}{N_i} t_{ij} \right] \tag{1b}$$

where, z_i : consumption level of composite goods (price=1), a_i : land service, x_i : private trip, s_i : leisure time, r_i : residential land rent, q_i : the average generalized price of private trip, w : wage (constant), T : total available time, n_{ij} : number of household who lives in zone i and works in zone j, t_{ij} : travel required time from zone i to j, N_i : number of household in zone i, $\alpha_z, \alpha_a, \alpha_x, \alpha_s$: parameters and δ^B, δ^S : unit commuting trip for a year to business and school, respectively.

The solution of the utility maximization programming in (1) gives demand functions as z_i, a_i, x_i and s_i, respectively.

$$z_i = \alpha_z I_i, \quad a_i = \frac{\alpha_a I_i}{r_i}, \quad x_i = \frac{\alpha_x I_i}{q_i}, \quad s_i = \frac{\alpha_s I_i}{w} \tag{2}$$

where, I_i : the full income except commuting required time $\left[= w \left\{ T - \left(\delta^B + \delta^S \right) \sum_{j \in \mathrm{I}} \frac{n_{ij}}{N_i} t_{ij} \right\} \right]$.

The term $\left\{ \sum_{j \in \mathrm{I}} \frac{n_{ij}}{N_i} t_{ij} \right\}$ in the full income indicates the average required time of commuting trips from zone i to j. The formulation of consuming behavior of private and commuting trips is described fully in the next section. We can obtain the utility level V_i^H by substituting (2) into (1a).

$$V_i^H = \ln I_i - \alpha_a \ln r_i - \alpha_x \ln q_i - \alpha_s \ln w + C \tag{3}$$

where, $C = \alpha_z \ln \alpha_z + \alpha_a \ln \alpha_a + \alpha_x \ln \alpha_x + \alpha_s \ln \alpha_s$.

The household chooses the zone to reside according to distribution of the attractive index for each zone which consists of the utility level V_i^Z and the providing available capacity of residential land $\overline{a_i^S}$. We formulated this location behavior model by a mathematical programming like the following.

$$S^H = \max_{P_i^H} \left[\sum_i P_i^H \left\{ \theta_1^H V_i^H + \theta_2^H \overline{a_i^S} + \theta_3^H \right\} - \frac{1}{\theta_1^H} \sum_i \left\{ P_i^H \ln P_i^H \right\} \right] \tag{4a}$$

$$\text{s.t.} \ \sum_i P_i^H = 1 \tag{4b}$$

where, S^H : inclusive expected utility, P_i^H : probability chosen zone i to locate, $\overline{a_i^S}$: volume of providing available capacity for residential land and $\theta_1^H, \theta_2^H, \theta_3^H$: logit parameters.

This programming yields to the location probability function expressed by the logit model.

$$P_i^H = \frac{\exp \left\{ \theta_1^H V_i^H + \theta_2^H \overline{a_i^S} + \theta_3^H \right\}}{\sum_i \exp \left\{ \theta_1^H V_i^H + \theta_2^H \overline{a_i^S} + \theta_3^H \right\}} \tag{5}$$

Substituting the (5) into (4a), we get the inclusive expected utility.

$$S^H = \frac{1}{\theta_1^H} \ln \sum_i \exp \left\{ \theta_1^H V_i^H + \theta_2^H \overline{a_i^S} + \theta_3^H \right\} \tag{6}$$

2.3. Composite goods firm behavior

The composite goods firm produces commodities by inputting land service, business trips and labors so as to maximize its profit under the production technology constraint. This behavior is formulated by below.

$$\Pi_i^F = \max_{A_i, X_i} \left[Z_i - R_i A_i - Q_i X_i - wL_i \right] \tag{7a}$$

$$\text{s.t.} \ Z_i = \eta_i (ACC_i) A_i^{\beta_A} X_i^{\beta_X} L_i^{\beta_L} \tag{7b}$$

where, Π_i^F : profit of the composite goods firm, Z_i : output of the composite goods firm, A_i : land service input, X_i : business trip input, L_i : labor input, R_i : business land rent, Q_i : the average generalized price of business trip and $\eta_i, \beta_A, \beta_X, \beta_L$: parameters, ACC_i : accessibility index.

The η_i indicates products scale parameter. In this CUE model, η_i is formulated as the function of accessibility ACC_i. The ACC_i is defined as the weighted average business trip required time by the staying employee population E_i^v of each zone. This formulation implies to be taken into consideration "agglomeration economies", whose important also have been pointed out by Fujita et al., 1999.

$$\eta_i = A \exp \left[B \left\{ \frac{1}{ACC_i} \right\} \right] \tag{8a}$$

$$ACC_i = \frac{\sum_j q_{ij} E_j^v}{E^{Tv}} \tag{8b}$$

where, E^{Tv} : total number of staying employee population.

The solution of the profit maximizing programming in (7) yields factor demand functions as A_i, X_i and L_i, respectively.

$$A_i = \left[\frac{Z_i}{\eta_i(ACC_i)} \left\{ \frac{\beta_A Q_i}{\beta_X R_i} \right\}^{\beta_X} \left\{ \frac{\beta_A w}{\beta_L R_i} \right\}^{\beta_L} \right]^{\frac{1}{\beta_A + \beta_X + \beta_L}} \tag{9a}$$

$$X_i = \left[\frac{Z_i}{\eta_i(ACC_i)} \left\{ \frac{\beta_X w}{\beta_L Q_i} \right\}^{\beta_L} \left\{ \frac{\beta_X R_i}{\beta_A Q_i} \right\}^{\beta_A} \right]^{\frac{1}{\beta_A + \beta_X + \beta_L}} \tag{9b}$$

$$L_i = \left[\frac{Z_i}{\eta_i(ACC_i)} \left\{ \frac{\beta_L R_i}{\beta_A w} \right\}^{\beta_A} \left\{ \frac{\beta_L Q_i}{\beta_X w} \right\}^{\beta_X} \right]^{\frac{1}{\beta_A + \beta_X + \beta_L}} \tag{9c}$$

where,

$$Z_i = \left[\frac{\beta_A + \beta_X + \beta_L}{c_i} \right]^{\frac{\beta_A + \beta_X + \beta_L}{1 - (\beta_A + \beta_X + \beta_L)}} \tag{9d}$$

with,

$$c_i = \left[\frac{1}{\eta_i(ACC_i)} R_i^{\beta_A} Q_i^{\beta_X} w^{\beta_L} \right]^{\frac{1}{\beta_A + \beta_X + \beta_L}} \cdot$$
$$\left[\left\{ \left(\frac{\beta_A}{\beta_X} \right)^{\beta_X} \left(\frac{\beta_A}{\beta_L} \right)^{\beta_L} \right\}^{\frac{1}{\beta_A + \beta_X + \beta_L}} + \left\{ \left(\frac{\beta_X}{\beta_A} \right)^{\beta_A} \left(\frac{\beta_X}{\beta_L} \right)^{\beta_L} \right\}^{\frac{1}{\beta_A + \beta_X + \beta_L}} + \left\{ \left(\frac{\beta_L}{\beta_A} \right)^{\beta_A} \left(\frac{\beta_L}{\beta_X} \right)^{\beta_X} \right\}^{\frac{1}{\beta_A + \beta_X + \beta_L}} \right] \tag{9e}$$

Substituting (9) into the (7a), we obtain the profit function of composite goods firm.

$$\Pi_i = \Pi_i(R_i, Q_i) \tag{10}$$

The firm's location choice behavior is formulated as well as the choice model for the household, expressed in previous section. Although we have adopted the household's utility level V_i^H as an index to determin the location choice, as for firm, we use the profit function, solved in (10). As a result, the probability chosen zone i to locate is guided as next logit type.

$$P_i^F = \frac{\exp\left\{ \theta_1^F \Pi_i + \theta_2^F \overline{A_i^S} + \theta_3^F \right\}}{\sum_i \exp\left\{ \theta_1^F \Pi_i + \theta_2^F \overline{A_i^S} + \theta_3^F \right\}} \tag{11}$$

where, P_i^F : probability chosen zone i to locate, $\overline{A_i^S}$: volume of providing available capacity for business land and $\theta_1^F, \theta_2^F, \theta_3^F$: logit parameters.

2.4. Transport behavior

Transport behaviors are modeled for the private and business trip, and commuting trip. And the route traffic volume is estimated by traffic assignment analysis from the traffic pattern obtained by their transport model.

Private and business trip

The private and business trips, x_i and X_i solved in (2) and (9b) are considered as indicating total number of generation trips. We formulated the probability chosen the destination zone and chosen the traffic mode by applying the nested logit type, as well as the location choice model of household or firm. Here we express the only form of logit model.

[Destination choice probability]

$$P_{ij}^D = \frac{\exp\left[\theta_1^D S_{ij}^D + \theta_2^D E_j / A_j^T + \theta_3^D T_i + \theta_4^D\right]}{\sum_j \exp\left[\theta_1^D S_{ij}^D + \theta_2^D E_j / A_j^T + \theta_3^D T_i + \theta_4^D\right]} \tag{12a}$$

where, P_{ij}^D : probability chosen the zone of destination, S_{ij}^D : inclusive expected utility for the modal choice, E_j / A_j^T : employee population density, T_i : dummy variable for the traffic from zone *i* to *i* and $\theta_1^D, \theta_2^D, \theta_3^D, \theta_4^D$: logit parameters.

[Traffic mode choice probability]

$$P_{ij,C}^S = \frac{\exp\left[\theta_1^S q_{ij}^C + \theta_4^S\right]}{\exp\left[\theta_1^S q_{ij}^C + \theta_4^S\right] + \exp\left[\theta_1^S q_{ij}^M + \theta_2^S M_j + \theta_3^S IG_j\right]} \tag{12b}$$

where, $P_{ij,k}^S$: probability chosen the traffic mode, q_{ij}^k : generalized transport price of mode k , M_j : station density, IG_j : egress time and $\theta_1^S, \theta_2^S, \theta_3^S, \theta_4^S$: logit parameters.

S_{ij}^D indicates the inclusive expected utility for the modal choice like below.

$$S_{ij}^D = \frac{1}{\theta^S} \ln \sum_k \exp\left[\theta^S \left\{-q_{ij,k}^S\right\}\right] \tag{13}$$

Commuting trip

Commuting trips are formulated as the gravity type. The number of its generation trip is yielded from multiplying the household locating number, N_i by unit commuting generating trips, δ^B or δ^S. The number of attraction trip is obtained from the employee number, E_j by unit commuting attracting trips, δ'^B or δ'^S.

Though we are able to get the value of N_i and E_j from the equation (5) and (11), respectively, the staying stratum for location choice was introduced to the CUE model. In the other word, the agent of each zone is separated staying stratum and moving stratum, and we set the only moving stratum to object of relocating (See Fig. 4). So the each agent location number, N_i and E_j is yielded by next equation.

$$N_i = P_i^H \cdot N^T + N_i^v \tag{14a}$$

$$E_j = P_j^F \cdot E^T + E_j^v \tag{14b}$$

where, N^T : total household number of moving stratum (constant) and E^T : total employee number of moving stratum (constant), N_i^v : household number of staying stratum in the zone i (constant) and E_j^v : employee number of staying stratum in the zone j (constant).

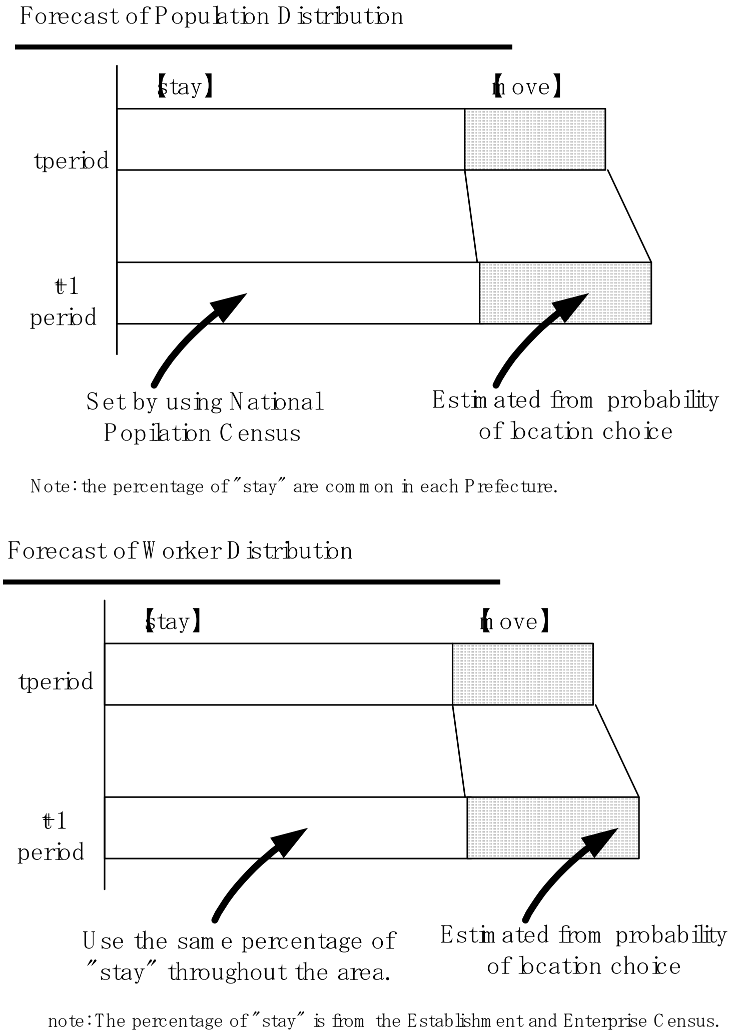


Figure 4. Location change considering the stay and move stratum

From that result, the gravity model with double constraints of the commuting trips is modeled as below,

$$n_{ij} = \left\{ \mu_i \cdot \delta^{B,S} N_i \right\} \left\{ \nu_j \cdot \delta'^{B,S} E_j \right\} \exp(\rho \cdot q_{ij}) \qquad (15a)$$

$$\mu_i = \frac{1}{\sum_j \left\{ \nu_j \cdot \delta'^{B,S} E_j \right\} \exp(\rho \cdot q_{ij})}, \quad \nu_j = \frac{1}{\sum_i \left\{ \mu_i \cdot \delta^{B,S} N_i \right\} \exp(\rho \cdot q_{ij})} \qquad (15b)$$

where, n_{ij}: number of commuting trip from zone i to j, q_{ij}: generalized transport price and μ_i, ν_j, ρ: parameters.

The modal choice model for commuting trips is formulated by the same logit type of (12a).

Route choice behavior

The automobile traffic distribution, that is the OD table, is obtained from the transport model on private and business trips or commuting trips. The traffic assignment analysis is carried out by using this OD table and road network data. Here we apply the stochastic user equilibrium traffic assignment, formulated as below,

$$\min \sum_a \int_0^{x_a} t_a^C(s)ds - \frac{1}{\theta^R}\sum_a f_r^{ij} \ln \frac{f_r^{ij}}{P_{ij,C}^S \cdot \left[x_{ij} + X_{ij} + n_{ij}\right]} \tag{16a}$$

$$\text{s.t. } x_a = \sum_{ij}\sum_r \delta_{ar}^{ij} f_r^{ij}$$

$$P_{ij,C}^S \cdot \left[x_{ij} + X_{ij} + n_{ij}\right] = \sum_r f_r^{ij} \tag{16b}$$

$$f_r^{ij} > 0$$

where, x_a : traffic volume of link a, f_r^{ij} : traffic volume of path r, δ_{ar}^{ij} : factor of link-path incidence matrix.

This optimal programming yields the each path traffic volume as below logit model.

$$f_r^{ij} = P_{ij,C}^S \left[x_{ij} + X_{ij} + n_{ij}\right] \frac{\exp\left[-\theta^R t_{ij,r}^C\right]}{\sum_a \exp\left[-\theta^R t_{ij,r}^C\right]} \tag{17}$$

2.5. Absentee landowner behavior

The absentee landowner supplies the land for the households and firms with the land supply function in (18).

$$a_i^S = \overline{a_i^S}\left(1 - \frac{\sigma_i^H}{r_i}\right) \tag{18a}$$

$$A_i^S = \overline{A_i^S}\left(1 - \frac{\sigma_i^F}{R_i}\right) \tag{18b}$$

where, a_i^S, A_i^S : provided volume of residential land and business land, respectively, $\overline{a_i^S}, \overline{A_i^S}$: volume of providing available capacity for residential land and business land, respectively and σ_i^H, σ_i^F : parameters.

The profit of absentee land owner is expressed as below,

$$\pi_i^H = r_i\, a_i^S \tag{19a}$$

$$\pi_i^F = R_i\, A_i^S \tag{19b}$$

where, π_i^H, π_i^F : profit of absentee land owner for residential land and business land, respectively.

2.6. Equilibrium conditions

In this model, the equilibrium conditions consist of two types, location equilibrium conditions and market equilibrium conditions.

Location equilibrium conditions

In this CUE model, though the staying stratum and moving stratum are separated for the location choosing behavior of each agent, the location equilibrium condition is indicated that the total household number of moving stratum corresponds to the sum total for the moving household number of each zone as below.

$$N^T = \sum_i N_i^m \tag{20a}$$

$$N_i^m = N^T P_i^H \tag{20b}$$

where, N_i^m : the moving household number of each zone.

And the condition for the employee of the composite goods firm is also described as

$$E^T = \sum_j E_j^m \tag{21a}$$

$$E_j^m = E^T P_j^F \ . \tag{21b}$$

where, E_i^m : the moving employee number of each zone.

Market equilibrium conditions

In this paper, we state conditions for the only land markets, which include the residential type and business type. So market equilibrium conditions are guided as below,

For the Residential type: $$a_i^S = N_i \cdot a_i \tag{22a}$$

For the Business type: $$A_i^S = E_i \cdot A_i \tag{22b}$$

2.7. Benefit Definition

The benefit of projects are measured through the increase of household utility, the profit change of firm and absentee land owner those are computed by the CUE model.

The benefits enjoyed by households are defined by the concept of equivalent variation (EV). This is formulated as below by using the indirect utility function obtained in equation (3),

$$V_i^{H\,B} = V_i^H \left(r_i^A, q_i^A, w^A, I_i^A + EV_i^H \right) \tag{23}$$

where EV_i^H : the benefit of household, A,B: meaning of without project and with project, respectively.

The benefits enjoyed by firm and absentee land owner are defined directly by profit change of each agent.

Firm's benefit: $$EV_i^F = \Pi_i^B - \Pi_i^A \tag{24a}$$

Absentee land owner's benefit:

$$EV_i^L = \left\{ \pi_i^{H\,B} - \pi_i^{H\,A} \right\} + \left\{ \pi_i^{F\,B} - \pi_i^{F\,A} \right\} \tag{24b}$$

where EV_i^F : the benefit of firm and EV_i^L : the benefit of absentee land owner.

Total project benefit is expressed as below,

$$EV = \sum_i \left[EV_i^H + EV_i^F + EV_i^L \right] \tag{25}$$

3. Benefit evaluation of transport infrastructure projects

3.1. Parameter setting

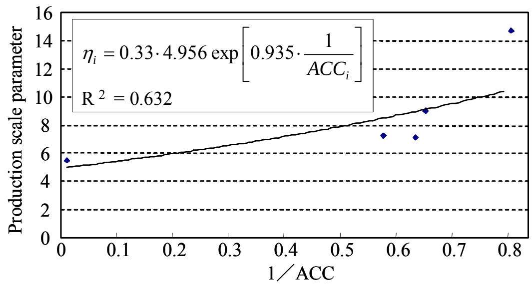
Before evaluating project benefit, we need determine the parameters of the utility

Table 1. Results of setting parameters

Utility function

Household		Parameters
Composite commodity	α_Z	0.346
Private trip	α_X	0.0181
Land	α_a	0.0515
Leisure	α_L	0.585

Production scale parameter function



Commuting trip model 1(unit trip)

		Parameter	
		Unit trip	Const.
Commute (Business)	Gen.	0.272	257.67
	Atr.	0.727	-21953
Commute (school)	Gen.	0.064	240.33
	Atr.	0.104	2110.3

Commuting trip model 2 (Distribution)

	Parameter	Correlation
Commute (business)	4.440	0.963
Commute (school)	3.960	0.930

Private and Business trip model 1 (Distribution)

		Private		Business	
		parameter	t-value	parameter	t-value
Worker Density	θ_1^D	8.581	35.067	10.444	43.844
In-in dummy	θ_2^D	4.541	61.568	3.266	45.000
Utility	θ_3^D	1.095	69.092	1.131	72.666
Constant	θ_4^D	-5.926	-418.6	-5.347	-460.4
Correlation		0.747		0.722	

Production function

Firm		Parameters
Labor	β_L	0.584
Land	β_A	0.0532
Business trip	β_X	0.0424

Location choice model (Household)

	Utility : V	Area	Constant
Parameter	3.591	154.90	-29.730
t-value	6.560	13.466	-5.950
Correlation	0.730		

Location choice model (Firm)

	Profit : Π	Area	Constant
Parameter	0.000346	87.531	2.076
t-value	14.385	11.173	22.483
Correlation	0.830		

Commuting trip model 3(mode choice)

		Commute (Business)		Commute (school)	
		parameter	t-value	parameter	t-value
Traffic cost	θ_1^S	-1.506	0.031	-1.202	0.0524
Density of Stations	θ_2^S	-0.202	0.0142	-0.0164	0.0282
Egress	θ_3^S	0.626	0.0192	0.172	0.0223
Constant	θ_4^S	-1.291	0.0206	-1.845	0.0327
Correlation		0.793		0.714	

Private and Business trip model 2 (Mode choice)

		Private		Business	
		parameter	t-value	parameter	t-value
Traffic cost	θ_1^S	-0.923	0.0317	-0.956	0.0309
Density of Stations	θ_2^S	-0.359	0.00785	-0.248	0.00646
Egress	θ_3^S	0.380	0.0186	0.299	0.0174
Constant	θ_4^S	-0.248	0.0185	0.165	0.0168
Correlation		0.805		0.757	

function, production function, the land supply function and some logit model in location choice model or transport choice model. We employ the calibration method for parameter setting of utility function and production function in which the benchmark year is 1995, and the least squares method for parameter estimation of location choice model or transport choice model. The estimated parameters are shown in Table 1.

3.2. Outline of the projects

We will apply the CUE model to project evaluation of transport infrastructure at Tokyo Metropolitan Area. Outline of those projects are as follows.

Road infrastructure projects

Here, three belt highways, nine radial highways and the Second Costal Highway were made applicable to evaluate that are submitted in the long-range design of road projects by Ministry of Land, Infrastructure and Transport (See Fig. 5).

Railway infrastructure projects

As the projects on railway, we consider as the candidate the railway lines those are recognized the necessity of building by 2015 by the transport policy council (See Fig. 6).

3.3. Solution of the CUE model

When the simulation by the CUE model is performed, it is necessity to solve simultaneously the location, land markets and transport network equilibrium conditions. However, because these conditions are expressed as simultaneous equations of high dimension, these cannot be computed easily. So we calculated the location volume, equilibrium rents and equilibrium transport required times which make total surplus maximize by adopting the sequential search method. Fig. 7 shows its simulating process. And we applied the Walras search process to solve land market equilibrium conditions.

Figure 5. Established and project plan of road network infrastructure

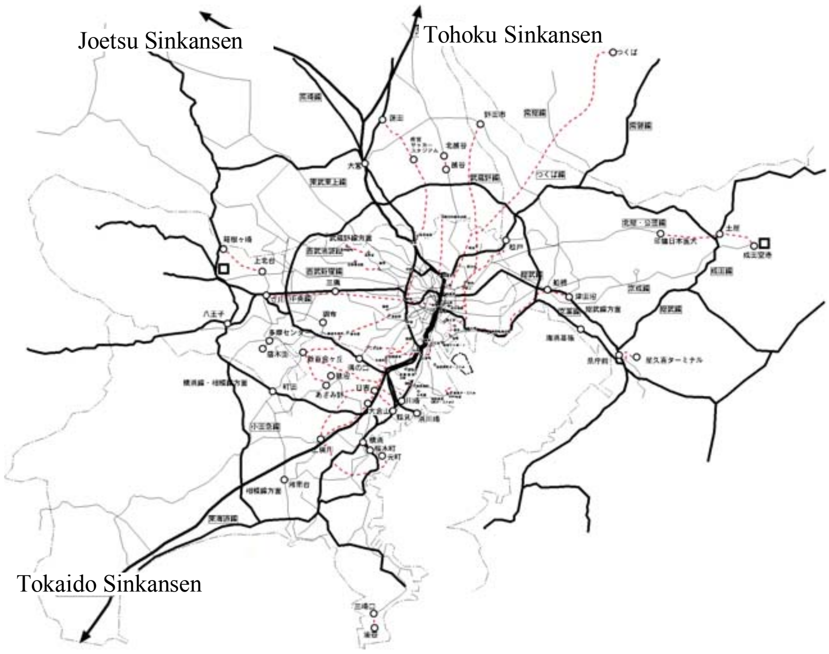


Figure 6. Established and project plan of railway network infrastructure

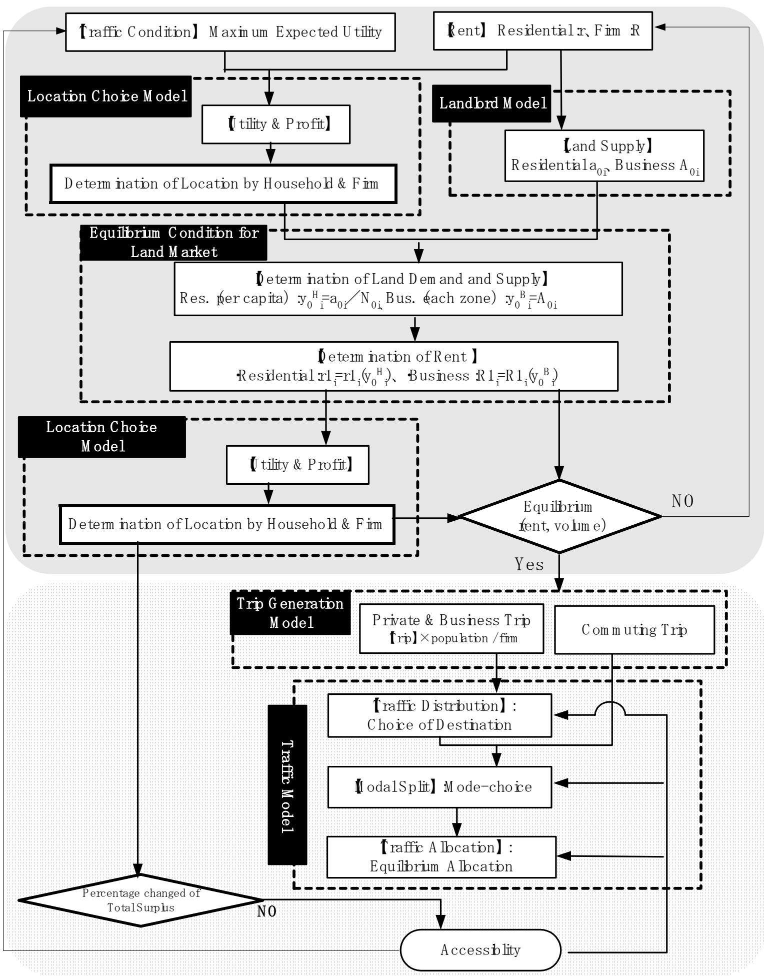


Figure 7. Solution method of the CUE model

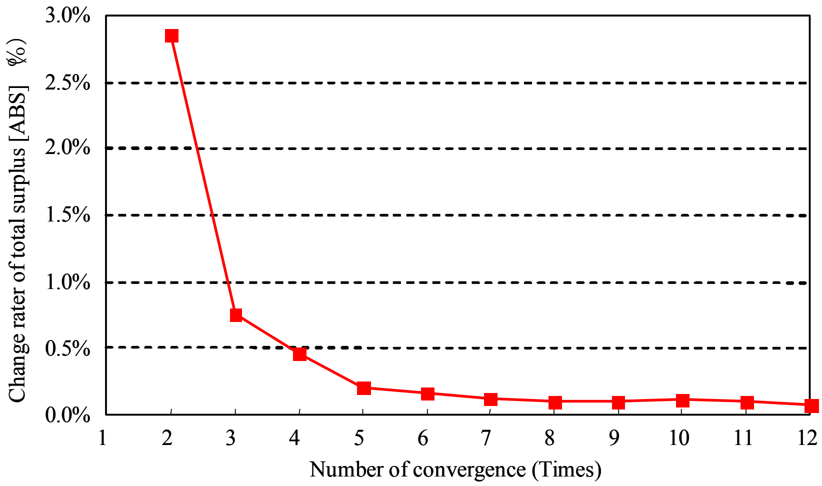


Figure 8. Convergence solution

The convergence situation in this calculation is shown in Fig. 8. The change rate of total surplus is taken along the vertical axis there and it turns out to converge 0.1% or less by 12 repetition calculation.

3.4. Results of numerical simulation

Next we show the change of the location pattern obtained from the numerical simulation by the CUE model, change of traffic volume, change of the amount of production, change of CO2 emissions and the calculation result of the amount of benefits. Here, we assumed to be build the entire road and railway infrastructure expressed in previous section by 2030, so we made 2030 the object year.

Results of population change

It is Fig.9 which shows population change of each zone from benchmark year 1995 to evaluating year 2030 for without projects case and with, respectively. In without case, the population increases around in center of Tokyo Metropolitan (radius of 15-25km within the circle) from 1995 to 2030, and population is decreasing in the suburban area. That is, the concentration to center of Tokyo is seen. On the other hand, in with case, population decreases in the center of Tokyo and is increasing in the suburban area. This is the so-called suburban extension type, and it turns out with case and without case that the result is reverse. It is thought that this cause has the transport accessibility at suburban area in having improved by transport infrastructure projects.

Then, the result of employee population change of each zone is shown in Fig.10. This also is the change from 1995 to 2030 for without projects and with. It turns out, in without case, the employee population is increasing in the city dump of each area materialized from the beginning, and, in with case, the center of Tokyo is high-accumulated up.

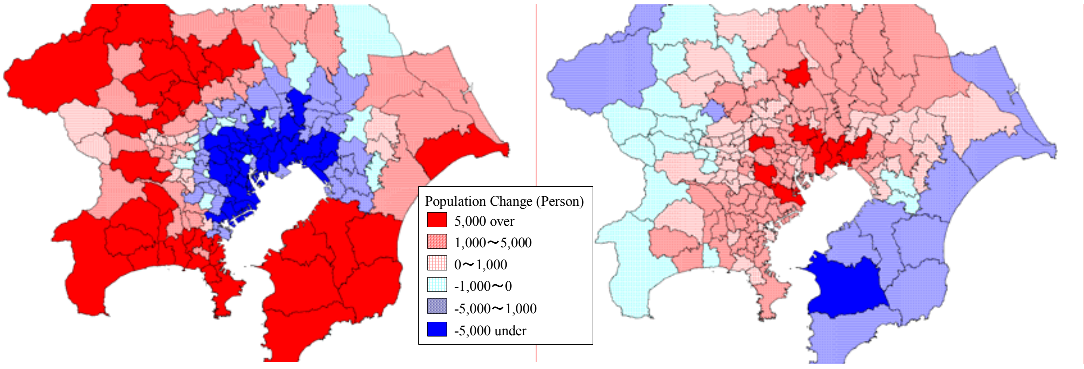


Figure 9. Change of population (1995-2030)

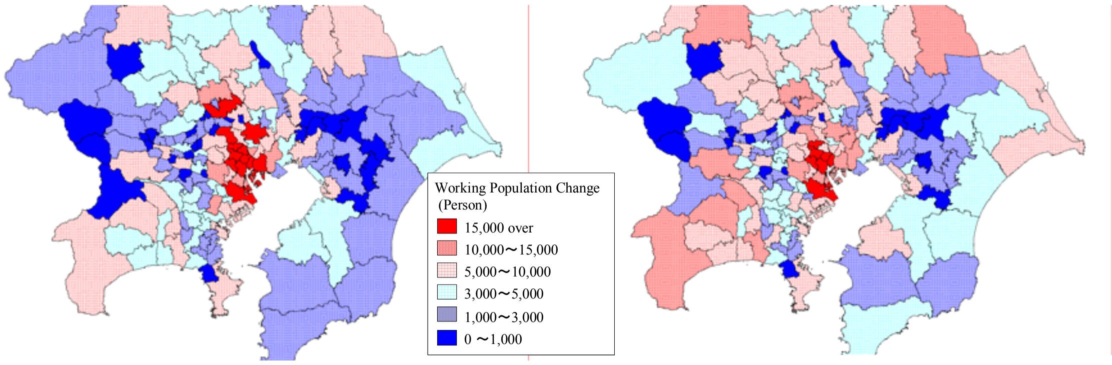


Figure 10. Change of employee population (1995-2030)

The result of without case has a reason in which, since the total working population is assumed to increase 2% from 1995 to 2030 in this case study, the working population for the increase comes to work in the existing city dump. It is because the transport accessibility of that area is higher than other area from the beginning. On the other hand, the influence of having taken the agglomeration economies into firm behavior has appeared in the result of comparative analysis for without projects and with. That is, at first, the transport infrastructure improvement to the radial direction from center of Tokyo raises transport accessibility in the center of Tokyo directly, and infrastructure of belt highway also improve transport accessibility in center of Tokyo indirectly since passage traffic comes to detour. And being improved transport accessibility in center of Tokyo raises the production efficiency of the firm in there with large population by making the agglomeration economies act. Consequently, since the rate of return in center of Tokyo is increased, the accumulation of working population in there is progressed.

Results of trips change

Next, the result of traffic volume change is explained. The change rate of the total generated trips, the automobile and railway passenger-km and automobile vehicle-km were shown in Fig. 11. In without case, the total number of generated trips will decrease in 2030 compared with 1995. Its cause is thought that the traffic trips generated by 2% population increasing by 2030 have made congestion aggravate as a result. In addition, being increased automobile and railway passenger-km is considered to have a reason in being extended the length of individual trip generated by moving people to suburban area, contrary to reduction of the total trip.

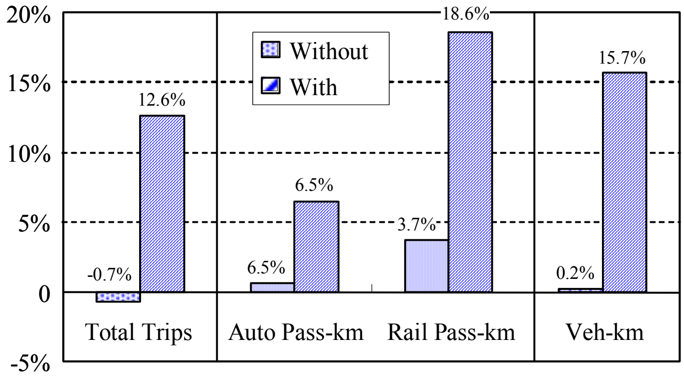


Figure 11 Results of benefit evaluation

However, in with case, the total number of trips increases about 12.6%. This is caused by the induced or development traffic pointed out at the beginning. Automobile and railway passenger-km is also increasing drastically. It is interesting that the increasing rate of railway passenger-km is especially larger. In addition, the difference in the increase rate of automobile passenger-km and vehicle-km is because, as for vehicle-km, the freight transport is taken into consideration to passenger-km taking only passenger transport into consideration. The freight transport is considered especially to increase vehicle-km since it comes to use more the belt highway.

Result of benefit evaluation

We show the evaluated benefit for these projects in Fig.12. The benefit is measured by being divided into the household, firm and absentee land owner, based on formulization of equation (25). The distribution of benefit to each zone is also shown in Fig.12. It turns out from the result of benefit evaluation in Fig.12 that benefit enjoyed by firm is very large. It is a cause in being arisen effectively the agglomeration economies. As for the benefit of absentee land owner, the sum total of all zones serves as zero theoretically. However, because accumulation in the center of Tokyo progressed and the land rent went up greatly with consideration of the agglomeration economies of firm, it is thought that the land rent revenue of absentee land owner increased more.

As for the distribution of benefits, that of household is higher in center of Tokyo and edge of object area. The benefit of firm is higher in center of Tokyo and lower in suburban area, and the absentee land owner is higher in edge of object area.

In this case study, the big benefit is expected to occur with transport infrastructure improvements. However, increase of traffic volume is afraid to increase CO2 emissions. The change of CO2 emissions is shown in Fig.13 that is calculated from the result of traffic volume gotten in the previous simulation. It is estimated that CO2 emissions will increase11.8% as compared with 1995 by constructing the transport infrastructure.

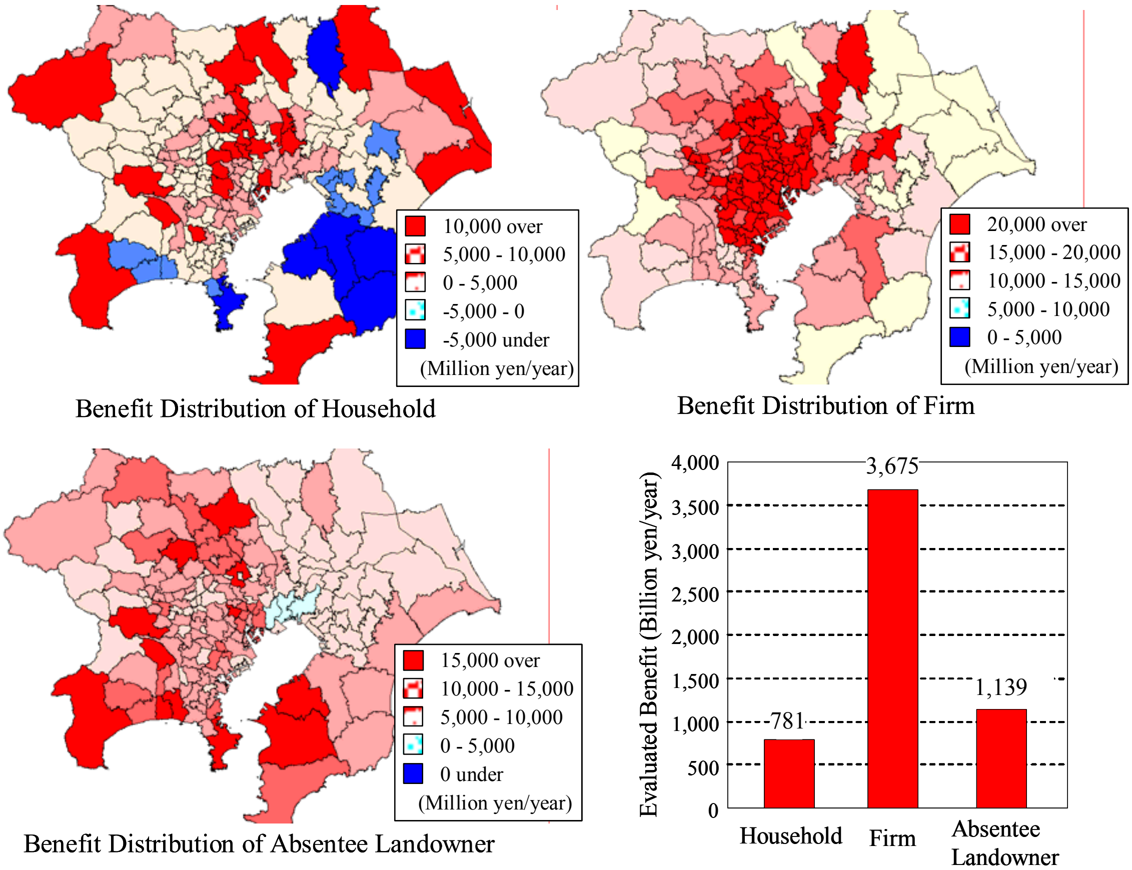


Figure 12. Results of benefit evaluation

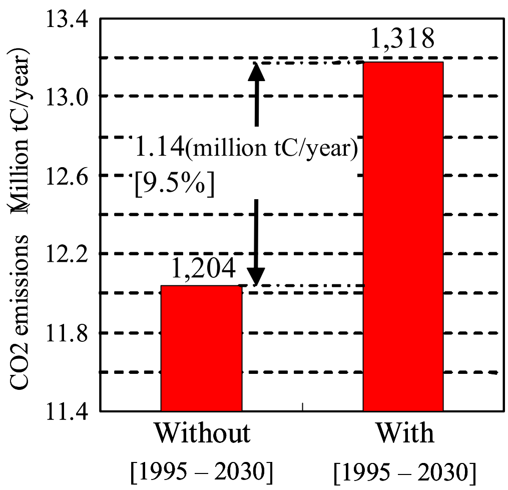


Figure 13. Results of CO2 emissions

Benefit incidence analysis

The benefit incidence table is drawn up in Table 2 based on the research of Morisugi and Ohno, 1992 in order to grasp the incidence structure of benefits for the detail items. The numerical values in the table indicate the one measured by being similar to trapezoid content.

Table 2. Benefit incidence table

		Household		Firm		Landlord		Total
Commuting (business) trip	Car	$-\sum_i N_i x_i^{w^C} dq_i^{w^C}$	1, 317					1, 317
	Railway	$-\sum_i N_i x_i^{w^R} dq_i^{w^R}$	1, 528					1, 528
Commuting (school) trip	Car	$-\sum_i N_i x_i^{s^C} dq_i^{s^C}$	166					166
	Railway	$-\sum_i N_i x_i^{s^R} dq_i^{s^R}$	445					445
Private trip	Car	$-\sum_i N_i x_i^C dq_i^C$	1, 188					1, 188
	Railway	$-\sum_i N_i x_i^R dq_i^R$	451					451
Business trip	Car			$-\sum_i E_i X_i^C dQ_i^C$	861			861
	Railway			$-\sum_i E_i X_i^R dQ_i^R$	248			248
Go-home trip	Car	$-\sum_i N_i x_i^{r^C} dq_i^{r^C}$	2, 285					2, 285
	Railway	$-\sum_i N_i x_i^{r^R} dq_i^{r^R}$	2, 117					2, 117
Land		$-\sum_i N_i a_i dr_i$	−5, 270	$-\sum_i E_i A_i dR_i$	−6, 100	$y_i^H dr_i + y_i^B dR_i$	11, 370	0
Agglomeration effect				$-\sum_i E_i \{A_i^{\beta_A} X_i^{\beta_X} L_i^{\beta_L}\} \frac{\partial \eta_i}{\partial ACC_i} dACC_i$ $\left(dACC_i = \frac{\sum_j E_j^v dq_{ij}}{E_j^v} + \frac{\sum_j q_{ij} dE_j^v}{E_j^v} - \frac{ACC_i}{E_j^v} dE_j^v \right)$	27, 430			27, 430
Composite goods		$-\sum_i N_i z_i dp_Z$		$\sum_i E_i Z_i dp_Z$				0
Labor		$\sum_i N_i L_S dw$		$-\sum_i E_i L_i dw$				0
Total		4, 227		22, 439		11, 370		38, 036
Total 【EV】		7, 814		36, 750		11, 385		55, 949

It turns out from the table that, as for the effects of time serving, the benefit enjoyed by household is bigger than another agent. The benefit enjoyed by firm with agglomeration economies is generated about 2.7 trillion yen/year and is accounts for about 70% to the total amount of benefit calculated in the benefit incidence table. Since the wage and composite good price is given in this model, the influence of being changed them cannot appear in this table, too.

4. Conclusion

When the project plans of road and railway infrastructure are carried out at Metropolitan Area, we evaluated the influence which it has on transport system, urban structure and CO2 emissions, and measured the benefit of projects by the CUE model, in this paper. From the results, those transport infrastructure projects were clarified by bringing the great benefits of 5.6 trillion yen/year through the induced and development traffic as well as effects of time saving. As for the change of urban structure, it is made clear that firm is high-accumulated up in center of Tokyo and household is extended to suburban area with the projects. On the other hand, as for the change of CO2 emissions exhausted from transport sectors, the result of increasing about 9.5% for comparing without projects and with is obtained, since the length of individual trips comes to be longer by generating the induced or development traffic and changing to those urban structure.

In future, it is necessity to argue the scheme to regulate CO2 emissions without generating the economic damage as much as possible. Example, we will examine the scheme that it makes the core business city distributing to suburban area, it levies some burden such as pricing or tax to transport sector directly or it combines the policies to land use and transport.

Acknowledgement

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