A STUDY ON TRAVEL DEMAND FORECAST MODEL WITH CONSIDERING URBAN DESIGN – A MODAL SHARE MODEL –

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Abstract: The purpose of this study is to assess correlation between commuting mode share and micro-scale land use factors empirically in order to evaluate the effect of urban design to reduce environmental impact. First, we clear the substances of urban design measures, and then formulate several variables by integrating available spatial data in GIS. Generalized linear model was employed to explain this model. As a result of model estimation applied to suburban residential area, both mixed-use and transit LOS could reduce auto use rather than neighborhood design factors and socioeconomic attributes. Simulation with improvements floor-area ratio and frequency of bus service showed that improvement of transit service is necessary for urban design to be effective.

1. INTRODUCTION

In recent years, as concerns have been raised about the environmental impact of auto-use on urban sustainability, urban design measures have been said to be an effective planning method to reduce that impact in the long run. Low environmental impact urban design measures can include restriction of land use development, mitigation of urban climate, biological diversity, and energy conservation in a wide sense. In this study, we use "urban design" as it means land use policy on district level to improve urban mobility. So-called "new urbanism" – mixed land use, grid type road design, and transit-oriented development (TOD) – is expected to be a useful long range travel demand management (TDM) to reduce auto use in urban / suburban areas (Calthope, 1993). CAAA in 1991 also explained the effectiveness of this method. Newmann and Kenworthy (1996) pointed out the importance of reconnection of land use and transportation by dense, mixed-use planning, because disconnection of land use and transportation will come at a great cost in combination of urban environment, economy, and society.

Major urban areas in Japan are developed very densely accompanied by railway improvement, and their land use is highly mixed comparing with U.S. or European cities. Especially surrounding areas of transit stops (railway stations) are very dense and mixed. So, urban forms look like TOD type design, though they are actually not. In fact, it is difficult to say that these land use forms can reduce environmental impact in the future. Therefore, understanding of the combination of micro-scale land use or urban design and auto use is said to be an important topic.

On the other hand, thanks to the availability of micro-scale data sets and the power of GIS-transportation, various land use and related variables were computed from several sources. Such data is very helpful to understand relationships between urban design and auto use. Traditional landuse-transportation models have paid little attention to such urban designing factors, by only estimating demand of auto use in large-scale zones. In order to evaluate a walk-scale-planning method, we have to say that traditional models have many limitations.

Considering such backgrounds, this study will explore a mode share model applicable to suburban areas in Japan to explain the relationship between urban design and auto-use by using micro-scale spatial data. To estimate the effect of urban design in the long run, it is also necessary to model residential place choice, car owning choice, mode choice and destination choice. Among these models, mode choice is directly related to auto-use. Commuting trips only are analyzed in this study because of data availability. To begin with, models on the relationship between urban design and modal share are reviewed in the following chapter, and then major points of urban design measures are cleared. Secondly, by integrating available digital maps in GIS database, we formulated several variables to explain urban design and mode share. Thirdly, this model was applied to a suburban residential area of western Tokyo. Finally, simulation was conducted under certain scenarios to improve urban design.

2. URBAN DESIGN MEASURES AND ITS EFFECT

2.1 URBAN DESIGN MEASURES

Urban design to reduce auto use in urban or suburban areas is categorized into two major methods; transit oriented development (TOD) and traditional / neo-traditional design (TND) or planned unit design (PUD). Definitions and characteristics differ between scale and places where they are applied. Their definitions are summarized as following.

TOD is a development strategy to concentrate valid dense residential areas around transit stops accompanied by public facilities, offices, and commercial facilities (Calthope, 1993). Mixed-use around transit stops (about 600m radial) and improvement of pedestrian or bicycle paths are major objects. In city centers, dense land use is mainly applied within 0.8-16km from transit stops. In suburban areas, both accessibility of transit stops and connectivity between public facilities and residential areas or transit stops have to be improved. In order to understand TOD effects, accessibility of transit stops, level of mixed-use, connectivity of pedestrian / bicycle paths, LOS of transit (including frequency or amenity), and connectivity of facilities should be evaluated.

TND includes a center that has a mix of land uses such as offices, retail, civic buildings and apartments above retail stores. TND has been popularized in the last decade by many urban designers. TND mainly seeks improvement of pedestrian / bicycle paths, diversity of dwellings, dense residence, and wide public spaces. In order to estimate these methods, validity of road design, density of residential areas, connectivity of paths, diversity of households should be evaluated (Atash, 1996). PUD, on the other hand, designs segregated, clustered land use, low residential densities, missing sidewalks, and homogeneous housing. It houses about 5000 people in up to 2000 housing units providing 3000 jobs on no more than 40.5 ha. The Radburn System is the typical PUD. McNally & Ryan (1994) found that, in general, TND tends to reduce overall trip length and automobile travel speed. At the same time, they stressed that the effect of neighborhood design depends not only on network topology but also on geographical characteristics.

In table 1, these design measures are categorized from the viewpoint of planning scale, applied areas, design objects, and design supporting factors. For example, increasing bus frequency from residential areas to railway stations is not TOD matter. But this can reduce

Table 1. Urban design factors to effect modal share

Method	**TOD**			**TND**	**PUD**
Area		City center	Suburb	Suburb	
Scale (Radius)	0.6 km	0.8-1.6 km	2-5 km	0.8-1.6km	
Design Factor	Mixed-use around transit stop Pedestrian & bicycle environment	Dense land use around transit stop	Public facilities to be accessed on foot	Grid-type network	Cul-de-sac (Radburn System)
Design Supporting Factor	Connectivity of pedestrian / bicycle road	High LOS of transit	High LOS of transit Connectivity of facilities	Connectivity of public facilities Variety of house type	
Evaluation Index	Accessibility of transit stop Level of land use mixture Connectivity of pedestrian / bicycle road LOS of transit (frequency / amenity) Accessibility of public facilities			Validity of road design Road density Connectivity of pedestrian / bicycle road Diversity of dwellings Density of house Scale of public space	

auto users and increase the number of railway passengers. As Nakamura (1997) discusses, improving transit service should be accompanied with an urban / suburban land use policy in Japan. He insists that auto-use to suburban shopping centers or other facilities should be increased without such services.

In Japanese cities, density and mixture are depending on land use zoning system. But the ranges of land use from transit stops are not strictly decided. Only the demarcation of zones restrains the natural expansion of residential area. Thus, It is hard to address that residential areas in Japan were developed in the measure of TOD.

As for neighborhood design, several original neighborhoods were planned based on the grid type or the Radburn System. T-type intersections or U-type feeder roads were combined for both grid-type and Radburn Systems in order to reduce though traffic. Combinations of the grid-type and the Radburn System were also applied to the suburban residential area. Thus, topological features of neighborhood designs do not always reflect their functions. For example, grid-type neighborhoods with a Radburn System would increase auto use because of connectivity to arterial roads, or variation of road width will increase accessibility to feeder roads. Therefore, it may not be useful to assume that either TND or PUD would be powerful to reduce auto use in Japanese residential areas.

2.2 LITERATURE REVIEW

On the practical level, several offices have introduced urban design factors to urban traffic demand forecast models, especially the modal share models. Well known models have been developed by Portland Metro, Chicago Area Transportation Studies (CATS), Washington Council, Montgomery County, and Sacramento (Eash, 1995; Replogle, 1995). For example, Portland Metro's LUTRAQ introduced the "Pedestrian Environmental Factor (PEF)" to the auto / non-auto mode share model. In this model, negative correlation is clearly depicted between pedestrian improvement and auto-use reduction (1000 Friends of Oregon, 1993). CATS model also uses PEF variables to estimate both trip generation and modal share. Especially in this model, trips of employers are reduced when PEF becomes better. PEF in each model is an aggregated index that contains connectivity and width of pedestrian space, setback condition of buildings, amenity of transit (bus) stops (ex. existence of shelter), condition of cycle paths (ex. existence of bicycle lane) and so on.

Frank & Pivo (1994) suggested that the relationship between urban structure (population density, employer's density, and mixture level of land use) and non-auto use reveals strong correlation, especially the choice of walk. Carvero & Gorham (1995) found an interesting point that increases in density have a stronger effect of inducing transit commuting in grid type transit-neighborhoods than cul-de-sac type auto-neighborhoods. Handy (1996) identified four Bay Area neighborhoods with comparable regional accessibility and socioeconomics as either typical suburban or traditional on the basis of local accessibilities (which were lower and higher, respectively). Handy found that highly accessible communities possibly encourage walking as a viable option for shopping and other nonwork trips. Cervero (1996) modeled a relationship between mode share and landuse condition, household's attribute, and commuting vehicle kilometers traveled (VKT). He showed that the increase of population density and the improvement of facility location induces transit and walk mode share. Kockelman (1996), by using disaggregated trip data, explained that increase of land use mixture and local accessibility might induce transit or walk mode share rather than passenger's attribute. Messenger & Ewing (1996) also analyzed the relationship between transit use (especially bus use) and household's socio-economic attributes, land use (job-housing balance, neighborhood design, and population density), and level of transit service. However, they showed that household's attributes have significant coefficients to transit choice rather than population density or job-housing balance. Kitamura *et al.* (1997) also assumed that attitudinal variables tend to explain most of the variance in the trips and mode choice and that socioeconomic variables generally explain more of the variance than neighborhood variables.

As shown in Table 2, these modal share / mode choice models only employed such explanatory variables that relate only to urban design and other socioeconomic attributes. The models revealed significant coefficients of each explanatory variable, but fitness of them was not so good. We assume that this is caused by the following two reasons:
1) Index definition. For example, most of the above mentioned researchers calculated a

Table 2. Relationships between urban design factor and modal share in existing studies

Authors	Spatial Unit	Trip Type[1]	Model Type[2]	Variables[3]					
				Accessibility	Road design	Land use-mix	Population density	Household Characteristics	LOS[4]
1000 friends of Oregon (1993)	TAZ	HBW	ML		○ (PEF)	○			
Frank & Pivo (1994)	Census tract	HBW HBS	OLS		○	○	○		
Carvero & Gorham (1995)	District	HBW	OLS		○	○		○	
Handy (1996)	District	HBW, HBS, HBO	OLS	○	△	△			
Messenger & Ewing (1996)	District	HBW, HBS, HBO	OLS		–	○	△	△	○
Cervero (1996)	District	HBW	BL	○		△	○		
Kockelman (1996)	District	HBW, HBS, HBO	BL	○	△	○		–	
Kitamura et al. (1997)	District	HBW, HBS, HBO	ML		–	–			
Eash (1999)	TAZ, & District	HBW, HBS, HBO	ML		○ (PEF)	○			

Note)
1) HBW: Home-base work, HBS: Home-base shopping, HBO: Home-base other.
2) OLS: Ordinary Least Square method, BL: Binary Logit Model, ML: Multinomial Logit model.
3) ○ : high correlation, △ : low correlation, – : no correlation.
4) means service level of public transport.

straight-line distance from the zone centroid to the transit stops to define accessibility. But the distance from one point to another is effected by topographical change. Or, in other studies, land use entropy was used to explain mixed-use. Entropy index is good to explain complex phenomena. But an appropriate land use combination is hard to represent. Additionally, in order to evaluate effects of urban design measures in Japanese urban areas, it is necessary to consider several factors to improve the effect of urban design. Furthermore, several design indexes are not appropriate when applied to suburban residential areas in Japan.

2) Model validity. Many researchers estimated by ordinary least square (OLS) model or Logit model, assuming that prediction error is in monoskedastisity. But as for the data used in the modal share / mode choice model, the average of the modal share rates changes with that of variance. Besides, estimation error is spatially biased. Such kind of statistical problems should be considered in each aggregate or disaggregate model.

Thus, in the next chapter, we first formulate variables applicable to our study area and then in Chapter 4, the statistical model will be explained.

3. DEFINITION OF URBAN DESIGN FACTORS

3.1 NECESSARY CONDITIONS OF URBAN DESIGN FACTORS

1) SCALE OF SPATIAL UNITS

Traditional land use-transportation models have employed large size zone only to forecast auto demand. However, when using such zones, it is difficult to explain effectiveness of dense, mixed-use policy or neighborhood design. Therefore, micro-scale zones as small as neighborhoods should be used in the models. Strictly speaking, the validity and stability of the spatial unit should be statistically analyzed. This matter will be analyzed in another paper.

2) INDEX SELECTION

To analyze the effect of urban design, not only design factors or socioeconomic factors but also such factors that improve effect of design measures should be employed. Here we call these factors the "design supporting factors" as shown in Table 1. The expectation is that increases in land use intensity, balances, and integration will reduce auto use via several causal channels. Thus, accessibility, neighborhood design, and land use index should be selected. As factors to make design effective, connectivity of daily-use facilities and transit stops, service level of transit (especially frequency of bus service), and amenity of transit stops should be tested. Population density is also related to land use. Household types (housing type, own housing ratio, and number of children) are employed to explain the socioeconomic situation. The rate of working women and elderly people, and the commuting rate to city center can describe the commuting condition of the study area.

In this study, we only employ variables related to trip origin by assuming that the destination side condition will strongly effect the residential choice.

3.2 DEFINITION OF EXPLANATORY VARIABLES

URBAN DESIGN FACTORS

1) ACCESSIBILITY TO RAILWAY STATION

As mentioned above, few researchers employed a three-dimensional distance from the zone to the station. In Japan, many suburban residential areas were developed by flatting the hill slope. So the accessibility has been changed by topographic feature. The power of GIS makes it possible to calculate this kind of distance with integrating topographic analysis and network analysis. In this study, we weighted the angle slope of topography to shortest network path distance from the station to the zone centroid.

First, slope angle was calculated from topography map and then average slope was weighted to each network link in order to calculate link cost. Here we didn't consider the velocity of link slope. Finally shortest network path distance from the station to the zone centroid was calculated (Figure 1).

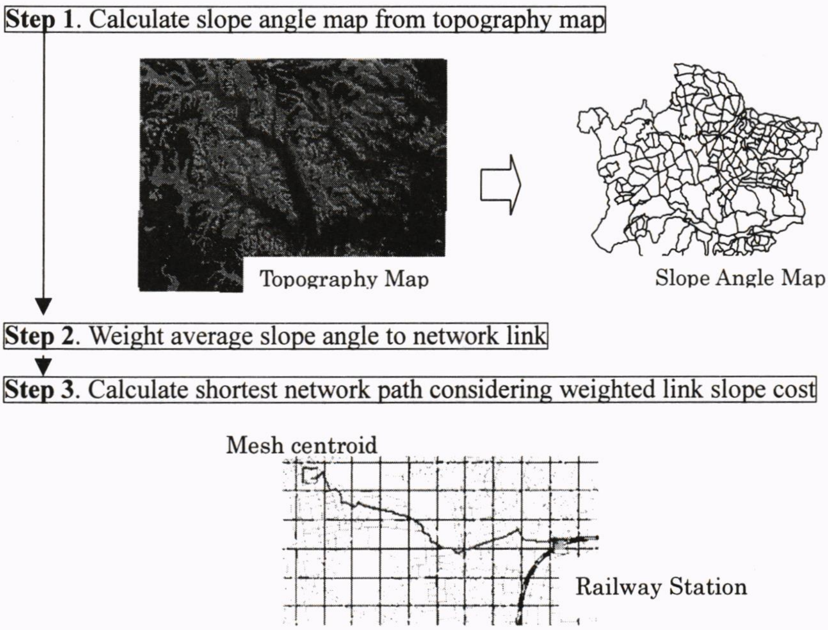

Figure 1. Flow to calculate weighted distance

2) NEIGHBORHOOD DESIGN

In suburban residential area in Japan where the land readjustment project (kukaku-seiri project) was applied, access roads are planned wider than 4 meters. Fortunately, in Japan, Digital Road Map contains all roads with more than 3.5-meter width.

Many researchers have compared grid-type and cul-de-sac type neighborhoods. However, as discussed above, many suburban neighborhood in Japan were planned under the land readjustment project, and typical neighborhood access roads of them were designed in the combination of the Radburn System, U-type, T-type, and grid type. Thus, neighborhood indexes should be made by considering both their feature and function. Especially, connectivity of feeder roads and composition of road widths play rather important roles, as well as neighborhood features. Here, we employed three kinds of variables: the number of intersections in grid pattern neighborhoods (including T-type and U-type grid), the accessibility to arterial roads of each zone, and the combination of road widths. The second index is given 1 if arterial roads are passing through the zones, otherwise 0. The last index is given 1 if the feeder roads with 3-5.5 meters width are directly connected to the next level of access roads with 5.5-13.0 meters width, else if the access roads with 5.5-13.0 meters width are directly connected the access roads.

3) LANDUSE INDEX

Land use index is one of the most important factors to explain the efficiency of urban design. Most transportation researchers are familiar with the measure of land use entropy concept (= $\Sigma_j\{(\text{landuse}[j] \times \ln(\text{landuse}[j]))/\ln[J]\}$). This measure is actually appropriate for computing the combination of land use. In order to analyze the effectiveness of mixed-use, however, it is necessary to consider not only floor area ratio but also desired land use combination. Thus, in this study, we calculate a summation of land use area by weighting both floor area ratios of zone and desirability (Equation 1). Desirability weight of land use is shown in Table 3.

$$LU = (floorarea\_ratio) \cdot [\sum w \cdot \ln(landuse_i)/5 \cdot \ln(landuse)] \tag{1}$$

Table 3. Weight index for land use index

Land use	I	I & R	P	R/C/O	Mixed-use (R/C/O)
Weight	1	2	3	4	5

Note: R = Residential, C = Commerce, O = Office, P = Public facility, and I = Industry.

DESIGN SUPPORTING FACTOR

4) SERVICE LEVEL OF TRANSIT

The improvement of service level of public transportation is expected to increase commuters by transit. Especially, railway and bus are assumed to play important roles. Here, frequencies of railway and bus lines in the peak period and accessibility of bus stops will be used. But, we only employ frequency of buses that are directly connected to railway station. Bus stop accessibility index is 1 if zone centroids are within 200 meters from bus stops, otherwise 0.

5) AMENITY OF TRANSIT STOP

Amenity is also an inevitable factor for TOD. For example, the PEF of the CATS model uses whether bus stops have shelters or not as a transit stop condition. But in this study, we employed bicycle-pooling space of each railway station.

Here, indexes on service level and amenity are assigned to each zone by calculating thiessen boundaries in GIS, assuming that commuters daily use the nearest station or bus stop from their home.

SOCIOECONOMIC INDEX

Socioeconomic indexes were employed as the following list.
- Density of commuters: Number of commuters was directly used.
- Detached house: Number of households with detached house.
- Housing tenure: Number of housing tenures.
- Rate of working women: Number of working women per commuter.
- Rate of old person: Number of elder people per dwelling.
- Rate of commuters to city center: Number of workers who commute to Tokyo's 23 wards as share of total commuters.

4. MODEL

4.1 MODEL ASSUMPTION

As pointed out in 2.2, ordinary models have some statistical limitations. In this study, we will employ an aggregate model. Thus, model hypotheses are to be described related to aggregate model. We assume that low fitness is caused by the following two reasons.

1) The traditional OLS model $y = \beta x + \varepsilon$ assumes normal distribution of prediction error ε. But OLS does not consider the range of objective variables. The data we use here - mode share - is, however, the exactly range from zero to one. In this case, the range of the objective variable cannot be connected to the model $E(y) = \beta x$.
2) OLS assumes mono-skedastisity that change of objective variable y will not affect the variance of y. But in many cases, a change of y's average accompanies a change of its variance. So monoskedastisity assumption is unrealistic. Thus, in this study, generalized linear model (GLM) is employed to estimate commuting mode share model by assuming heteroskedastisity.

4.2 GENERALIZED LINEAR MODEL (GLM)

GLM may be described by the following assumption (Venables & Ripley, 1998).

- The stimulus variables may only influence the distribution of objective variable (y) through a single linear function called the linear predictor.
  $$\mu = \beta_1 x_1 + \beta_2 x_2 + \Lambda\ \beta_p x_p \tag{2}$$
- The distribution of y has a density of
  $$f(y_i;\theta_i,\varphi) = \exp[A_i\{y_i\theta_i - \gamma(\theta_i)\}/\varphi + \tau(y_i,\varphi/A_i) \tag{3}$$
  where phi is a scale parameter (possibly known), Ai is a known prior weight and parameter θ_i depends upon the linear predictor
- The mean, η, is a smooth inheritable function of the linear predictor.
  $$\eta = g(\mu) \tag{4}$$
  The inverse function is called the link function.
- The mean is also a function of variance.
  $$Var(y) = \phi V(\mu) \tag{5}$$
  This function is called the variance function

The variance function in equation (4) should be selected from Gaussian, Binomial, Poisson, Gamma, and other response distributions. Each response distribution allows a variety of link functions to connect the mean with the linear predictor.

The log-likelihood is computed by equation (6).

$$D_M = 2\sum A_i[\{y_i\theta(y_i) - \gamma(\theta(y_i))\} - \{y_i\hat{\theta}_i - \gamma(\hat{\theta}_i)\}] \tag{6}$$

Since explicit expressions for the maximum likelihood estimators are not usually available estimate must be calculated iteratively. Thus, parameters are estimated by iterative re-weighted least square (IRLS) of the following steps.

1. Calculation of working weights W_0 and working value z_0. Initial values for W and z can be calculated from the initial predictor.
   $$W = A/V(d\mu/d\eta)^2 \tag{7}$$
   $$z = \eta + (y-\mu)/(d\mu/d\eta) \tag{8}$$
2. At iteration k, a new approximation of the estimate of coefficient vector is found by weighted regression of the working values z_k on $X=\{x_1, x_2 \dots x_p\}$ with

weights W_k.

In order to evaluate the fitness of the model, analysis of deviance table is used. Parameters will be used if variance deviance of model is at minimum point. The IRLS is different from the Newton-Raphson scheme in that the Hessian matrix is replaced by its expectation.

5. MODEL ESTIMATION & SIMULATION

5.1 STUDY AREA

As case study area, Aoba ward in Yokohama City, a suburb of Tokyo, was selected. This area was developed along railway accessing to the center of Tokyo from southwest to northeast (Figure 2). Land readjustment project was adopted to plan residential area around stations.

In the study area, 53 % of workers are commuting to the city center of Tokyo (23 wards) and 20% of them are women. Commuting modal share of car is about 21 %. But as the distance from the station becomes longer, its ratio increases. Nearly 60% of Aoba ward is residential area (Table 3). Mixed-use is only permitted around stations or along arterial roads.

Table 3. Land use pattern of study area (%)

Land use	Mixed-use	Residential	Commerce	Office	Public	Industrial
Share	2.61	51.66	1.63	24.72	10.49	2.68

Note:
1) "Mixed-use" includes land use mix of residential, commerce, office and public
2) "Industrial" includes mixed-use of industrial and residential

In the residential area, three major neighborhood types were designed: ordinary grid neighborhoods, grid neighborhoods with T-type and U-type, and Radburn TU-type (Fig. 3).

5.2 DATA AND SOFTWARE

250-meter mesh scale population census data in 1990 aggregated by Yokohama City was provided. This data contains commuting mode share and household's socioeconomic indexes. We employed two types of land use data: one is aggregated in 250-meter mesh scale, and the other one is aggregated in building level. Digital road map (DRM) contains both network feature and intersection characteristics. The database was built in ArcView GIS and S-Plus was used for statistical analysis.

5.3 RESULTS OF MODEL ESTIMATION

The estimation results of parameters by GLM and OLS are shown in Table 4. GLM revealed the best fitness when we employed logit type link function and binomial type variable function. Residual deviance of GLM is smaller than OLS.

Coefficients of distance, land use index, LOS of bus, and ratio of workers who commute to the city center was statistically significant. High mixture of land use and dense population decreases commuting auto use. The increase of bus frequency and bicycle pool space is also expected to be useful for controlling commuting auto use. The effect of neighborhood type on mode share was statistically less significant than other design indexes. But only accessibility of arterial road revealed positive coefficient. The residential type and ratio of working women, on the other hand, were statistically insignificant. Interesting correlation

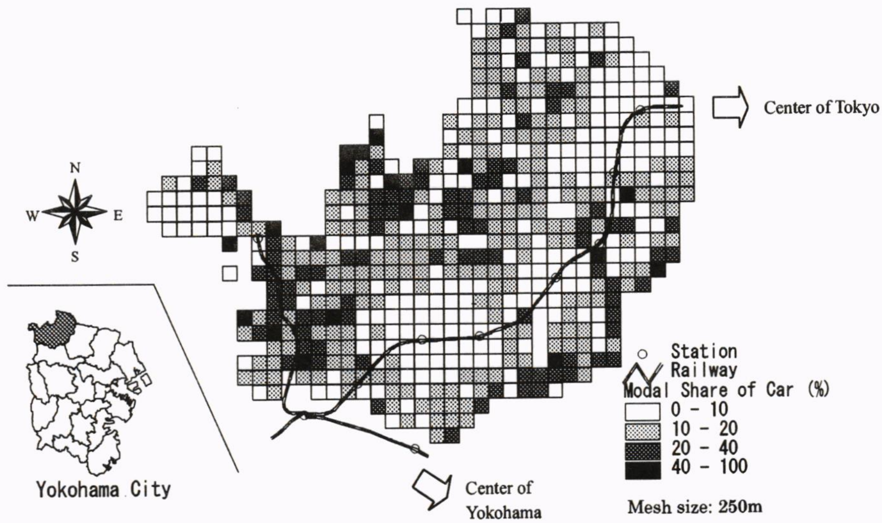

Figure 2. Study area and its modal share of car for commuting
(Source: Population Census aggregated to 250m mesh scale by Yokohama City)

Figure 3. Combination of Road Network in the Study Area
(Source: Digital Road Map)

Table 4. Model results

Parameters	GLM		OLS	
Log(Weighted distance)	0.858	(2.75)	0.78	(2.73)
No. of grid road	-0.0007	(-0.06)	-0.05	(-0.12)
Access to arterial roads	1.032	(2.03)	1.00	(1.96)
Combination of neighborhoods	-0.772	(-1.38)	-0.51	(-1.33)
Land use index	-0.705	(-2.45)	-0.04	(-1.81)
LOS (train)	-0.025	(-1.04)	-0.02	(-1.42)
LOS (bus)	-0.380	(-3.68)	-0.30	(-1.52)
Accessibility of bus stop	-0.298	(-0.60)	-0.35	(-0.45)
Scale of bicycle pool	-0.101	(-1.56)	-0.09	(-1.38)
Density of commuters	-0.017	(-2.62)	-0.02	(-2.83)
Detached house	-0.007	(-0.61)	-0.01	(-0.53)
Housing tenure	0.016	(1.29)	0.01	(1.18)
Children	0.040	(2.11)	0.04	(2.35)
Rate of working woman	-0.033	(-0.62)	-0.04	(-0.79)
Rate of old person	0.194	(2.18)	0.19	(2.79)
Rate of commuters to city center	-0.327	(-11.67)	-0.33	(-12.18)
Constant	26.480	(3.45)	33.31	(10.24)
Residual Deviance		44.62		58.1

Note: Numbers in the parenthesis mean t statistics.

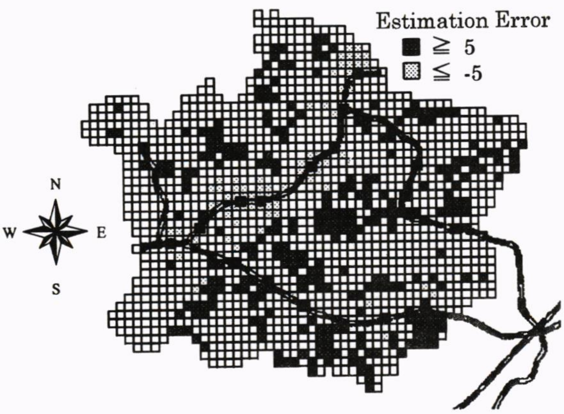

Figure 4. Spatial distribution of estimation error with OLS

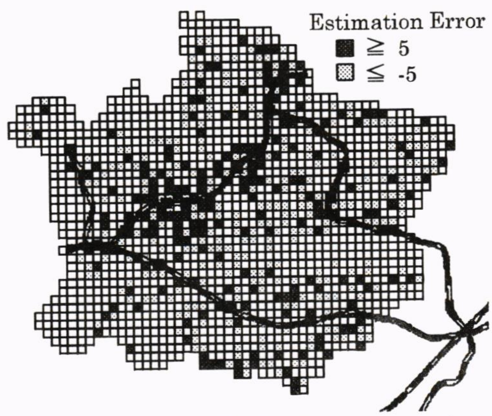

Figure 5. Spatial distribution of estimation error with GLM

was revealed in the rate of workers who commute to the center of Tokyo. One may assume that this negative coefficient is also correlated to residential place choice.

When we estimated the model by OLS, estimation error is spatially distributed (Figure 4). With GLM model, however, spatial bias of estimation error was reduced (Figure 5.).

5.4 ASSESSMENT OF SCENARIOS

In relation to urban design effect, we conducted two cases of simulations. In the first case, increase of floor area ratio was simulated. In the study area, nearly 80% of the buildings did not correspond to the designated floor area ratio. Thus, in this case, we assumed situations in which the floor area ratio of each building was raised to the designated one. The second simulation was related to bus frequency to stations. Here, our question was that how supporting factors would improve urban design effect.

Scenario 1) Increase of floor area ratio

In this case, floor area ratio was changed to the designated ratio. At the place without designation, we used the ratio as they were. As a result, mode share of car decreased along arterial road with 150% floor area ratio (Figure 6).

Scenario 2) Improvement of bus service level

To test the effectiveness of bus service, we assumed 1.5 times frequency. In this case, mode share of auto decreased in residential area far from the station (Figure 7). Total decrease of auto share in this case was larger than that in case 1. Comparing the results of these two cases, it can be said that improvement of transit service is a powerful measure to increase TOD effect.

6. CONCLUSION

In this study, we have given the attention to correlation between mode share of home-based-work and urban design factors to reduce auto use, by conducting suburban residential area in Tokyo. Results are summarized as followings.

- Several variables on urban design and related factors were proposed by integrating available spatial data sets. In order to formulate indexes, we classified them into three categories; urban design factors, design supporting factors to improve design effective, and socioeconomic background.
- The model is more accurate because of weighting the slope angle of topography to the shortest road network path distance from station to zone centroid. At the next stage, time cost of link considering velocity of slop (or psychological impact of up and down slope) should be employed to estimate the effect of accessibility.
- Parameters were estimated by GLM, and fitness of model was higher than that of OLS. Model result showed that urban design factor and factors to improve design effective have stronger connection to commuting mode share than socioeconomic variables. Especially, one can judge that accessibility, land use mixture, and frequency of bus are the powerful variables. Spatial bias of estimation error was also reduced by GLM.
- Scenario analysis showed that improvement of bus service decreased auto use more effectively than denser land use.

This research is supporting new-urbanists' assumption that land use-transportation connection is an effective measure to reduce reliance on the automobile. Especially, simulation results showed that dense and mixed land use plan should be accompanied by the improvement of transit service in suburban residential areas.

The estimation result raises another question: the residential place choice model. Both accessibility and commuters destination were statistically significant to mode choice. Thus policy makers can lead residential choice by controlling them. Therefore, at the next stage of this study, a residential choice model is to be explored.

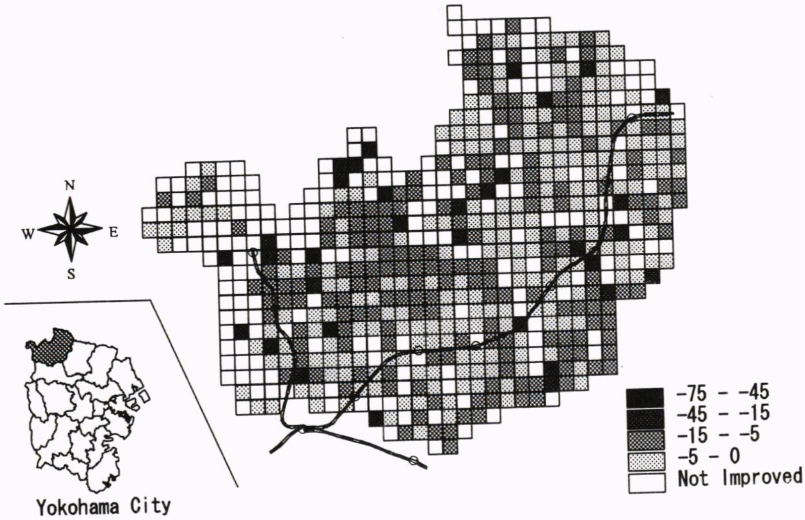

Figure 6. Simulation Result of Scenario 1

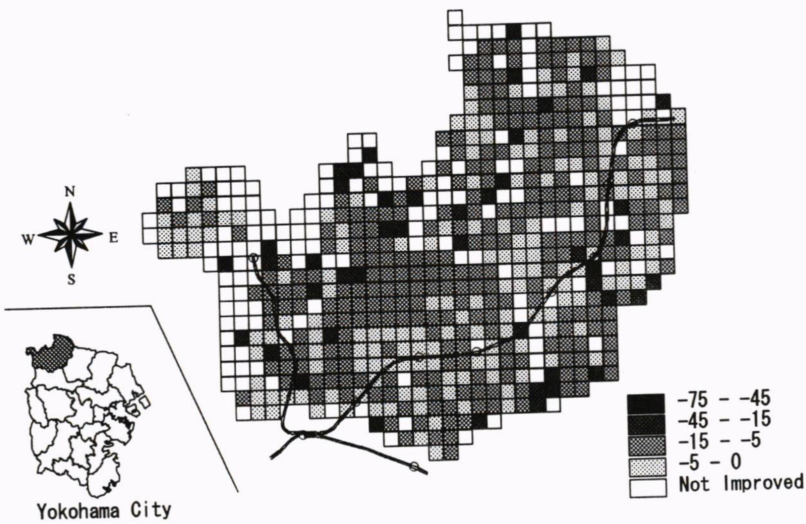

Figure 7. Simulation Result of Scenario 2

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