# Chapter 18
# Impacts of Transport Infrastructure Policies in Population-Declining Metropolitan Area

## Business Productivity and Quality of Urban Life in Tokyo

**Kiyoshi Yamasaki, Takayuki Ueda, and Shinichi Muto**

**Abstract** In The Tokyo metropolitan area, population growth and economic growth have caused serious urban problems like sprawl at urban fringe, heavy congestion not only in road network but also in railway network, environmental emission and so on. Although there still now remain the difficult problems for us to tackle with, the transport infrastructure policies until today have succeeded in sustaining the high business productivity with high spatial agglomeration and quality of life in the population-growing trend.

Japan is however now at the down-slope of the population trend curve and Tokyo is predicted to begin a decade-long decline in population. The significant population decline in Tokyo metropolitan area is an inexperienced situation for the people and policy makers. They may be concerned that the population decline would reduce the great merit of spatial agglomeration in Tokyo. The question at the heart of policy discussion is how we can sustain the high level of business productivity and quality of life in the Tokyo metropolitan area by spatial restructuring. This paper has developed the Computable Urban Economic Model, which re-formalizes the conventional landuse-transport interaction model on the basis of microeconomic foundation, so as to answer the above question.

As a result, we found that the central Tokyo remains as the center of the economy in 2050 with high spatial agglomeration since the agglomeration is accelerated by the scale economy. On the other hand, population which is not affected by agglomeration, is decreasing at each zone with the same level.

K. Yamasaki (✉)
Value Management Institute, Tokyo, Takeda, Kofu, Japan
e-mail: kiyoshi_yamasaki@vmi.co.jp

T. Ueda
School of Engineering, The University of Tokyo, Tokyo, Takeda, Kofu, Japan

S. Muto
Department of Civil and Environmental Planning, Yamanashi University, Takeda, Kofu, Japan

J. Klaesson et al. (eds.), *Metropolitan Regions*, Advances in Spatial Science,
DOI 10.1007/978-3-642-32141-2_18, 

The investment to the three Ring Roads is expected to contribute to developing more dispersive urban structure since the three Ring Roads increase the transportation convenience at the suburb and it induces to the entry of the firms and population as well. This does not, however, the central Tokyo loses its competitiveness but they still remain strong in terms of the spatial distribution of the firms. The reduction of population mitigates the congestion of the road network. It enables us to increase our convenience in terms of the trip by car. It induces to more trips to the households and business people, which bring about more communication, that is one of the keys for the productivity growth and the enhancement of households' utility. During this period, traffic density of car increase due to the enhancement of the transport convenience by car.

**Keywords** Spatial agglomeration • Productivity • Land use • Induced and development traffic • Network

## 1 Introduction

Tokyo has been the largest metropolitan area in the world and the growth pole which has led the Japanese national economy. Since the years of rapid economic growth after the War, Tokyo has attracted a huge amount of population from the country-sides to result in mono-centric spatial structure of Japan.

In Tokyo metropolitan area, the population growth and the economic growth have caused the serious urban problems like sprawl at urban fringe, heavy congestion not only in road network but also in rail network, environmental emission and so on. Transport infrastructure systems in the metropolitan area have been developed so as to solve these problems by expanding the coverage and capacity of the networks. Although there still now remain the difficult problems for us to tackle with, the transport infrastructure policies until today have succeeded in sustaining the high business productivity and quality of urban life in the population-growing trend. The spatial agglomeration in Tokyo metropolitan area has been functioning effectively with the transport infrastructures.

Japan is now at the down-slope of the population trend curve and Tokyo is predicted to soon lose its population in a decade. The significant population decline in Tokyo metropolitan area is an inexperienced situation for the people and policy makers. They may be afraid that the population decline would reduce the great merit of spatial agglomeration in Tokyo. The question at the heart of policy discussion is how we can sustain the high level of business productivity and quality of urban life including residential environment in the Tokyo metropolitan area by spatial restructuring. We should evaluate transport infrastructure policies so as to answer the question.

The population decline may make incentives for business sectors to relocate to more productive districts where they can enjoy the more advantage in the exchange of information and knowledge though business communication. In other words, the population decline may result in more extensive local agglomeration of business sectors. Some types of transport infrastructure policies can contribute to such spatial restructuring. The population decline will also greatly impact on housing market or residential land market. Transport infrastructure policies affect on the spatial distribution of residents and then the quality of their urban life. Since the impacts of the policies are so location-specific, we do need a well-designed tool for geographical analysis.

We employ the Computable Urban Economic (CUE) model as the tool for the policy analysis. The CUE model is developed in the tradition of Transport-Land Use Interaction (TLUI) model. We should remark on the merits of the CUE in contrast to the old TLUI models. First, the CUE model is fully based on the urban economic theory in Alonso tradition. The microeconomic foundation in urban economics enables us to evaluate policies consistently with standard methodologies of cost benefit analysis. The location choice behaviors of residents and business sectors are described b logit model in the Anas tradition Anas (1984) and the demand–supply in land markets should determine land price distribution in an urban economy. The transport demand for each type of transport service are derived from utility maximizing behavior or profit utility maximizing behavior and the user equilibrium of transport network in the Wardrop tradition is simulated.

This paper shows the impacts of transport infrastructure policies in the population-declining metropolitan area by applying the CUE model to the greater Tokyo Metropolitan Area. We examine whether or not the polices under discussions between policy makers can sustain business productivity and quality of urban life in Tokyo at a population declining trend.

# 2 Structure of the Computable Urban Economic Model

## 2.1 Sketch of the Model

### 2.1.1 Features of the Model

There are two advantages for the CUE, which introduces the microeconomic foundation into the conventional transportation/land-use model.

One is consistency of behavior hypothesis with a simulation result. The behaviors of the household and the firm are formalized on the basis of the micro-economics. Micro-econometrics including the discrete choice model has enables the utility-max or the profit-max behaviors to be statistically verified so that the microeconomic behavior hypothesis can work as an operational tool.

The other is that the model enables us to evaluate the benefit of a transport policy in the incidence form where the distribution of project benefits among stakeholders in spatial dimension. In contrast, a conventional transport/land-use model measures the project benefit only in the origin form where the benefit of transport users and supplies are accounted for. The project benefit in the incidence form can provide policy makers with information like “who is benefited?”, “where and how much benefit is generated ?”. This advantage contributes to consideration of the fair balance among the stakeholders on sharing the cost and benefit of a transport project.

In the CUE model, the land and the transport markets attain an equilibrium simultaneously. The equilibrium of the transport market is attained according to the first Wardrop principle. This is represented by the point where the inverse demand function intersects with the average cost function (link performance function, not the marginal cost function). We then assume that users in a road network only consider the information on the average cost and pay less attention to the marginal increase in the user cost that occurs from an additional user.

The traffic assignment is based on the average cost. The composite average cost, which denotes the transportation cost from the specific origin to the destination, is the horizontal summation of the link transportation costs, This inverse demand function indicating the number of OD trips changes its functional form according to the land-use at each zone and the trip generation. On the one hand, the composite average cost function shifts to the right horizontally if the number of links increases because of the further increase in the OD trips. The change in the transport cost causes the change in the land-use and then the state of the transport system shifts to a new equilibrium through the change in the inverse demand function.

The equilibrium of the land market is attained by adjusting the rent at each zone. The supply function for land is the marginal cost curve assumed not to shift endogenously. The demand for land is derived from multiplying the population at each zone with the per capita land demand or the individual land demand. The individual land demand is derived from the household’s or resident’s utility maximization.

The total population is distributed to each zone according to the utility values at each zone. Thus, the decrease in the transport cost due to a road network development would increase the net income (gross income minus commuting cost), the individual land demand and the population at the zone. The limited availability of the land at each zone makes the land rent higher and the price mechanism clears the market.

The CUE model attains the equilibrium if the transport market is cleared for each OD demand and the supply and demand of the land market are equalized for each zone. Since the CUE model adopts the stochastic approach, the logit model which assume the Gambel distribution in the error term, is used for both transport and location choice.

### 2.1.2 Major Assumptions in the Model

The CUE model in this paper has the following assumptions

- The Tokyo Metropolitan Area that is divided into 197 zones.
- There are households with an identical preference and firms with an identical production technology for the composite good and absentee landowners each of which representatively owns the land.

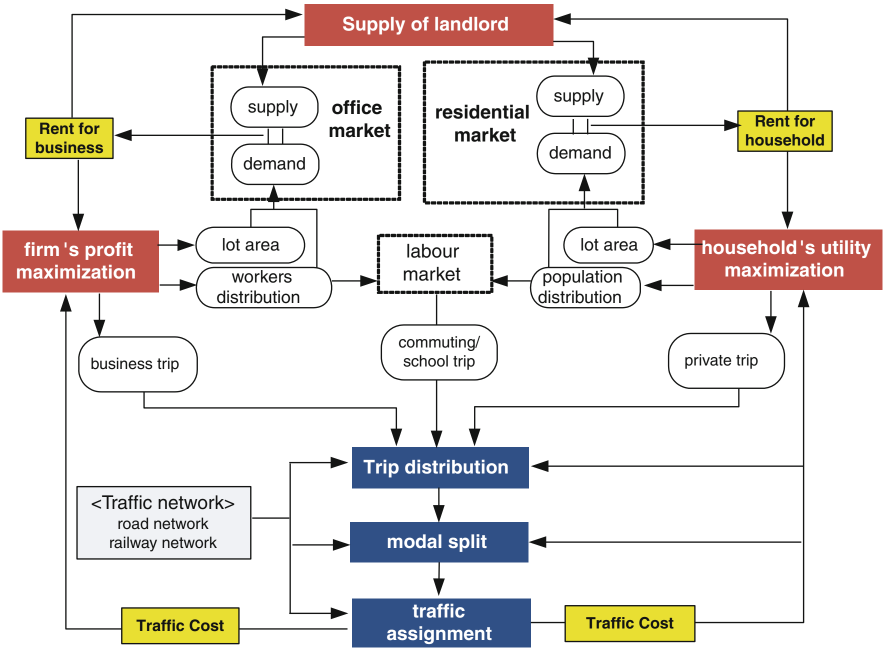



**Fig. 18.1** Whole structure of CUE

- The land markets for the residential use and for business use are assumed to exist in each zone.
- The prices except land rents, such as the wage and the composite good price are assumed to be constant at the WITH/WITHOUT case.
- Total number of households and employees are also given.

The household maximizes the utility under the income constraint and chooses the residential zone to locate according to the attractiveness of each zone. The firm maximizes its profit by using land and business trip and sells the products to the households. The firm also chooses its location according to the profit. Finally, the absentee landlord provides with land available to the households and the firms in order to get the rent. The absentee landlord decides how much percentage of land available is supplied to the market.

As is already mentioned, the CUE model requires simultaneous equilibrium of land and transport markets, which is adjusted by the generalized transport cost and the rent of the land. The overall structure of the CUE model is shown in the Fig. 18.1.

## 2.2 Formulation of Each Agent's Behavior

### 2.2.1 The Model of the Household Behavior

The household earns the income by providing labor and consumes the composite good 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 trip or labor, can be considered in the model. In order to consume the composite good, the household need input the travel trips. These trips can be interpreted as the private trips. This utility maximizing behavior is formulated as follows.

$$V_i^H = \max_{z_i, a_i, x_i} \left[ \alpha_Z \ln z_i + \alpha_a \ln a_i + \alpha_x \ln x_i^p \right] \tag{18.1}$$

$$\text{st. } z_i + r_i a_i + q_i^p x_i^p = w\left(T - q_i^w x_i^w - q_i^s x_i^s\right) \tag{18.2}$$

$V^H i$: utility level at zone i
$Z_i$: consumption level of composite good
$a_i$: land service
$x^P{}_i$: private trip
$r_i$: residential land rent
$q^P{}_i$: the average generalized price of private trip
T: total time available
$x^w{}_i$: number of the commuting trip (business)
$x^s{}_i$: number of the commuting trip (school)
$q^w{}_i$: commuting cost (business)
$q^s{}_i$: commuting cost (school)
$\alpha$: distribution parameter

Price $q$ of private trip is defined by the transport cost multiplied by the wage rate. Then, the constraint includes the notion of time as a part of household's income. The solution of the utility maximization problem defined by (18.1) and (18.2) gives demand functions as follows.

$$z_i = \alpha_Z I_i \quad a_i = \frac{\alpha_a}{r_i} I_i \quad x_i = \frac{\alpha_x}{q_i} I_i$$
$$I_i = w\left(T - q_i^w x_i^w - q_i^s x_i^s\right) \tag{18.3}$$

The induced traffic is considered at the generation stage, since the private trip increases as the private and commuting trip cost decreases. We can obtain the indirect utility function by substituting (18.3) into (18.1).

$$\begin{gathered} V_i^H = \ln I_i - \alpha_a \ln r_i - \alpha_x \ln q_i + C \\ where, C = \alpha_z \ln \alpha_z + \alpha_a \ln \alpha_a + \alpha_x \ln \alpha_x \end{gathered} \tag{18.4}$$

The household chooses the zone to reside according to distribution of the attractive index for each zone which is given by (18.4). We assume the probability of the residential location choice is given by the following.

$$P_i^H = \frac{\exp \theta^H V_i^H}{\sum_i \exp \theta^H V_i^H} \tag{18.5}$$

$P^H_i$: probability that a household chooses zone i
$V^H_i$: utility level at zone i
$\theta_H$: logit parameter

Equation 18.5 is deduced from the following problem.[1]

$$\begin{aligned} S^H &= \max_{P_i^H} \sum_i \left[ P_i^H V_i^H - \frac{1}{\theta^H} P_i^H \ln P_i^H \right] \\ st.\ & \sum_i P_i^H = 1 \end{aligned} \tag{18.6}$$

Ueda (1992) shows that the utility level at each zone becomes identical if we only consider the deterministic where the entropy term in (18.6) can be omitted. When $\theta^H$ is large enough, we can ignore the entropy term.

$$\begin{aligned} S^H &= \max_{P_i^H} \left[ \sum_i P_i^H v_i^H \right] \\ st. & \sum_i P_i^H = 1 \end{aligned} \tag{18.7}$$

The Kuhn-Tucker condition for the problem is given as follows.

$$\begin{aligned} L &= \sum_i P_i V_i - \lambda \left( 1 - \sum_i P_i \right) \\ \frac{\partial L}{\partial P_i} &= V_i - \lambda \quad \frac{\partial L}{\partial \lambda} = 1 - \sum_i P_i \end{aligned} \tag{18.8}$$

From the condition above, we have the relationship below.

$$\begin{aligned} V_i^H &= \lambda \quad if \quad P_i^H \geq 0 \\ V_i^H &\leq \lambda \quad if \quad P_i^H = 0 \end{aligned} \tag{18.9}$$

[1] This can be interpreted as the expected utility maximization behavior of the risk averter when the Gambel distribution is assumed for the uncertainty of the utility. See Ueda and Tsutsumi (1999).

Thus, (18.9) suggests that (18.6) includes the notion of the equalized utility in urban economics.

### 2.2.2 Firm's Behavior

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

$$\Pi_i^B = \max_{Z_i, A_i, X_i} [Z_i - R_i A_i - Q_i X_i] \tag{18.10}$$

$$\text{st. } Z_i = \eta_i E^{\sigma} A_i^{\beta_A} X_i^{\beta_x} \tag{18.11}$$

$\Pi^B{}_i$: profit at zone i
$Z_i$: output of the composite goods firm
$A_i$: land service
X: business trip input
$R_i$: business land rent
$Q_i$: the average generalized price of business trip
η: parameter regarding to production efficiency
σ, β: parameter
Ei: employees at zone i

As is shown in Fig. 18.2, the actual employee density at the central Tokyo is much higher than the population density. It means that there is high productivity as a result of frequent business communication, which has been enabled *by spatial agglomeration*.

In order to describe the mechanism of the spatial agglomeration, the positive externality has been introduced into the description of production technology. That is, the total factor productivity in a production function is dependent upon employee worker of each zone.

The solution of the profit maximizing problem in (18.10) and (18.11) yields factor demand functions of *A* and *Xi* respectively.

$$A_i = \frac{\beta_A}{R_i} Z_i \quad X_i = \frac{\beta_X}{Q_i} Z_i \tag{18.12}$$

$$Z_i = \left[ \eta_i E^{\sigma} \left( \frac{\beta_A}{R_i} \right)^{\beta_A} \left( \frac{\beta_X}{Q_i} \right)^{\beta_X} \right]^{(\beta_A + \beta_X)} \tag{18.13}$$


**Fig. 18.2** Actual employee density and population density

The firm's location choice behavior is formulated as well as the household's one. As a result, the probability choosing zone $i$ to locate is determined by the following logit type model.

$$P_i^B = \frac{\exp \theta^B \prod_i^B}{\sum_i \exp \theta^B \prod_i^B} \tag{18.14}$$

### 2.2.3 Land Supply by the Absentee Landlord

The absentee landowner supplies the land for the households and firms with the land supply function in (18.15). Note that the value in the parenthesis is assumed to take the range from zero to one.

$$y_i^H = \overline{y_i^H} \cdot \left(1 - \frac{\sigma_i^H}{r_i}\right) \tag{18.15}$$

$$y_i^B = \overline{y_i^B} \cdot \left(1 - \frac{\sigma_i^B}{R_i}\right) \tag{18.16}$$

$y_i^H$: land supply for residential use
$y_i^B$: land supply for business use

$\overline{y_i^H}, \overline{y_i^B}$: land area available to supply

σ: parameter

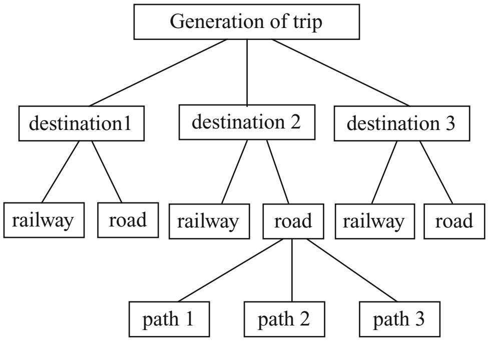



**Fig. 18.3** Choice structure of nested logit model

## 2.3 *Formulation of Transportation Behavior*

The Fig. 18.3 shows the structure of the nested logit model we use in the CUE model. Although the structure could be changed[2] due to the reflection of the result of the parameter estimation, the present research adopted the structure which is the same as the conventional four step estimation. In addition, these structures are basically applied to the trip moving to the different zone. The ratio of this trip and the trip inside the zone never changes.

### 2.3.1 Model of Trip Generation

Since commuting trips (business and school) has less influenced by the change in the transportation services, we used linear regression model for the generation forecast. However, we assume that the demand function of the private and business trip does not include traffic fares.

### 2.3.2 Choice of Destination and Modal Split

We formulate destination choice and modal split of each reason to move (eq. private, business, etc.) by the nested logit model explained above. In order to decide the cost inherent to each zone, $C_{ijm}$, we follow the proceeding work by Yoshida and Harada (1999), which introduced the variable dependent upon the amount of the zone area. The Generalized transportation cost includes gasoline for automobiles and fare for railways.

[2] For example, Maruyama (2002) reversed the order of the destination choice and modal split.

$$P_{ijm} = \frac{\exp\left[-\theta_1\left(C_{ijm} + q_{ijm}\right)\right]}{\sum_m \exp\left[-\theta_1\left(C_{ijm} + q_{ijm}\right)\right]} \tag{18.17}$$

$$P_{ij} = \frac{\exp\left[-\theta_2\left(C_{ij}^D + S_{ij}^D\right)\right]}{\sum_j \exp\left[-\theta_2\left(C_{ij}^D + S_{ij}^D\right)\right]} \tag{18.18}$$

$$S_{ij}^D = -\frac{1}{\theta_1} \ln \sum_m \exp\left[-\theta_1\left\{q_{ijm} + C_{ij}^S\right\}\right] \tag{18.19}$$

$P_{ij}$: probability of choosing zone j as destination by the trip generated at zone i
$P_{ijm}$: probability of choosing mode m at link ij

$S^D{}_{ij}$: expected minimum cost regarding to modal split
$q_{ijm}$: transportation cost of mode m at link ij
$C_{ijm}$: cost inherent to mode m at link ij(constant)
$C^D{}_{ij}$: cost inherent to ij (constant)
θ1,θ2: logit parameter

### 2.3.3 Traffic Assignment

The traffic assignment analysis is carried out by using the OD table and road network data. Here we apply the stochastic user equilibrium traffic assignment. By solving the problem, the probability where route *k* of transportation mode *m* between OD pair *ij* is determined by the following.

$$P_{ijmk} = \frac{\exp\left[-\theta_3\, q_{ijmk}\right]}{\sum_k \exp\left[-\theta_3\, q_{ijmk}\right]} \tag{18.20}$$

The traffic cost of route *k* is the sum of the traffic cost of each link.

$$q_{ijmk} = \sum_a \delta_{ijmk}^a t(x_a) \tag{18.21}$$

$P_{ijmk}$: probability of choosing route k of mode m in OD pair ij
$q_{ijmk}$: transportation cost of route k of mode m in OD pair ij
t: average transportation cost of link a

$\delta^a{}_{ijmk}$: variable which takes 1 if route k of mode m in OD pair ij includes link a (0 otherwise)
θ3: logit parameter

# 3 Estimation of Parameters

## 3.1 Land-Use Section

### 3.1.1 Distribution Parameter of the Production Function

The distribution parameter of the firm is set based on “Annual report on prefectural accounts (2003 edition)”. The land input is determined by the property income of the annual report and the gross regional product is used for the composite goods. The business trip input of the firm is calculated by using the total transportation cost based on the network distribution (Table 18.1).

### 3.1.2 Parameter on Utility Function

Parameter of utility function is estimated by using “Annual report on prefectural accounts (2003 edition)” Table 18.2 shows the result and the amount of the land demand is approximately 14.4 %.

## 3.2 Transport Section

The estimation result of the destination choice and the modal split in the transportation model are shown in Table 18.3 and 18.4.

# 4 Applications

## 4.1 Details of Assumptions and Settings

### 4.1.1 Coverage Area and Transport Infrastructures

The coverage area includes the southern part of Ibaraki prefecture in addition to Tokyo metropolitan area (Tokyo metropolitan, Kanagawa prefecture, Chiba prefecture and Saitama prefecture). The coverage area is divided into 197 zones. At the central Tokyo, the density of the employee is higher than that of population (Figs. 18.4, 18.5, and 18.6)

Figure 18.7 shows the road network considered. In this paper, we have excluded the local street. Figure 18.8 is the railway network and it has included only when a railway has been located in more than two zones.

**Table 18.1** Distribution parameters of production function

| | Parameters | t-statistic | R-squared |
|---|---|---|---|
| Input of land($B_A$) | 0.0062 | 11.0214 | 0.4558 |
| Input of business trip($B_x$) | 0.0202 | 13.2672 | 0.8710 |

**Table 18.2** Parameter on utility function of the household

| | Parameters | t-statistic | R-squared |
|---|---|---|---|
| Consumption on private trip($\alpha_X$) | 0.0295 | 22.8870 | 0.7287 |
| Consumption on land($\alpha_a$) | 0.1769 | 12.2045 | 0.2376 |

**Table 18.3** The result of parameter estimation for modal split

| | Commute | | School | | Private | | Business | |
|---|---|---|---|---|---|---|---|---|
| | Parameter | t-statistic | Parameter | t-statistic | Parameter | t-statistic | Parameter | t-statistic |
| Transport cost | −0.070 | −54.99 | −0.026 | −9.67 | −0.061 | −36.93 | −0.036 | −27.13 |
| Density of stations | 0.565 | 17.67 | 0.129 | 2.36 | 0.462 | 29.23 | 0.313 | 32.285 |
| Egress | −0.790 | −28.24 | −0.311 | −6.52 | −0.914 | −19.46 | −1.038 | −26.54 |
| Constant | −0.858 | −20.98 | −1.910 | −27.34 | 0.226 | 4.892 | 0.225 | 6.079 |
| R-squared | 0.801 | | 0.752 | | 0.700 | | 0.660 | |
| Sample | 5,207 | | 1,182 | | 3,869 | | 3,638 | |

**Table 18.4** The result of parameter estimation for choice of destination

| | Commute | | School | | Private | | Business | |
|---|---|---|---|---|---|---|---|---|
| | Parameter | t-statistic | Parameter | t-statistic | Parameter | t-statistic | Parameter | t-statistic |
| Expected minimum cost | −0.030 | −88.59 | −0.021 | −50.93 | −0.022 | −68.06 | −0.018 | −69.86 |
| Density of employee | 1.162 | 71.338 | 0.750 | 41.861 | 0.897 | 54.272 | 1.053 | 72.866 |
| R-squared | 0.69898 | | 0.56896 | | 0.70227 | | 0.82461 | |
| Sample | 11,122 | | 7,507 | | 9,518 | | 9,523 | |

### 4.1.2 Total Population and Employees in Metropolitan Area

The total population in the Tokyo metropolitan area has been predicted by using the growth rate of population at the Tokyo metropolitan area shown in *Population Projections by Prefecture* (2007) published by the National Institute of Population and Social Security Research. As a result, the total population in 2050 decreases 9 % compared to 2000. As for the forecast of the employee, there is little survey

**Fig. 18.4** Coverage area (197 Zone)

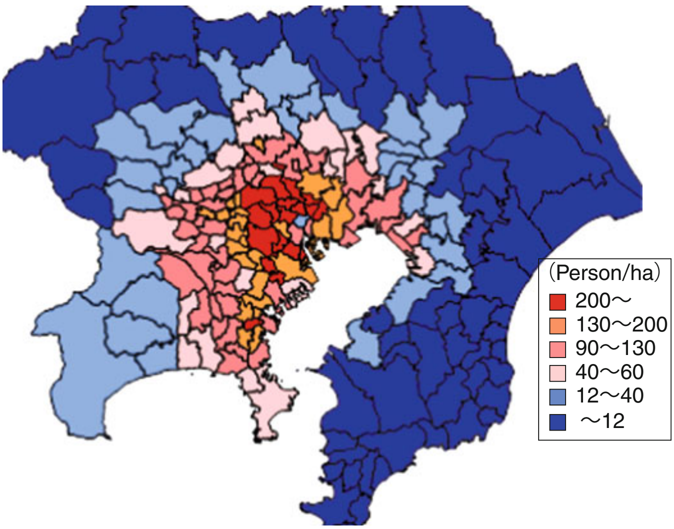



**Fig. 18.5** Population density distribution

available than population. Although some other report set the growth rate of employee worker unchanged for next 25 or 30 years, we adopt the half of the growth rate of the population. Then population framework for the model is

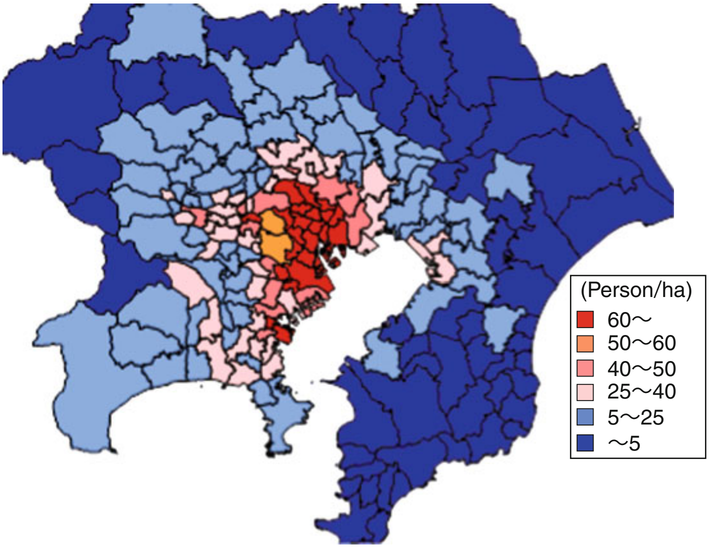



Fig. 18.6 Employee density distribution

Fig. 18.7 Road network

summarized in Fig. 18.9. The population in Tokyo metropolitan area will become 31.6 million while the number of the employee worker will be 16.7 million in 2050.

### 4.1.3 Transport Infrastructure Policy

We will simulate the socio-economic impacts on Tokyo metropolitan area in 2050 between the cases with/without the three-Ring Road (Fig. 18.10).

Fig. 18.8 Railway network

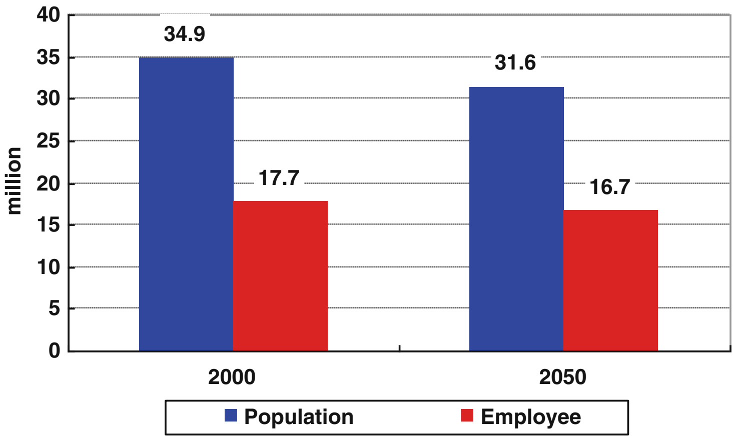



Fig. 18.9 Total population and employees in metropolitan area

### 4.1.4 Setting of Cases

We apply the CUE model to evaluate the effects of transport infrastructure in the Tokyo Metropolitan Area. In this paper, the following four cases are simulated. The first two cases combined are able to evaluate the effect of the three Ring road at year 2000. while the last two cases do the same for year 2050. By recombining the four cases we can compare the effect at 2000 with that of 2050 (Table 18.5).

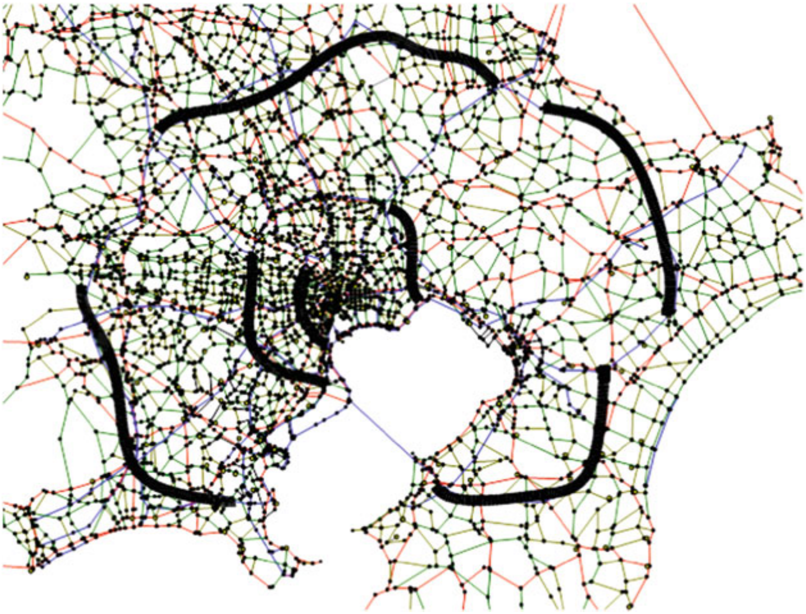


**Fig. 18.10** Plans for construction of three-ring road (Source: MLIT web page)

**Table 18.5** The cases

| | Year | Three-ring road |
|---|---|---|
| Case1 | 2000 | Without |
| Case2 | | With |
| Case3 | 2050 | Without |
| Case4 | | With |

## *4.2 Impacts on Land Use*

### 4.2.1 Changes in Population

The following two figures show the change in the population at each zone in 2050 compared to 2000 (without). Figure 18.11 says there is no difference among zones even though their population densities are quite diverse. In Fig. 18.12, however, the decrease of the population becomes smaller when the population density is small. This is because in the difference of Case 3 and Case 4 is "with or without" of the three Ring Road, which is surrounded by the less population density areas.

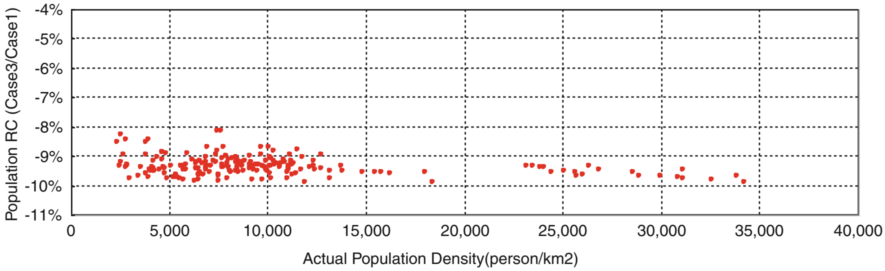



**Fig. 18.11** Population change in 2050 (without three ring-road) (Case3/Case1)

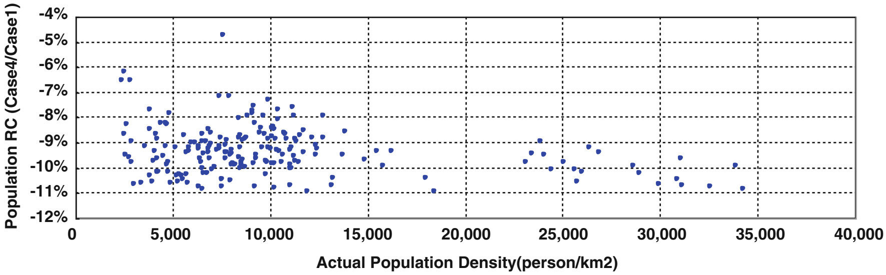



**Fig. 18.12** Population change in 2050 (with three ring-road) (Case4/Case1)

### 4.2.2 Changes in Employee

Figure 18.13 shows the change of the employee worker density of each zone in Case 3. There is less decrease in Chiyoda-ku, Minato-ku and Chuo-ku while the zone with lower density located in the suburb has bigger decrease. This depends on our specification of the production function, which increases the productivity when the employee density becomes higher. The same figure for Case 4 is drawn in Fig. 18.14. There are some zones whose employee densities are low but the degree of decrease is not as much as Fig. 18.13. The main reason for this is because the existence of the three Ring Road increases the productivity of low employee worker density area through the additional entry of firms.

### 4.2.3 Passenger and Traffic Modal Split

The passenger trip in 2050 decreases about 8 % in each case. This decrease brings about the increase in transport share of car for 1 %. The construction of three Ring Road makes passenger trip increase about 3 % and the transport share of car about 0.5 %.

The heavily populated area like Tokyo metropolitan area tends to be short supply in terms of the road infrastructure and it leads to the higher share of the railway.


**Fig. 18.13** Change of employee worker (without three ring-road) (Case3/Case1)

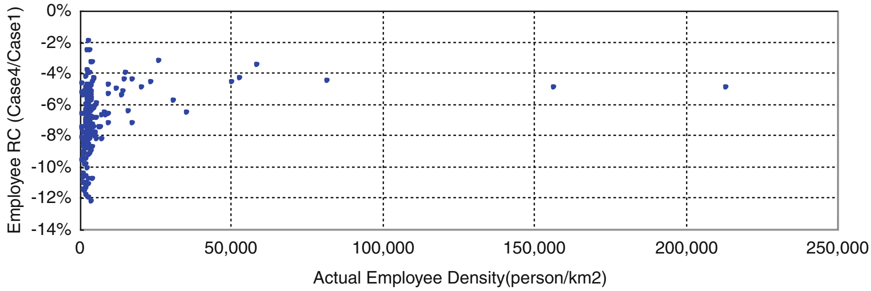



**Fig. 18.14** Change of employee worker (with three ring-road) (Case4/Case1)

There is a possibility that the transport share by car would be increased when the heavy congestion is mitigated because of population decrease. In addition, construction of an arterial high-standard highway like three Ring Road might induce more car traffic since it enhances the convenience (ig. 18.15).

### 4.2.4 Evaluation Indices

Next we compare the Evaluation index of the road network between 2000 and 2050. The passenger trip by car decreases according to the population and employee worker's decrease in 2050. However, it is still higher than the total rate of population decrease, which is 8 % by 2050. As we pointed out before, it is because the decrease of the passenger trip by car mitigates the congestion and it results in increasing the transport share by car. If the three Ring Roads are completed, the rate of decrease becomes smaller as well.

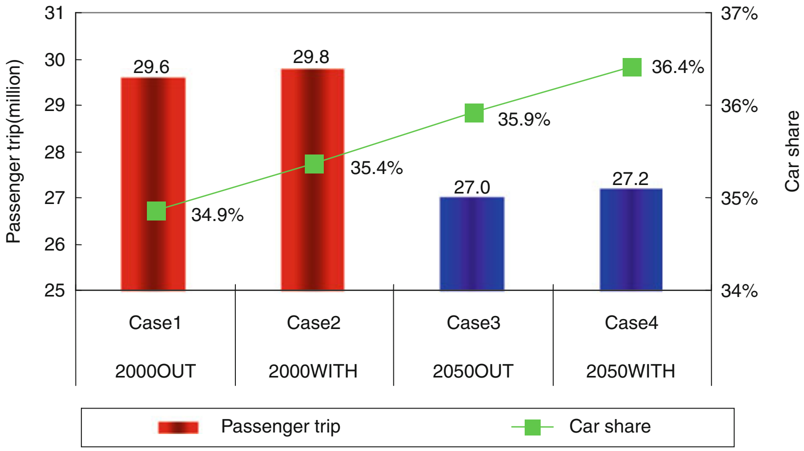



**Fig. 18.15** Comparisons of passenger trip and car share

The average trip length by car in 2050 gets longer a little bit in Case 3 while it becomes longer buy 1.6 % in Case 4. The product of the average trip length by car and the passenger trip by car remains at an lower decrease rate of 2.8 %.

The total traffic cost, which is an index to measure the efficiency of the total road network, decreases 9.4 % in 2050 with Case 3 while it is 10 % in Case 4, both of which are much better than the one in 2000.

The average speed by car increases by 4 % even in Case 3. This is because of less congestion by population decrease and this effect is much higher in Case 4. The average speed increases 8.7 % if the 3 Ring Road is completed.

One of the distinguished features of the CUE model is that it can consider induced traffic and the developed traffic. In case 3 (without the induced and developed traffic) CO2 emission in 2050 decreases by 7.1 % while in Case 4 (with the induced and developed traffic) 6.9 %. Thus considering the induced and developed traffic increases only 0.2 % of CO2 emission( Figs. 18.16, 18.17, 18.18, 18.19, 18.20, and 18.21).

### 4.2.5 Traffic Volume Change in the Road Network

In this subsection, we analyze the traffic volume on the network in each case. Comparing Case 3 and Case 1, the traffic volume is significantly reduced due to reduction of passenger trip followed by population decrease. As a result, there is almost no link whose traffic volume is increased compared to 2000.

When we compare Case 1 with Case 4, there is huge increase around the three Ring Road while the links in the other area basically decrease the traffic volume.

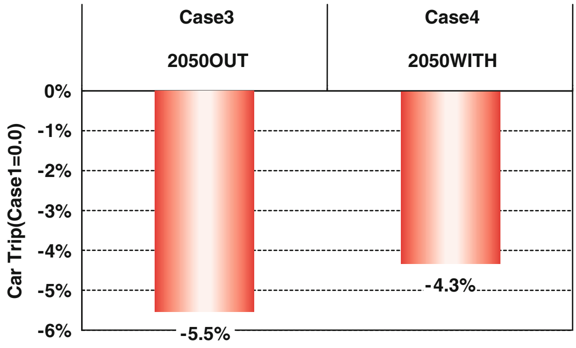



**Fig. 18.16** Change in passenger trip by car

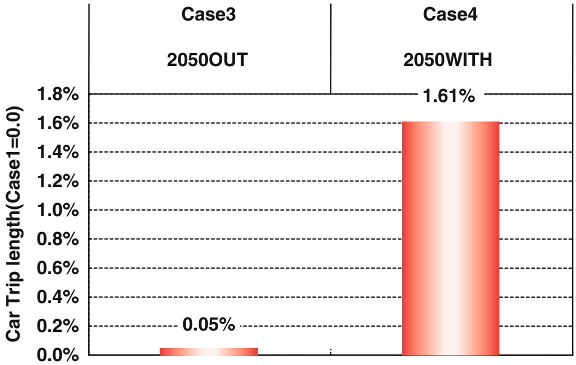



**Fig. 18.17** Change in average trip length by car

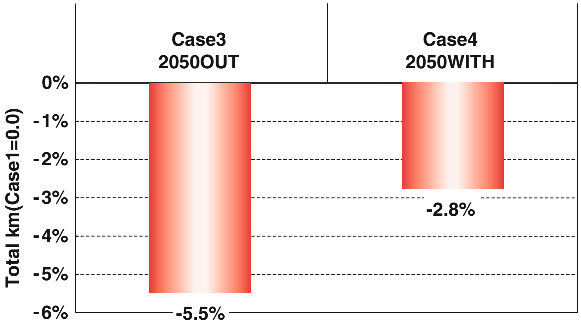



**Fig. 18.18** Change in total km

The links which are directly connected with the three Ring Road, we observe the increase in terms of the traffic volume due to the induced traffic and the developed traffic. In order to visually check this situation, we compare Case 3 with case 4 as follows (Figs. 18.22, 18.23, and 18.24).

**Fig. 18.19** Change in total traffic cost

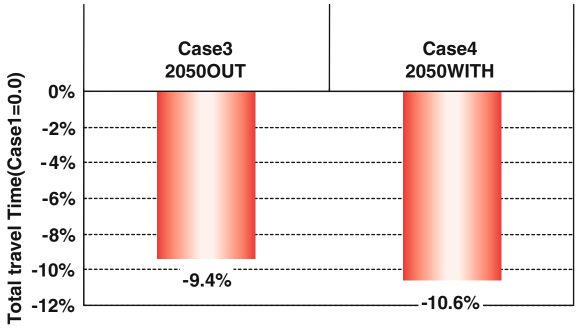



**Fig. 18.20** Change in average speed by car

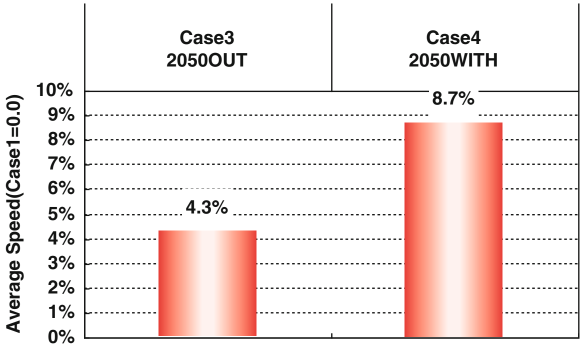
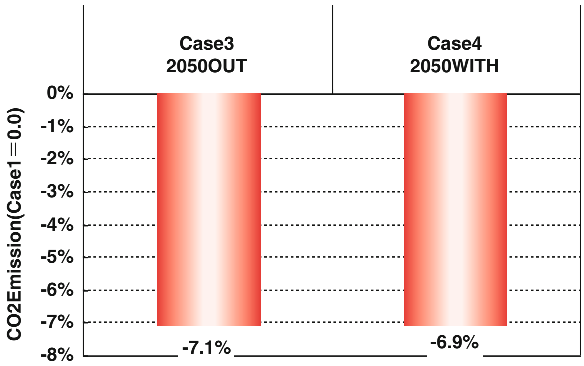



**Fig. 18.21** Change in emission of CO2




### 4.2.6 The Result of the Benefit Evaluation

Finally we analyze the total benefit of road construction when the population decrease. As is shown in Fig. 18.25, the benefit decreases about 7.8 % in 2050 compared to 2000. Since the change of the population is about 9 % and change in employee worker is 6 %, it seems that the change of the benefit depends upon population change.

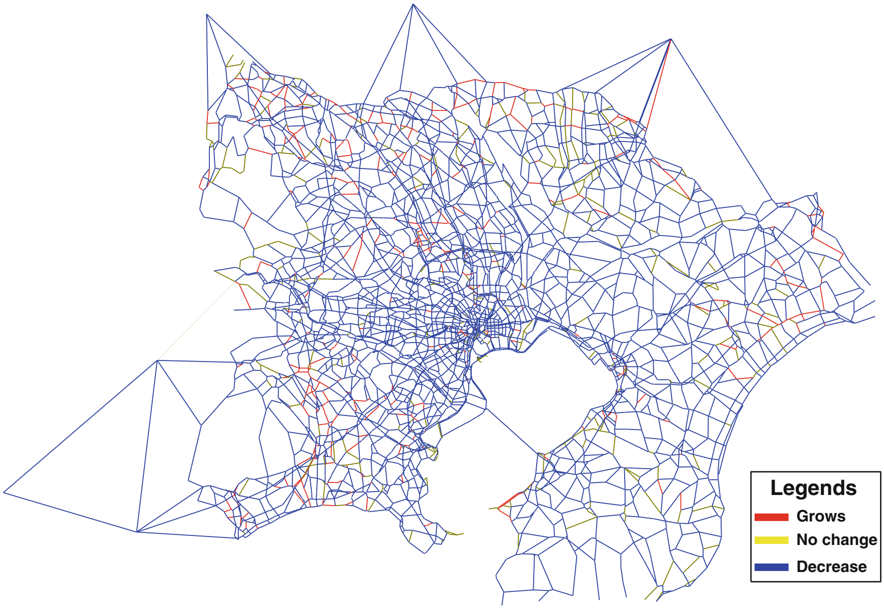



**Fig. 18.22** Case3 2050/with -Case1 2000/without

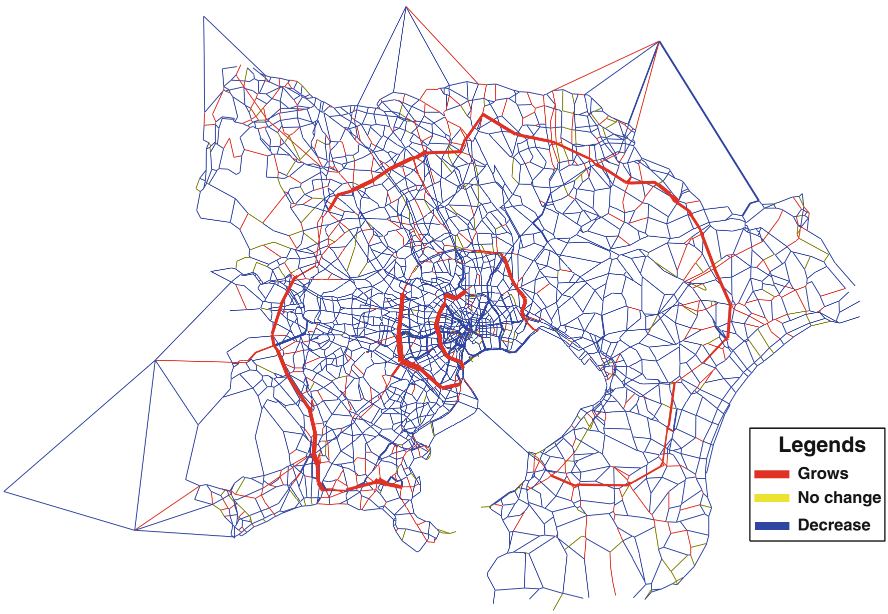



**Fig. 18.23** Case4 2050/with -Case1 2000/without

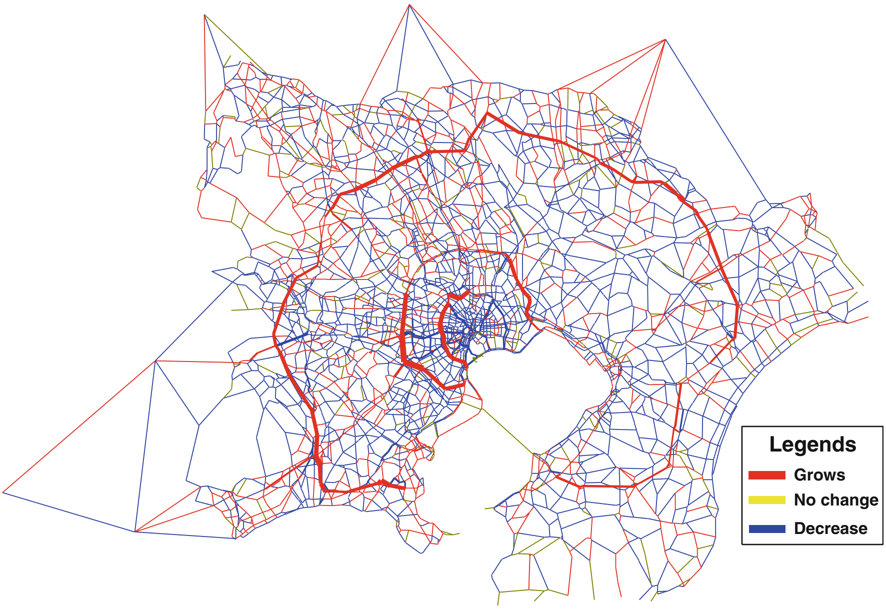



**Fig. 18.24** Case4 2050/with -Case3 2050/without

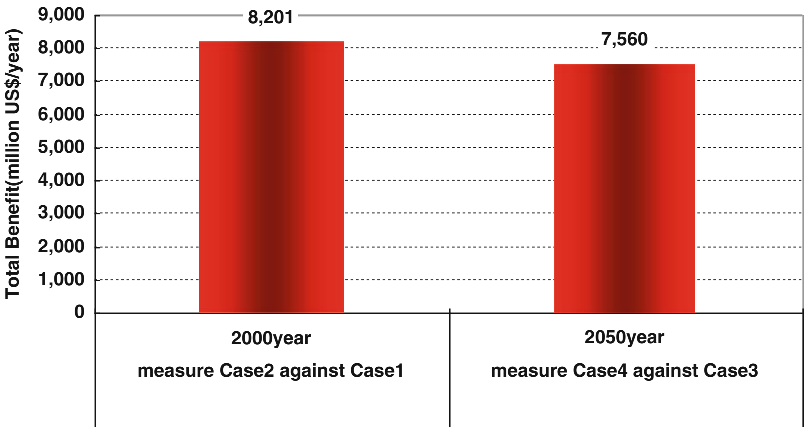



**Fig. 18.25** Change of benefit

## 5 Conclusion

In this paper, we analyzed the effect of road construction at Tokyo metropolitan area when population is decreasing by using the CUE model. As a result, we found that the central Tokyo remains as the center of the economy in 2050 with high spatial agglomeration since the agglomeration is accelerated by the scale economy.

On the other hand, population which is not affected by agglomeration, is decreasing at each zone with the same level.

The investment to the three Ring Roads is expected to contribute to developing more dispersive urban structure since the three Ring Roads increase the transportation convenience at the suburb and it induces to the entry of the firms and population as well. This does not, however, the central Tokyo loses its competitiveness but they still remain strong in terms of the spatial distribution of the firms.

The reduction of population mitigates the congestion of the road network.. It enables us to increase our convenience in terms of the trip by car. It induces to more trips to the households and business people, which bring about more communication, that is one of the keys for the productivity growth and the enhancement of households' utility. During this period, motorization advances due to the enhancement of the transport convenience by car.

For other general indices, it is worthy of attention that CO2 emission decreases significantly in2050. The better use by less congestion on the network enables us to curb the developed and induced traffic, which leads to less CO2 emission(0.2 %).

In Japan, population has started decreasing and it is expected to decreasing in Tokyo metropolitan area as well after 2015. We have not had enough research results showing the effect of the currently on-going transport projects after the long population-decreasing period, which Japanese has never experienced. The analysis in this paper partly answered these questions by showing the urban structure of Tokyo metropolitan area after 50 years with consistency in terms of traffic status, firm location and household location due to the intrinsic feature of the CUE model. In order to make public decision-making efficient, we will continue to try to simulate far-distant future with various scenarios.

## 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. Environ Plann 16(11):1489–1502

Maruyama T, Harata N, Ohta K (2002) Application of a combined network equilibrium model to mega metropolitan area. Infrastruct Plann Rev 19(3):551–560 (in Japanese)

Ueda T (1992) A general equilibrium model with re-defined location surplus. Infrastruct Plann Rev 10:183–190 (in Japanese)

Ueda T, Tsutsumi M (1999) A unified framework of land use models recently developed in Japan. In: Proceedings of the Japan society of civil engineers, no 625, pp 65–78

Yoshida A, Harada N (1999) Aggregate destination choice models incorporating probabilistic formation of a choice set. In: Proceedings of the Japan society of civil engineers, no 618, pp 1–13 (in Japanese)