Rural Sustainable Development by Constructing New Roads in Advanced Country - A Case Study of San-en Region in Japan -

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Abstract:

Japan's economy is entering a new phase of economic growth through the so-called "lost 15 years" since 1990. Particularly Tokyo and Aichi prefectures have been drawing attention as engine of new economic growth in Japan. Although the recovery of Japan's economy has resulted in an increase in the demand for traffic, construction of new roads in rural areas has been located in a serious situation. It is attributed to a decreasing trend in Japan's population and aging. Thus Japan's national budget will be being reduced in the future. Due to this situation, stricter economic assessment of construction of new roads in rural areas has particularly been required than before. Taking into account these backgrounds, this article aims to present a model integrating the concepts of economic equilibrium and transport network equilibrium. This model heavily depends on the input-output data in estimating parameters, and will be able to be extended into a full spatial equilibrium model. And then setting San-en region in Aichi prefecture as a study area which consists of many rural areas, this study also aims to measure the economic impacts of construction of new roads to realize sustainable development of rural areas in this region.

1. Introduction

Under the limited budget for infrastructure, selective investment is required maximizing the total benefit brought by the investment at the same time. The study area in this study is the San-en region which is the industrial base of Japan but includes many rural areas. The improvement of road network including the construction of high standard roads is necessary to meet the increasing demand for the capacity in logistics. However, there exists a concern over the cost and benefit for/from the road construction. This study aims to develop a model to forecast the total benefit by new roads construction and network improvement in the study area particularly focussing on rural areas in this region. The concept of benefit is based on the theory of general equilibrium. The transportation equilibrium model is developed to estimate the benefits which are led back into the economic equilibrium model focusing on the land use (location behavior) and economic sectors. The construction of economic sectors heavily depends on the IO table in this region.

In the following sections, the authors review the concept of equilibrium and approaches for the measurement of economic impact by similar models. Then, the model for the evaluation of economic impacts is developed. This model is applied to measure the economic impact by alternative scenarios of new roads construction and improvement in the study area. The paper concludes with the description of the issues to be improved in the model and the future challenges including sustainable development of rural areas in advanced countries.

2. Review of the Equilibrium Theory

2.1. Transport Network Equilibrium Model

The transportation equilibrium model is developed to estimate the benefits yielded by transport network development. The transport demand in the state of equilibrium is led back into the economic equilibrium model. The total benefit generated by transport network improvement will be computed as transport users' surplus, given the model for travel-demand calculation which properly forecasts the combined land-use and transport system equilibrium. Equilibrium in transport system is associated with the assignment of travelers to link in consideration of travel cost and travel time to maximize their utility. The transport users' surplus in transport system can be measured from their travel demand, because it represents their willingness to pay, i.e. his or her monetary value of performing activities that are distributed in space (Martinez, 2000). The travel demand in real transportation network depends on the level of transport service between OD pairs. Consequently the travel demand is dynamic and the transportation equilibrium model should be based on this hypothesis. Furthermore, the equilibrium is based on the principle that no transport users between alternative routes will be able to improve its utility by unilaterally switching to another route. In other words, equilibrium is regarded to be achieved when all transport users are in their individual minimum cost paths, or, when travel time is equal in all paths connecting an origin-destination pair. Travelers' surplus represents a measure of the road network improvement/development in access at zone i to travel to get opportunities in zone j. This important feature is described in studies of commodity transport, by Samuelson (1952) for competitive markets, Jara-Díaz (1986) for the monopolistic case, and by Mohring (1961, 1976) and Wheaton (1977) in the context of urban-passengers trips. They conclude that total surplus which is aggregated across h, i, and j, is equivalent to the total benefit induced on activities at the trip origin and destination zones by a change in transport costs. As this study aims to obtain the total benefit where the economic/location choice model and the transport model reach equilibrium simultaneously, the so-called integrated transport and economic model is applied to calculate the travelers' surplus. It allows for endogenous transportation costs and prices, and is based on the assumptions of individual's rational behavior and optimization of welfare, utility, profit or cost (de la Barra, 1989). Reviews of integrated transport and economic models can be found in Anas (1982), Anas and Duann (1986), Berechman and Gordon (1986), Henderson (1988), Berechman and Small (1988), Webster et al.(1988), and Rietveld (1944).

2.2. General Formulation of Transport Equilibrium Model as Optimization Problem

With regard to the trip assignment, it is viewed as a problem of route choice (de la Barra, 1989). It is the process by which trip matrices by mode and user type are transformed into the number of trips that use each link of the transportation network. To perform this task the Wardrop's two criteria is taken into consideration. The two criteria are; a) the concept of average travel time which assumes that travelers act considering only their individual travel times in making the route choice decision, and b) the concept of marginal travel time which assumes that travelers are aware of the way their individual route choice influences the overall travel time. The former criterion gives rise to user equilibrium state which is mathematically expressed as follows:

$$\left(c_{rs}^{k} - c_{rs}\right)\cdot f_{k}^{rs} = 0\,,\ {}^{\forall} r,s,k \tag{1}$$

$$c_{rs}^{k} - c_{rs} \geq 0\,,\ {}^{\forall} r,s,k \tag{2}$$

$$f_{k}^{rs} \geq 0\,,\ {}^{\forall} r,s,k \tag{3}$$

where

c_{rs}^{k} : travel time in path *k* in OD pair *rs*, function of link travel time and link flow

c_{rs} : travel time in the shortest path in OD pair *rs*

f_{k}^{rs} : route flow of path *k in* OD pair *rs*

With travel times and other cost-related parameters, generalized transport costs can be estimated. From the generalized cost calculations, two main feedbacks are recognized. The first goes back to the trip distribution stage because, as congestion builds up in certain parts of the network, the distribution of trips is affected, and the probabilities of choosing each mode can change. This feedback is equivalent to the equilibrium between supply and demand of transport. Because of the characteristics of the transport system, this equilibrium is assumed to take place instantaneously.

The second feedback loop goes back to the location of activities, affected by changes in the generalized cost of travel between zones. When individuals rationally choose route and mode, they aim to maximize their utility or satisfaction level. At the same time, they try to minimize the generalized travel cost. The definition of transport user equilibrium and optimization problem under the state represented in equation (1) to (3) is formulated as below.

$$min\ \ Z = \sum_{a\in A}\int_{0}^{x_a} t_a(w)dw \tag{4}$$

subject to

$$\sum_{k \in K_{rs}} f_k^{rs} - Q_{rs} = 0 \quad \forall rs \in \Omega \tag{5}$$

$$x_a = \sum_{k \in K_{rs}} \sum_{rs \in \Omega} \delta_{a,k}^{rs} f_k^{rs} \quad \forall a \in A \tag{6}$$

$$f_k^{rs} \geq 0, x_a \geq 0 \tag{7}$$

where

t_a, $t_a(\cdot)$: travel time and performance function for link *a*

f_k^{rs} : route flow

Q_{rs} : traffic distribution volume of OD pair *rs*

$\delta_{a,k}^{rs}$: dummy variable (1: when route *k* in OD pair *rs* includes link *a*, 0: otherwise)

In this study, the economic benefit produced by road network improvement in San-en region which lies across Aichi and Shizuoka prefectures is estimated to evaluate the direct/indirect impact. The integrated transport and economic model is used to analyze the potential and long term effect/impact of transport measure referring to the previous study (Muto and Ueda, 2006). It is important to notice that the output of simulation will not accord with the realized value as the transport market is adjusted in short term, on the other hand, land market takes long period of time for adjustment. Muto et al. have developed the Computable Urban Economic (CUE) model that is the combined model both on transport networks and location choice equilibrium. The CUE model has an advanced merit that the benefits given by the development trips as well as the induced trips can be evaluated exactly (Muto et al., 2004). The simulation analysis of transport network improvement employed in this paper refers to the CUE model as the purpose of the analysis is to estimate the benefit considering the connection of economic behavior including location choice and transport behavior.

3. Overview of Case Study

3.1. Road Network Improvement Scenarios

The transport model in this study aims to calculate the reduction in travel time as the positive effect by road network improvement within transport market in consideration of travel cost. The methodology of demand forecasting is based on the four traditional steps mentioned in the previous section. The trip attraction/generation is firstly forecasted, then, future OD trip volume, modal split, and traffic assignment are calculated as shown in Figure 1. Vehicle OD data is used for calculation because of the limitation of available data. As for public the transportation which exists in real network, the balancing function is applied. This study forecasts the OD trip rate by travel purpose considering the performance characteristics of each mode. Consequently the traffic assignment is calculated repeatedly in this paper, instead of applying the model described in equation (13). In the process of this calculation, the mode distribution rate by trip purpose is multiplied. Then the future traffic is assigned to reach equilibrium. In the last stage, the travel cost in the equilibrium state is estimated. This effect is fed back to the economic equilibrium model which estimates the socio- economic benefit brought by road network improvement considering location choice. In this study, the three scenarios are set up for the estimation of the benefit of road network improvement in the case study area. Three scenarios assume that the network im

Table 1. Outlines of Road Network Development Scenarios

	Scenario 1	Scenario 2	Scenario 3
national express-way	Construction of new Tomei expressway	Extension of new Tomei expressway	Extension of Sanen-Nanshin Expressway
inter-regional high-way	Extension of Road 23	Increase in lanes of Road 259	Increase in lanes of Road 23
harbor road	-	Construction of Mi-kawa harbor road	Increase in lanes of Mikawa harbor road
number of link	2083	2124	2145
number of node	1406	1431	1442

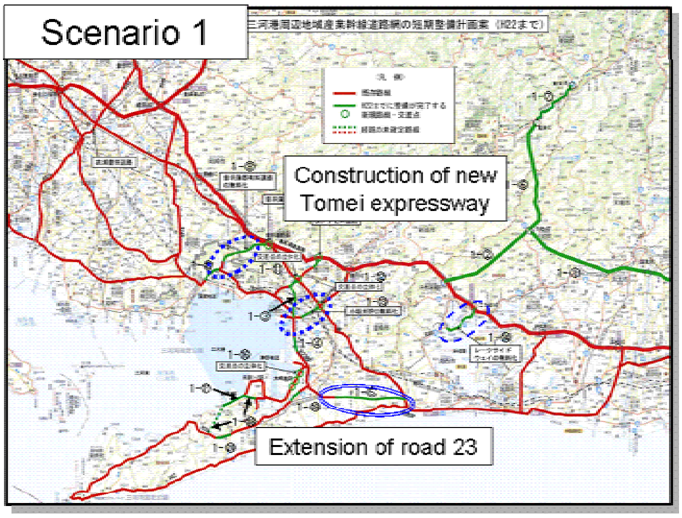

Figure 1. Overview of Scenario 1

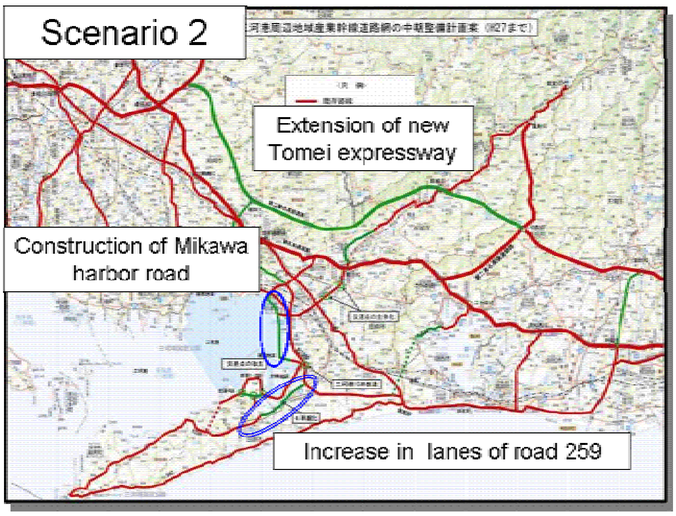

Figure 2. Overview of Scenario 2

provements are implemented gradually. They include road construction in national expressways, inter-regional highways, anda harbor road. Table 1 and Figures 1 to 3 illustrate the outlines of these scenarios.

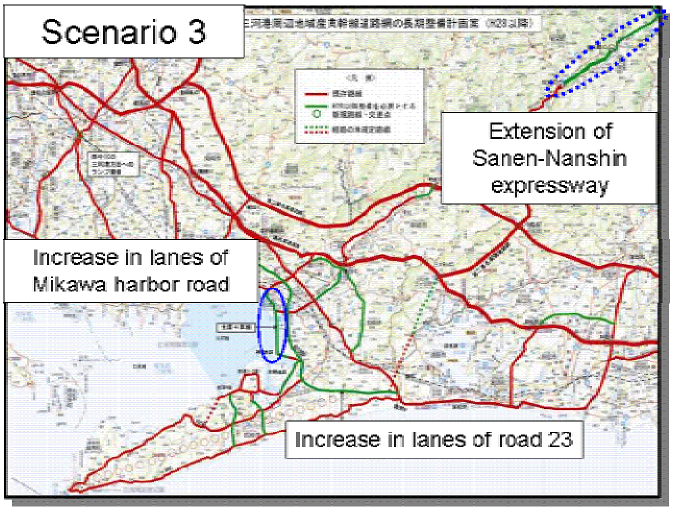

Figure 3. Overview of Scenario 3

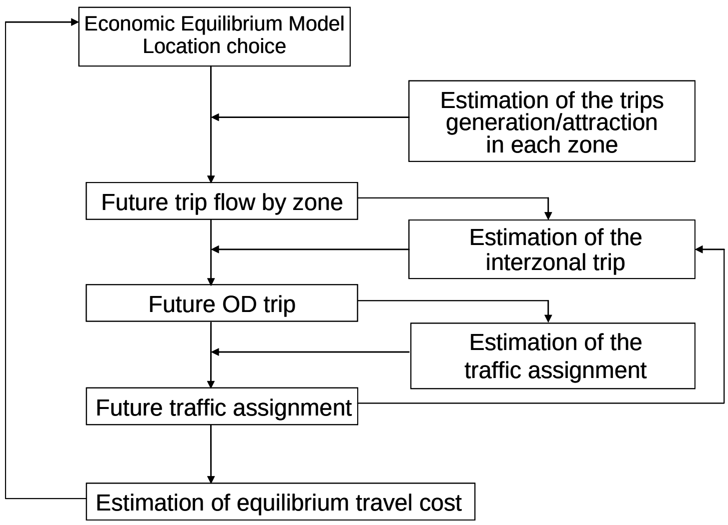

Figure 4. Flowchart of Transport Demand Forecasting

3.2. Procedure of Transport Demand Forecasting

The forecasting of transport demand means to obtain the equilibrium transport flow considering socio-economic system of demand side and future transport systems of supply side. Transport demand forecasting consists of four traditional steps; trip generation/attraction, trip distribution, modal split, and traffic assignment. The trip generation/attraction model transforms the activities by type per zone estimated by the economic equilibrium model, into trip generations and attractions, that is, the number of trips that originate in each zone and the number of trip ends in each zone. The trip distribution model connects productions with attractions to produce a set of origin-destination trip matrices. The modal split model separates these trip matrices by mode. Trip distribution and modal split can be combined into a single model. The resulting OD trips by mode are then assigned to the different routes available in the network by the assignment model. Finally, all these calculations are used to estimate travel times between zones by mode, which are affected by the level of congestion in each link of the network. Figure 4 shows the flowchart of transport demand forecasting in this study.

4. Estimating Benefit of Road Network Development

4.1. Trip Generation/Attraction Forecasting

This study utilizes the data from the national traffic census 2000. The case study area is divided into 76 zones based on the definition in the census. Equation (8) is specified as the formulation of trip generation/attraction forecasting model for this case study.

$$\hat{G}_i = \alpha_0 + \sum_{i=1}^{n} \alpha_i X_i \tag{8}$$

where

$\hat{G}_i$: trip generation/attraction from/to zone i

$\alpha_{0,} \alpha_i$: parameters

X_i : explanatory variable (the number of population or the number of workers)

In this study, the numbers of population and workers are verified that they significantly affect the trip generation/attraction from the result of correlation analysis. Consequently they are applied as explanatory variables in the model. Other factors related to trip generation/attraction are considered applying

Table 2. Result of Parameters Estimation of Trip Generation and Attraction

	trip purpose	constant term	population	employed population	R^2 value
trip generation	commuting	2064.7 (3.99)	-	0.370 (9.17)	0.539
	leisure/shopping	460.8 (0.84)	0.215 (7.89)	0.136 (3.12)	0.680
	business	1298.7 (1.98)	0.176 (5.38)	0.281 (5.37)	0.659
	return home	1811.4 (1.95)	0.419 (10.7)	-	0.615
trip attraction	commuting	926.5 (2.06)	0.244 (12.8)	-	0.696
	leisure/shopping	877.0 (1.71)	0.247 (9.64)	0.032 (0.78)	0.684
	business	1208.9 (1.85)	0.194 (5.92)	0.254 (4.84)	0.660
	return home	1694.3 (1.90)	0.266 (5.96)	0.314 (4.40)	0.644

Note: *t* values are in parentheses.

factor k_i as follows:

$$G_i = k_i \hat{G}_i \tag{9}$$

In equation (9), k_i represents an adjustment factor which eliminates the gap in the actual and estimated trips. The estimation result of parameters is shown in Table 2. The figures in parentheses show *t* values. From the result, it is indicated that the parameters of the numbers of population and workers are statistically significant.

4.2. Trip Distribution

In the theory of transportation equilibrium, trip distribution is assumed to be expressed as equations (10) to (12).

$$q_{rs} = A_r B_s O_r D_s \exp(-\gamma c_{rs}) \tag{10}$$

$$A_r = \left[\sum_{s \in S} B_s D_s \exp(-\gamma c_{rs}) \right]^{-1} \tag{11}$$

$$B_s = \left[\sum_{r \in R} A_r O_r \exp(-\gamma c_{rs}) \right]^{-1} \tag{12}$$

where

q_{rs} : OD trip rate

O_r : generated trips in node *r*

D_s : attracted trips to node *s*

c_{rs} : OD travel cost

A_r, B_s : balancing factor

γ : parameter

4.3. Trip Assignment

The transportation equilibrium is achieved when given trip flow which satisfies equations (10) to (12) is assigned to transport networks appropriately. To calculate the travel cost which is in conjunction with the OD trip flow and the assignment volume in the framework of demand responsive user equilibrium, the combined distribution/assignment model is developed. The solution of the combined distribution/assignment model gives the equilibrium state considering cost and travel demand. The concept of equilibrium is based on the assumption that all travelers can choose the shortest route with sufficient information. This is the so-called deterministic equilibrium. However, this is impracticable in real network. To cope with this issue, the stochastic user equilibrium model which considers the dispersion in users' route choice and traffic congestion should be developed. This model reaches more realistic equilibrium, although it has difficulty in practical use because of the hardness of its solution method and parameter setting. In this paper, thus the deterministic equilibrium theory is applied.

4.4. Future OD Trip Forecasting

In this step, the future OD trip associated with a change in travel condition is obtained. To grasp the trip distribution, the gravity model mentioned below is applied.

$$T_{ij} = k(G_i)^{\alpha}(A_j)^{\beta}\exp(\gamma C_{ij}) \tag{13}$$

where

T_{ij} : OD trip between zone i and j

G_i : trip generation in zone i

A_j : trip attraction to zone j

C_{ij} : generalized travel time between zones i and j induced by adding the travel cost in terms of time which is obtained by dividing monetary travel cost by time value

k, α, β, γ : parameters

Taking logarithm of the both sides in equation (13), the following equations are derived.

$$\ln T_{ij} = \ln k + \alpha \ln G_i + \beta \ln A_j + \gamma C_{ij} \tag{14}$$

$$k = e^{a0} \tag{15}$$

The parameters are estimated applying the current trip distribution. From Table 3, it can be said that statistically significant results are obtained from the t values, although the coefficients of correlation are not so high. This may be attributed to the fact that zones with low trips are excluded in the process of estimation. Therefore, these parameters are interpreted as expressing aggregate trend in the study area. In forecasting the trip distribution in each zone, an adjustment factor is introduced. This factor is calculated from dividing the actual value which is obtained by the trip distribution data by the value estimated in the model mentioned above.

5. Land Use and Economic Sectors

Up to the previous sections, transportation models are emphasized. In turn, land use (location behavior) and economic sectors in our model are described hereafter.

Table 3. Parameter Estimation Result of OD Trip Model

	parameter k	parameter α	parameter β	parameter γ	R^2
commuting	0.143 (-4.13)	0.510 (12.9)	0.433 (12.1)	-0.029 (-31.7)	0.439
leisure/ shopping	0.479 (-1.22)	0.442 (8.72)	0.370 (7.40)	-0.033 (-28.0)	0.423
business	1.140 (0.26)	0.347 (9.51)	0.356 (9.50)	-0.036 (-43.4)	0.522
Return home	0.109 (-4.27)	0.444 (11.3)	0.517 (12.9)	-0.032 (-33.2)	0.431

Note: t values are in parentheses.

5.1. Firms Behavior

Each firm is defined as per worker, that is, the number of workers in each firm is unity. Each firm under this study is assumed to input land, business trips, and labor, and produce single type commodities (composite commodity) maximizing its profit. The behavior of each firm is denoted as follows:

$$\pi^F_i \equiv max\ \ Z_i - R_i A_i - Q_i X_i - wL_i - \sum_{j=1}^{I} p_{ij} n_{ij} / E_i \tag{16}$$

$$with\ respect\ to\ A_i\ \ \text{and}\ \ X_i$$

subject to

$$Z_i = mA_i^{\beta_A} X_i^{\beta_X} \qquad (0 < \beta_A + \beta_X < 1) \tag{17}$$

where

Z_i : output of a firm (numeraire good)
R_i : land rent for business use
A_i : input of business land
Q_i : generalized price of business trip
X_i : input of business trip
w : wage rate (exogenous variable)
L_i : labor input (= 1)
p_{ij} : commuting cost between zones i and j
n_{ij} : the number of workers residing in zone j and working in zone i
E_i : the number of workers in zone i
m, β_A, β_X : technological parameters in a firm

In the formulation above, households' commuting costs are assumed to be paid by firms. Solving this profit maximization problem, one obtains demand functions in a firm for business land and business trip.

$$A_i = \left[\frac{m\beta_A}{R_i} \left(\frac{\beta_X}{\beta_A} \right)^{\beta_X} \left(\frac{R_i}{Q_i} \right)^{\beta_\alpha} \right]^{\frac{1}{1-\beta_A-\beta_X}} \tag{18}$$

$$X_i = \left[\frac{m\beta_X}{Q_i} \left(\frac{\beta_A}{\beta_X} \right)^{\beta_A} \left(\frac{Q_i}{R_i} \right)^{\beta_A} \right]^{\frac{1}{1-\beta_A-\beta_X}} \tag{19}$$

These factor demand functions are substituted into the firm's profit yielding the following profit function.

$$\begin{aligned}\pi^F_i = m & \left[\frac{m\beta_A}{R_i} \left(\frac{\beta_X}{\beta_A} \right)^{\beta_X} \left(\frac{R_i}{Q_i} \right)^{\beta_\alpha} \right]^{\frac{\beta_A}{1-\beta_A-\beta_X}} \left[\frac{m\beta_X}{Q_i} \left(\frac{\beta_A}{\beta_X} \right)^{\beta_A} \left(\frac{Q_i}{R_i} \right)^{\beta_A} \right]^{\frac{\beta_X}{1-\beta_A-\beta_X}} \\ & - R_i \left[\frac{m\beta_A}{R_i} \left(\frac{\beta_X}{\beta_A} \right)^{\beta_X} \left(\frac{R_i}{Q_i} \right)^{\beta_\alpha} \right]^{\frac{1}{1-\beta_A-\beta_X}} - Q_i \left[\frac{m\beta_X}{Q_i} \left(\frac{\beta_A}{\beta_X} \right)^{\beta_A} \left(\frac{Q_i}{R_i} \right)^{\beta_A} \right]^{\frac{1}{1-\beta_A-\beta_X}} - wL_i - \sum_{j=1}^{I} n_{ij} p_{ij} / E_i\end{aligned} \tag{20}$$

And then the firm's location choice probability for zone i is obtained by applying the Logit model.

$$P_i^F = \frac{exp\theta^F g_i^F \pi_i^F}{\sum_{k=1}^{I} exp\theta^F g_k^F \pi_k^F} \tag{21}$$

where

P^F_i : location choice probability of a firm for zone i

θ^F : logit parameter in firm's location behavior

g_i^F : parameter representing agglomeration economy in zone i (the number of workers is applied to this parameter.)

π^F_i : maximized profit in a firm in zone i

5.2. Households Behavior

Households are assumed to be utility maximizers in this study. Thus household behavior is specified as follows:

$$\begin{aligned} &v_i^H \equiv max \quad z_i^{\alpha_z} a_i^{\alpha_a} x_i^{\alpha_x} f_i^{\alpha_s} \qquad (\alpha_z + \alpha_a + \alpha_x + \alpha_f = 1) \\ &with\ respect\ to\ z_i, a_{i,} x_i, f_i \end{aligned} \tag{22}$$

subject to

$$z_i + r_i a_i + q_i x_i + wf_i = w\left[T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i\right] + y_i \tag{23}$$

where

z_i : consumption of composite goods by a household in zone i (numeraire good)

a_i : area size of land used by a household in zone i

x_i : household trip per capita in zone i

f_i : leisure time of a household in zone i

r_i : land rent for residence in zone i

q_i : generalized price of a household trip in zone i

w : wage rate (exogenous variable)

T : total time available of a household

y_i : dividend from firms to a household in zone i

n_{ij} : the number of households residing in zone i and working in zone j

t_{ij} : commuting time between zones i and j

N_i : the number of households in zone i

Solving this utility maximization problem, the following demand functions in a household are derived.

$$z_i = \alpha_z[w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] \tag{24}$$

$$a_i = \alpha_a[w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] / r_i \tag{25}$$

$$x_i = \alpha_x[w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] / q_i \tag{26}$$

$$f_i = \alpha_f [w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] / w \tag{27}$$

Substituting these demand functions into the utility function, one obtains the indirect utility function of a household.

$$v_i^H = \alpha_z^{\alpha_z} \left[\frac{\alpha_a}{r_i}\right]^{\alpha_a} \left[\frac{\alpha_x}{q_i}\right]^{\alpha_x} \left[\frac{\alpha_f}{w}\right]^{\alpha_f} [w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] \tag{28}$$

Finally household's location choice probability for zone *i* is calculated by applying the Logit model.

$$P_i^H = \frac{exp\theta^H g_i^H v_i^H}{\sum_{k=1}^{I} exp\theta^H g_k^H v_k^H} \tag{29}$$

where

P_i^H : household choice probability for zone *i*

θ^H : Logit parameter

g_i^H : parameter expressing agglomeration economy in zone *i* (the number of households in zone *i* is applied to this parameter)

v_i^H : indirect utility function in zone *i*

5.3. Equilibrium Conditions

In the economic sectors mentioned above, we consider only the land market to be equilibrated fixing the commodity price and wage rate. The reason is that the size of the study area is small, so the full equilibrium model seems rather to be a little unrealistic. Extension of the present model into a full equilibrium model is left as an important issue in the future study. Thus the equilibrium conditions in the land markets are specified as follows:

$$\text{residential areas :} \quad a_i^S = N_i a_i \tag{30}$$

$$\text{business areas :} \quad A_i^S = E_i A_i \tag{31}$$

where

a_i^S : supply of residential area in zone *i* (fixed)

A_i^S : supply of business area in zone *i* (fixed)

The equilibrium demands for land in each zone is obtained through finding land rents which clear the conditions (30) and (31) by the Walras algorithm.

5.4. Parameters in Firms

For the empirical study, parameters in firms and households must be estimated. However available data for parameter estimation is quite limited even in advanced country, since the area size of each zone is very small. So the IO table becomes the most significant data source in parameter calibration.

In this subsection, first, let us explain parameters in firms. Equation (17) shows the technology of a firm being specified as a Cobb-Douglas production function with homogenous degree less than unity. One can add other production factors to equation (17) to transform it with homogenous degree of unity.

$$Z_i = mA_i^{\beta_A} X_i^{\beta_X} L_i^{\beta_L} K_i^{\beta_K} \qquad (\beta_A + \beta_X + \beta_L + \beta_K = 1) \tag{32}$$

where

L_i : labor input of a firm in zone i (= 1)

K_i : input of other production factor in a firm in zone i

Euler's identity yields;

$$Z_i = \frac{\partial Z_i}{\partial A_i} A_i + \frac{\partial Z_i}{\partial X_i} X_i + \frac{\partial Z_i}{\partial L_i} L_i + \frac{\partial Z_i}{\partial K_i} K_i \tag{33}$$

When the firm behaves to maximize its profit, the marginal productivity principle holds leading to;

$$PZ_i = P(\beta_A Z_i + \beta_X Z_i + \beta_L Z_i + \beta_K Z_i) = R_i A_i + Q_i X_i + wL_i + \eta_i K_i \tag{34}$$

where

η_i : price of other production factor

Therefore parameters in the production function are obtained as follows:

$$\beta_A = R_i A_i / PZ_i \quad \text{and} \quad \beta_X = Q_i X_i / PZ_i \tag{35}$$

Assuming that w, L_i, η_i, and K_i are fixed, the efficiency parameter is calculated as follows:

$$m = Z_i /(A_i^{\beta_A} X_i^{\beta_X}) \tag{36}$$

These parameters are estimated by employing Aichi prefecture's IO table as presented in Table 4.

Finally the Logit parameter in firm's location probability is estimated by the maximum likelihood method.

$$\theta^F = 3.740\times10^{-9}, \quad t = 61.4, \quad R^2 = 0.854 \tag{37}$$

Here t value and the correlation coefficient are derived from the regression analysis between the actual number of workers and the estimated one obtained by the Logit model.

Table 4. Parameters in Production Function

efficiency parameter m	share parameter β_A	share parameter β_X
19818.465	0.016	0.086

5.5. Parameters in Households

Transforming equations (24) to (27) yields;

$$\alpha_z = 1\cdot z_i /[w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] \tag{38}$$

$$\alpha_a = r_i a_i / [w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] \tag{39}$$

$$\alpha_x = q_i x_i / [w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] \tag{40}$$

$$\alpha_f = w f_i / [w(T - \sum_{j=1}^{I} n_{ij} t_{ij} / N_i) + y_i] \tag{41}$$

The right hand sides in equations (38) to (41) are observable, thus one can calculate the parameters in household utility function by employing Aichi prefecture's IO table as well. The calibration results are shown in Table 5.

Same as in the firms behavior, the Logit parameter in household location choice probability is estimated by the maximum likelihood method.

$$\theta^H = 2.345\times10^{-7}, \quad t = 22.6, \quad R^2 = 0.988 \tag{42}$$

Here t value and the correlation coefficient are derived from the regression analysis between the actual number of population and the estimated one obtained by the Logit model.

Table 5. Parameters in Household Utility Function

composite good α_z	land α_a	trip α_x	Leisure α_f
0.325	0.086	0.021	0.568

6. Result of Surplus Evaluation

In this section, is presented the total travelers' surplus during 40 years after the improvement of road networks derived from the transport demand forecasting. The total generalized cost and time when OD

Table 6. Simulation Result of Generalized Time and Cost in Each Scenario

	total generalized time (million minutes)	Time-saved ratio (%)	Total surplus (trillion yen)	increase ratio of travelers' surplus (%)
Scenario 1	56.4	1.00	2.3	1.00
Scenario 2	54.3	0.96	3.3	1.46
Scenario 3	52.7	0.93	4.1	1.77

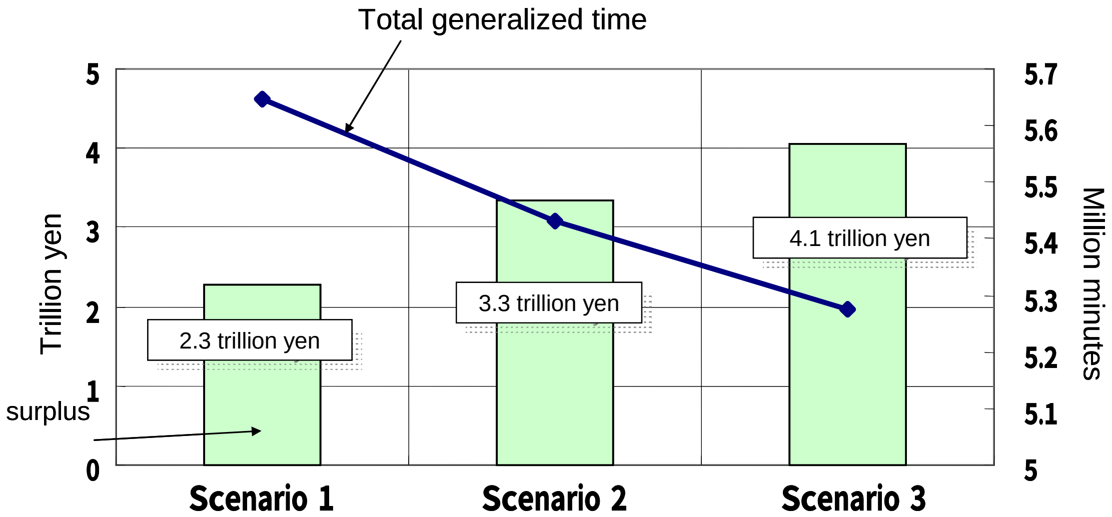

Figure 5. Changes in Generalized Cost Brought by Road Network Development

trip does not stochastically change in each scenario is calculated. The estimation results are shown in Table 6. The time-saved ratio are 1 % in Scenario 1, 0.96 % in Scenario 2, and 0.93% in Scenario 3, respectively. On the other hand, the total surplus which is expressed in monetary term increases from 2.3 trillion yen in Scenario 1 to 4.1 trillion yen in Scenario 3 gradually. These results can be interpreted as the travelers' surplus in transport system. The comparative analysis of surplus is illustrated in Figure 5. It is indicated that as the road networks are improved to higher level, the less total generalized time will be, then, the total transport users' surplus increases. However the marginal efficiency declines as the road network improvement proceeds to the final stage.

7. Estimating the Economic Benefit by Zone

In turn, we are ready to present the economic benefit by zone under the three scenarios. The economic benefit in each zone is defined by the equivalent variation (EV) plus land rent paid to absentee landowners. EV is defined as an income to compensate a change in household indirect utility, and it can be specified as follows:

$$v_i^H(r_i^A, q_i^A, y_i^A + ZCEV_i) = v_i^H(r_i^B, q_i^B, y_i^B) \tag{43}$$

where

v_i^H : household indirect utility function

A, B : indices expressing the states before and after a project, respectively

$ZCEV_i$: EV per capita in zone i

Since EV by zone is defined for a household, the benefit in each zone is obtained by multiplying the number of population in each zone by EV. By the way, households change their residential places according to a change of transport networks in our model. Thus the benefit by zone differs depending on the number of population before or after a project. That is, if one takes the number of households before a project, a change in the number of households after the project is not taken into account at all. Conversely, if one takes the number of households after the project, the benefit may be overestimated or underestimated. To avoid this ambiguousness, one should take into account the migration during the road construction. Therefore we derive the benefit of a project as follows:

$$ZSNB_i = \oint_{A \to B} [N_i(\tau) dZSNB_i(\tau) + d\pi_i^L(\tau)] \tag{44}$$

Formula (44) is expressed by line integral from the state without the project, *A*, to the state with the project, *B*. This line integral depends on the process of road construction, however, we assume that the roads ate constructed being proportional to time. Thus an approximation of the integral (44) may be written as follows:

$$ZSNB_i = N_i(A) ZCEV_i + \frac{1}{2}(N_i(B) - N_i(A)) ZCEV_i + \Delta \pi_i^L \tag{45}$$

where

$N_i(A)$, $N_i(B)$: the numbers of households before and after the project, respectively

This study employs formula (45) as a definition of the social benefit of the road construction in zone *i*. Following formula (45), the calculation results of the benefit by zone in Scenarios 1 to 3 are graphically illustrated in Figures 6 to 8.

First of all, the total annual benefits in the three scenarios are estimated as 381 billion yen in Scenario 1, 498 billion yen in Scenario 2, and finally 535 billion yen in Scenario 3 as presented in Table 7. As compared with the GRP in this region, it is estimated as about 8 trillion yen resulting in the fact that the impact ratios are 4.77%, 6.23%, and 6.69%, respectively. Taking into account that the environmental damage in GDP in Japan is estimated 1.5% to 2%, thus it can be said that this project has relatively higher efficiency. Calculating the benefit during 40 years with the social discount rate of 4%, it is 7 trillion and 540 billion yen in Scenario 1, 9 trillion and 861 billion yen in Scenario 2, and 10 trillion and 597 billion yen in Scenario 3. Comparing these values with the saving of generalized costs mentioned in the earlier section, the equilibrium benefits are more than double of the saved costs in the three scenarios.

Moving back to benefit in each zone, benefits of the new Tomei expressway, which connects Tokyo and Nagoya, the bypath of national road 23 and Mikawa harbor road, which connect the east and west regions in Toyohashi, and San-en Nanshin road, which connects the south area in Nagano prefecture and Toyohashi, are significant as shown in Figures 6 to 8. Note that some zones which would get significant benefit are located in rural areas, suggesting that new road construction even in advanced counties would realize the sustainable development of rural areas.

Table 7. Simulation Results of the Total Economic Benefit (in billion yen)

	Scenario 1	Scenario 2	Scenario 3
annual benefit	381	498	535
40 years benefit	7,541	9,861	10,597

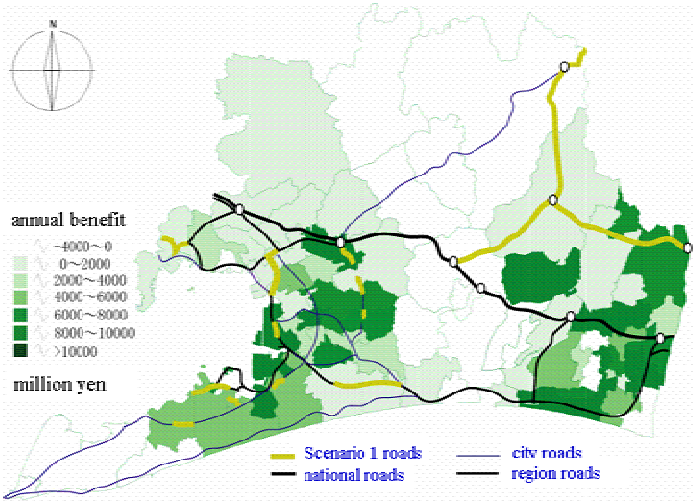

Figure 6. Economic Benefit in Scenario 1

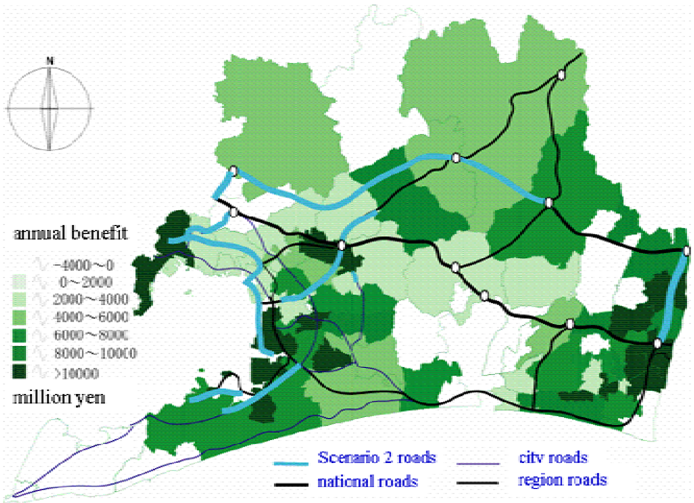

Figure 7. Economic Benefit in Scenario 2

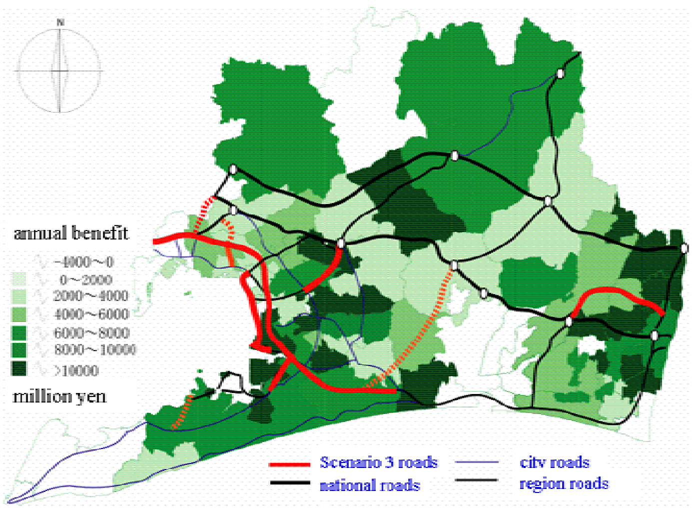

Figure 8. Economic Benefit in Scenario 3

8. Concluding Remarks

In this article, we have developed an integrated transportation and economic model for San-en region in Japan, and measured the economic impacts of new road construction by zone based on the equivalent valuation. From the simulation results, even rural zones in the study area have shown a possibility of future growth, if those zones are linked to newly constructed large scale roads. Our model is based on rational behavior of firms and households, thus our results seem to be applicable to other advanced countries.

Similar models have already been developed by other researchers, but the present model deals with much more complex road networks being appreciated as the first attempt for small zones' transportation, land use, and economy as far as the authors know. However the market under consideration is only land rental market excepting commodity and labor markets. Thus areas worth examining in the future include internalization of these markets.

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