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Technical Document of The Assessment Tool for Future Urban Structure by NILIM

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Ministry of Land, Infrastructure, Transport and Tourism

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1. Perspective of Assessment Tool for Future Urban Structure

1.1 The necessity of assessment for future urban structure

With the arrival of depopulating and super-aging era in Japan, coping with population change is accepted as one of the main issue of urban sustainability along with global environment, and public finance issues. The population, reaching its peak in 2005, is expected to fall by 30 percent, and the ratio of 65-year-old aknd over is expected to grow from 20.2% to as much as 40.5%, in 2055. This population decline and aging is in progress in various cities, and environmental and financial restriction in addition, formation of sustainable city under such changes in economic and social situation is a critical urban policy issue.

In many local cities, under assumption of ever-increasing growth, led to continuous expansion and spread of the urban area to the suburbs, and in areas of high population decline, such issues of maintenance and updating of existing urban infrastructure such as roads and sewerage, and low efficiency of public transportation, medical and welfare services, and management of open spaces and vacant lots and houses generated in suburban and rural districts, are being focused on.

Restructuring of city management strategy to offer administrative service which is efficient, cost-effective, and of high citizens' satiscoefficienty level is being urged. This situation necessitates city planning policy to take "selection and concentration" and sharp-based planning measures to cope with, and this awareness seems to have led to the recent "compact city" attempts in some cities and "intensive urban structure" policy by the Ministry of Land, Infrastructure, Transport and Tourism.

Meanwhile, to take "selection and concentration" measures, facilitation of prior general consensus-building is preferable as to the object and contents, to their definite advantage and disadvantage understandings, to reasons for being selected for intension or for not selected, and to range of compensation measures if taken. Instead of past urban policy distributing "fruits of the growth", current demand for urban policy is for "fare share of pain" or "minimum gross pain", and wide consensus of this policy's necessity, and open even-handed judgment is necessary to implement.

The National Institute for Land and Infrastructure Management (NILIM), in support of this diversion, begun "Research for Assessment Method for Future Urban and Regional Visions in the Depopulating Period", targeting local medium-size cities. In this research, which began in the fiscal year 2008, we tried to construct a technological system to assess urban policy by developing indices from the viewpoint of sustainability of administrative service costs, the quality of life and environmental load, and so on, to estimate and evaluate the future outcomes of the alternative planning policy scenarios for future intensive structure of cities, thus supporting choice of most suitable plan. Utilization of such assessment tools to urban policy aimed for sustainability are mainly seen in cities with rapid growth, however, with Japanese experience of depopulation and aging, restrictions on finance, and environmental load, our investigation will be a unique case.

1.2 Summery of Assessment Tool for Future Urban Structure

The composition of the research topic corresponding to the supposed assessment process is shown in Fig. 1.

Technical development consists of 4 main themes; "Application Methods of Assessment Input and Output data", "Systematized Organization of Optional Planning Measures", "Prediction Methods of Future Urban Structure", and "Evaluation Methods of Future Urban Structure". The emphasis was put and the research was concentrated to two latter development themes.

In developing "Prediction Methods of Future Urban Structure", we need to predict future changes of urban structure (population distribution land-use and traffic flow movement, etc.) and accompanying changes of the demand for infrastructure and other administrative services by alternative planning measure groups. In developing "Evaluation Methods of Future Urban Structure", in order to assess and compare sustainability of alternatives, indices for quality of life levels, administrative service costs, environmental impact levels, and disaster safety level and method of calculation should be studied.

Integration of land-use planning and transportation measure was significant achieve intensive urban structure, the land-use and transportation model was put as the core of the prediction method. The composition of the assessment tool was supposed as shown in Fig. 2.

The Future Urban Structure Assessment Tool correspond to big stream of local governments assessments. Summery of the tool with application images are as follow.

First, several alternatives for target cities or local areas are prepared and input to the model to efficiently carry out the estimation and assessment by the models. The alternatives consist of various policies on land-use, transportation, infrastructure, housing and so on, and are target of data correction and processing, comparison and evaluation. The changes of future urban structure through the implementation of measures, such as population distribution, land-use and traffic flow, and accompanying demand changes for governmental services is calculated as the predicted value by Future Urban Structure Estimation Model. Especially since it is need for coordination of land-use and transportation policies to realize intensive urban structure, the land-use transportation model is a main prediction method.

Future Urban Structure Evaluation Model evaluate the future urban structure alternatives from the viewpoint of sustainability. It can calculate about 30 indicators in five field: life (QOL), safety, environment, vitality and administrative service cost, using predicted values in Future Urban Structure Estimation Model. These predicted and evaluated results are shown as such a comparison of the advantages and disadvantages which would be brought by the future urban structure and measure alternatives. And they are so appropriate for a scene of the Plan Review by local government officers and other stakeholders including relevant citizens.

In addition, it is not assumed that this tool should be used for the specific city under the participation of the developer but used by various user in various cities with modifying the part of the model in some cases.

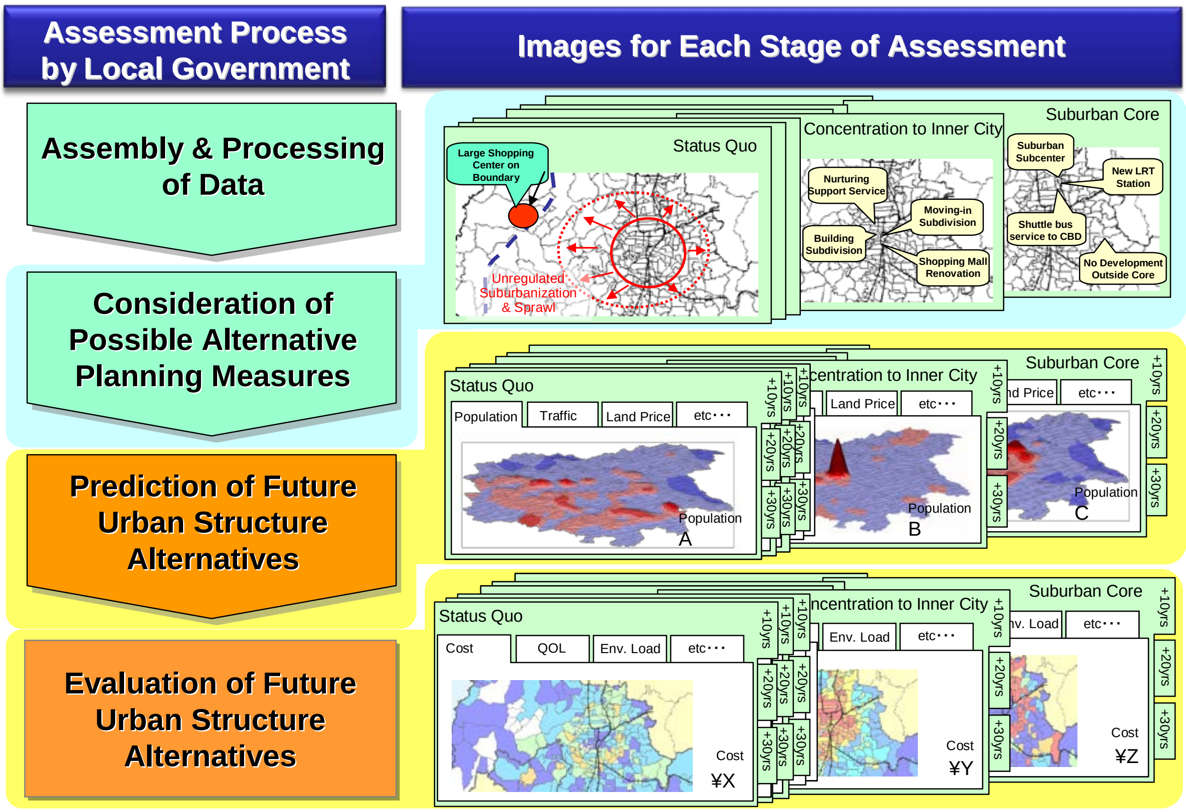

Figure 1. Procedure and Output Images of Assessment

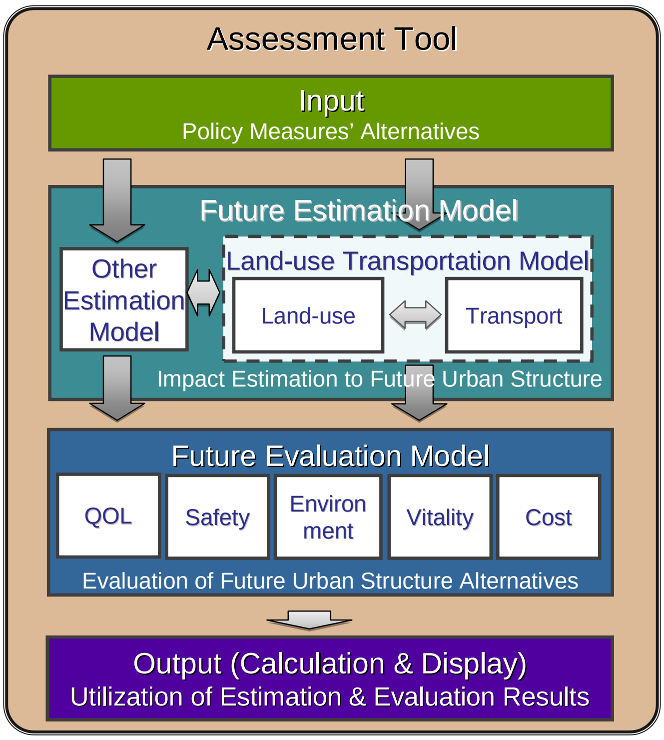

Figure 2. Major Composition of the Assessment Tool

2. Future Urban Structure Estimation Model

2.1 Outline and composition of Future Urban Structure Estimation Model

Future Urban Structure Estimation model, which predict the impact of future urban structure for measure alternatives, is aggregated land-use transportation model. The model sequential treats the status of land-use and traffic in zones based on interaction between land-use and transportation and the difference of the adjustment speed for measures (time lag from implementation to realization). The structure of the model is shown in Figure 3.

Considering the usability for local governments, input data to sub-models are aggregated values by zone obtained from Census surveys, Basic surveys of urban planning, Person trip surveys and so on. Land-use model is composed of 10 sub-models, accessibility model, land supply model, floor supply model, household type transition model, migration rate model, location choice target household adjustment, household location choice model, population conversion, firm location choice model and land price model.

These sub-models are sequentially operated and the location distribution of households, population and employees are simulated in each period. Among input data of land-use model, time distance between zones by mode is the output of the transportation model in the previous period, and land price by zone and location distribution of households, population and employees are the output of land-use model in the previous period. Moreover, locater distribution of the present period is inputted to transportation model in same period, and locator distribution and land price by use type are inputted to the land-use model for the next period.

Transportation model is a four-step estimation model which is utilized in the Person Trip Survey. Although the household based modeling has been carried out in land-use model, transportation model is a population-based. Therefore household distribution is converted to population one using the conversion coefficient of household type for population by age in population conversion model.

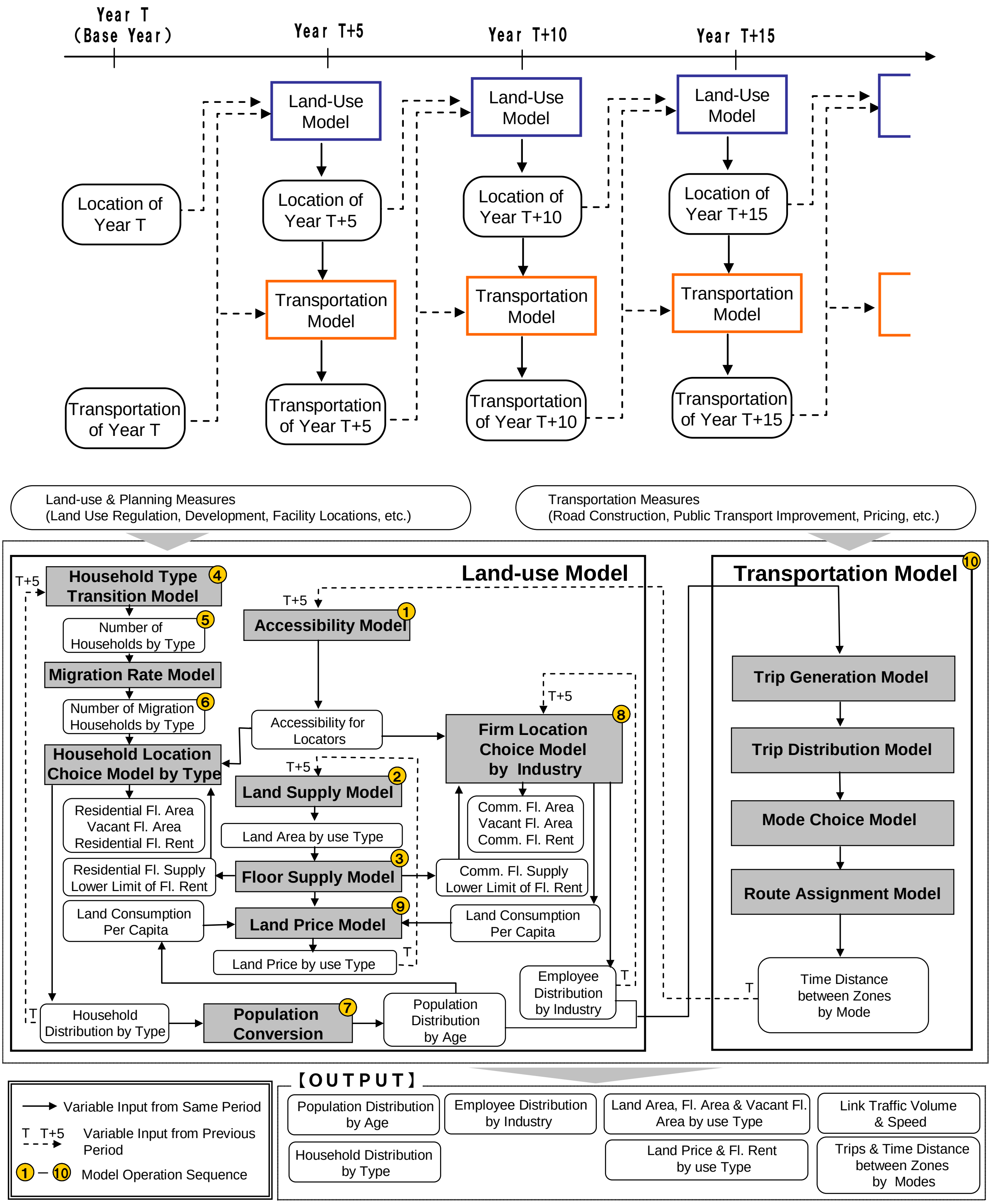

Figure 3. Structure of Future Urban Structure Estimation Model

2.2 Modeling Approach

In order to consider model designation, some existing practical land-use transportation model were reviewed. Their characteristics in model structure, assumptions and requirements are summarized as shown in Table 1.

Table 1. Review of the existing Land-use Transportation models

Model		URBANSIM (US)	DELTA (UK)	IRPUD (DE)	NYMTC-LUM (US)	VMcue (JP)	RURBAN (JP)
Developer		P. Waddell et al.	D. Simmonds et al.	M. Wegener et al.	A. Anas	Yamazaki, Muto, Ueda et al.	Miyamoto et al.
Modeling characteristics		Land-use microsimulation model	Aggregated land-use and economic model package by the linkage with exogenous transportation model	Aggregated land-use transportation model /Apply microsimulation only to residential location choice	Aggregated land-use transportation /Represent equilibrium of residential and commercial floor, labor and transportation market in each period	Computable urban economic model /Aggregated land-use transportation model /Represent equilibrium of land-use and transportation network for each period	Aggregated land-use transportation model /Represent steady-state of land-use for each period
Assumption for target area		Closed city	Closed city	Closed city	Closed city	Closed city	Closed city
Interaction between land-use and transportation		Interactive type	Interactive type	Interactive type	Integrated type	Integrated type	Interactive type
Outline and requirement of transportation model		Combined with exogenous transportation model including car ownership model	Combined with exogenous transportation model to consider only accessibility	Included four-stage estimation and car ownership model	Included four-stage estimation subject to user equilibrium assignment	Included four-stage estimation subject to user equilibrium assignment	Included four-stage estimation model
Residential locator		Household (1,890 categories)	Household (20-40 categories)	Household (80 categories)	Household (2 categories)	Population (1 categories)	Household (3 categories)
Target of location demand	Residential	Housing	Floor area	Housing	Floor area	Land area	Land area
	Firm	Floor area	Floor area	Floor area	Floor area	Land area	Land area

Future Urban Structure Estimation Model is developed with following modeling approaches based on above mentioned review results.

1) The total number of locators (population by age and employees by industry) in the target area are given exogenously. Closed city which has been defined in the urban economics is assumed. Location demands for zones are determined under such a condition.

2) Land-use and transportation markets are simulated in a stepwise by sequentially operating sub-models composing them. Price (transportation cost, land price, etc.) are taken into account, but the steady-state of each market with coordination mechanism of supply and demand in each period are not represented.

3) The model has a quasi-dynamic structure in order to represent the difference of the adjustment speed between transportation and land-use market. Land-use market for the present period is influenced by the transportation market in the previous term such as changes of transportation convenience. In other words, the development or supply of transportation infrastructure for the present period will affect the location demand of land-use for the next period. In addition, total numbers of locator will change through time period, and never reach strict equilibrium.

4) In this model, residential locator is household and considered the transition of attributes (life stage), disappearance and generation with cohort analysis. In location choice of households, the reservation of location is considered for a post-transition household. Number of location choice target households are determined by adjusting to the fixed total population by age for non-reserved and generated households. It is assumed that location choice target households make a choice according to utility-maximizing behavior, as the result, locating zone is determined. Figure 4 shows the flow of household-based location choice model.

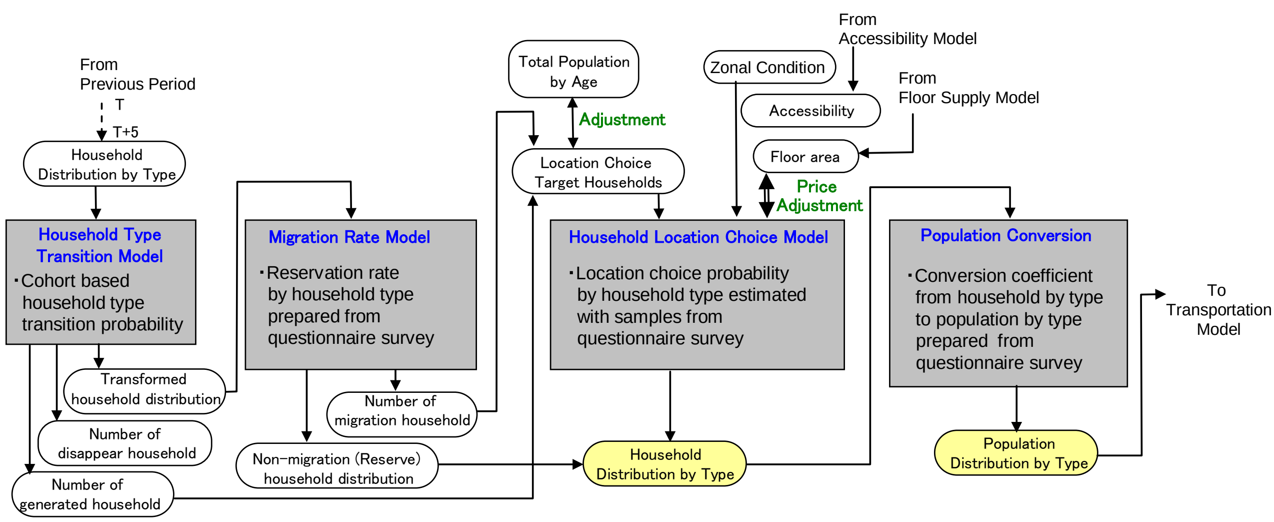

Figure 4. Flow of household based location choice model

5) Farm locator is adopted employees similar to most of existing land-use transportation models. It is assumed that the basical industry (manufacturing, public service, etc.) does not change in the land market mechanism of the city as well as the Lowry model, therefore the distribution of them is given exogenously to the location choice model. Location choice target of firm locator is only the service industry (the number of non-basic employees), and their location choice will be performed according to the utility-maximizing behavior and the amount of location in each zone is determined.

6) One absentee landowner exists in each zone and supply land area for each use type according to utility-maximizing behavior, as a result, the land area by use type in each zone is determined. The developer in the zone will determine the floor area supply considering the designated floor area ratio for available land by use type. Floor market and land market by use type are represented. Floor rent is determined by the location demand against the fixed amount of floor supply. It is assumed that there is lower limit for floor rent so the vacant floor will be arisen in case of the floor rent by location demand is less than the lower limit. Land price is determined at the end of the team through the land supply and location demand and affects the land market for the next period.

7) Traffic model is basically a four-step estimation method same as the Person Trip Survey that is done throughout the country. In some cases, the feedback of time distance between the zones from route assignment model will be applied to the trip distribution and mode choice model. Among input data of transportation model, land-use by zone (population and employee distribution) is the output of land-use model for the present period. Moreover, time distance by mode between zones is inputted to land-use model for the next period as the traffic conditions.

2.3 Detailed design of Land-use model

2.3.1 Accessibility model

Accessibility model creates an accessibility index from the transportation results and the location distributions for the previous period as the transportation conditions in each zone. From a theoretical point of view, it is desirable to provide an average traffic resistance using a Log sum function as the expected maximum utility that is led by time distance by mode from the target zone to the destination zone. Although the amount of calculation in the simulation increases slightly, weighted average with the number of household and employees is used considering the reproducibility of the model.

$$ACC_{li} = \frac{\sum_j N_{lj}^{t-1} \exp(C_{ij}^{t-1})}{\sum_j N_{lj}^{t-1}} \tag{1}$$

$$C_{ij}^{t-1} = \ln\left\{\sum_k \exp(C_{kij}^{t-1})\right\} \tag{2}$$

ACC_{li} : Accessibility to locator l (household, employee etc) in zone i

C_{ij}^{t-1} : Average time distance between zone i and j for the previous period (Log sum value of each transportation use)

C_{kij}^{t-1} : Time distance between zone i and j by mode k for the previous period

N_{lj}^{t-1} : Number of locator l (household, employee etc) in zone j for the previous period

2.3.2 Land supply model

Available lands (Inhabitable land) in each zone are classified into three categories: industrial, commercial and residential, and supplied by absentee landlords. It is assumed that industrial land is determined exogenously and residential and commercial land is determined endogenously. The total area of residential and commercial land is constant and the rate of division will be determined according to the rent. Modeling of the behavior of absentee landlords in this model is determinant of the assignment rate of residential and commercial land. It is represented that absentee landlords identify the market trends and determine the land-use to maximize the utility of its own. Land supply model is modeled the utility-maximizing behavior of absentee landlords. The utility of the landlord from the land supply to each use type in zone i is represented as follows.

$$V_{gi} = \lambda R_{gi}^{T-1} + \sum_a \theta_g^{YR} \cdot YR_i^a \tag{3}$$

YR_i^a : Dummy variable of designed use a in zone i (exogenous)

R_{gi}^{T-1} : Land price for the previous period (residential or commercial) for use type g in zone i

λ, θ_g^{YR} : Parameter

Choice probability of land supply to use type g in zone i by absentee landlords is represented by the following logit model.

$$P_{gi} = \frac{\exp(\lambda V_{gi})}{\sum_{g'} \exp(\lambda V_{g'i})} \tag{4}$$

P_{gi} : Land supply rate by use type g in zone i

λ : Parameter

The amount of land supply for each use type and zone for the present period is calculated as follows, .adopting the probability of use type choice to exogenously given available land area for commercial and residential land.

$$L_{gi} = L_i \cdot P_{gi} \tag{5}$$

L_{gi} : Amount of land supply to use type g in zone i

L_i : Inhabitable land area for residential and commercial land in zone i (exogenous)

2.3.3 Floor supply model

It is assumed that floor by use type in each zone is provided by high usage the land which supplied by the absentee landlord in the range of designated floor area ratio. The filling rate for designated floor area ratio is defined as a function of land price for the previous period and the dummy variable of use zoning and represented as follows.

$$P_{gi}^{FAR} = \frac{1}{1 + \exp(-V_{gi})} \tag{6}$$

$$V_{gi} = \theta_g^R \cdot R_{gi}^{T-1} + \sum_a \theta_g^{YR^a} \cdot YR_i^a \tag{7}$$

P_{gi}^{FAR} : Filling rate for designated floor area ratio of use type g in zone i

YR_i^a : Dummy variable of use zoning a in zone i

R_{gi}^{T-1} : Land price for use type g (residential or commercial) in zone i for the previous period

$\theta_g^R, \theta_g^{YR^a}$: Parameter

The floor supply by each use type in each zone for the present period is calculated as follows, by applying the building coverage ratio, the designated floor area ratio and the filling rate for designated floor area ratio to the commercial and residential area.

$$FLS_{gi} = L_{gi} \times BAR_i \times FAR_i \times P_{gi}^{FAR} \tag{8}$$

FLS_{gi} : Floor supply to use type g in zone i

FAR_i : Designated floor area ratio in zone i (exogenous)

BAR_i : Building coverage ratio in zone i (exogenous)

The lower limit of floor rent is set to 10 % of land price for the previous period.

$$FR_{gi}^{\min} = 0.1 \times R_{gi}^{T-1} \tag{9}$$

$FR_{gi}^{\min}$: Lower limit of floor rent for use type g in zone i

R_{gi}^{T-1} : Land price for use type g in zone i for the previous period

2.3.4 Household type transition model

Change of household type, disappearance and generation of household in each zone are represented by applying the transition probability between household types for household distribution by type for the previous period. The transition probability is exogenously given from the sample of households.

$$NH_{li}^{T} = \sum_{l'} (N_{l''i}^{T-1} \cdot \mu_{l'l}) \ NH_{li}^{T} = \sum_{l'} (N_{l'i}^{T-1} \cdot \mu_{l'l}) \tag{10}$$

$$VH_{l'} = \sum_{i} \sum_{l'} (N_{l''i}^{T-1} \cdot \mu_{l''}^{V}) \tag{11}$$

$$GH_{l} = \sum_{i} \sum_{l'} (N_{l''i}^{T-1} \cdot \mu_{l''l}^{G}) \tag{12}$$

NH_{li}^{T} : Number of household of after transition type l in zone i

$VH_{l'}$: Number of disappear household of type l'

GH_{l} : Number of generated household of type l

$NH_{l'i}^{T-1}$: Number of household of type l' for the previous period

$\mu_{l'l}$: Household transition probability of type l' to l (exogenous)

$\mu_{l'}^{V}$: Household disappear probability of type l' (exogenous)

$\mu_{l'}^{G}$: Household generated probability of type l' for type l (exogenous)

2.3.5 Migration rate model

The number of migration households and the distribution of non-migration households are calculated by applying the exogenous reservation rate to post-transition household.

$$NH_{l}^{M} = \sum_{i} (N_{li}^{T} (1 - \eta_{l})) \tag{13}$$

$$NH_{li}^{NM} = N_{li}^{T} \cdot \eta_{l} \tag{14}$$

NH_{l}^{M} : Number of migration household of type l

NH_{li}^{NM} : Number of non-migration household of type l in zone i

η_{l} : Reservation rate of type l (exogenous)

2.3.6 Location choice target household adjustment

The difference of population by age is set up from the number of post-transition household, number of generated household and population by age in future as an urban flame as follows.

$$TNJ'_{h} = \sum_{l} (\sum_{i} N_{li}^{T} + GH_{l}) \cdot \kappa_{lh}) \tag{15}$$

$$\Delta TNJ_h = TNJ_h - TNJ'_h \tag{16}$$

TNJ'_h : Population by age h for post-transition and generated household

TNJ_h : Total population in urban area by age h for the present period (exogenous value: National Institute of Population and Social Security Research)

ΔTNJ_h : Adjusted Population by age h

κ_{lh} : Population conversion coefficient of type l for age h

Adjusted number of households by type for the error of population by age is calculated by the following iterative adjustment calculation.

1) Setting of initial adjusted values of household

$$\Delta NH_l = \frac{\sum_h \Delta TNJ_h}{TNJ'_h}(N_{li}^T + GH_l) \tag{17}$$

ΔNH_l : Number of adjusted households by type l

2) Calculation of adjusted population by household type and age for number of adjusted households

$$\Delta NJ_{lh} = \Delta NH_l \cdot \kappa_{lh} \tag{18}$$

ΔNJ_h : Adjusted population by household type l and age h

3) Calculation of adjusting coefficient by household type for number of adjusted households

$$\alpha_l = \sum_h \left(\Delta TNJ_h \cdot \frac{ABS(\Delta NJ_{lh})}{\sum_l ABS(\Delta NJ_{lh})} \right) / \sum_h \Delta NJ_{lh} \tag{19}$$

α_l : Adjusting coefficient for number of adjusted households by type l

4) Update of number of adjusted households

$$\Delta NH'_l = \begin{cases} NH_l^M + GH_l + \alpha_l \cdot \Delta NH_l \geq 0 \rightarrow \alpha_l \cdot \Delta NH_l \\ NH_l^M + GH_l + \alpha_l \cdot \Delta NH_l < 0 \rightarrow \Delta NH_l \end{cases} \tag{20}$$

$\Delta NH'_l$: Number of Updated adjusted households by type l

5) Repeat the computation process from 1) to 4) until $\Delta NH'_l = \Delta NH_l$ $(\alpha_l = 1)$ for all type l.

Location choice target household by type l is set by adding the number of adjusted households to the numbers of migration and generated households.

$$NH_l^C = NH_l^M + GH_l + \Delta NH_l \tag{21}$$

NH_l^C : Location Choice Target Household Adjustment by type l

2.3.7 Household location choice model

It is assumed that all household is resident or working within any zone in the urban areas and housing location behavior is formulated with the logit model based on random utility theory. Locational attractiveness of household in zone i is composed of deterministic term and stochastic term (cognitive error), as follows.

$$V_{li} = v_{li} + \varepsilon_{li} \tag{22}$$

V_{li} : Utility of household type l in the location zone i

v_{li} : Deterministic term (indirect utility function)

ε_{li} : Stochastic term (immeasurable coefficients)

Although the stochastic term ε_{li} is not observed specific coefficients for each household and observed as if it is a random, the household location choice probability for zone i is represented by the following logit model by assuming these random variables according to the Gumbel distribution.

$$P_{li}^{H} = \frac{\exp(\theta v_{li})}{\sum_{i}\exp(\theta v_{li})} = \frac{\exp(v_{li}[p_Z, \mathbf{ACC_{l'i}}, \mathbf{XT_i}, \mathbf{XZ_i}, RH_i, \Omega])}{\sum_{i}\exp(v_{li}[p_Z, \mathbf{ACC_{l'i}}, \mathbf{XT_i}, \mathbf{XZ_i}, RH_i, \Omega])} \tag{23}$$

P_{li}^{H} : Location choice probability of household type l for zone i

$\mathbf{ACC_{l'i}}$: Accessibility characteristic vector for locator l' in zone i

$\mathbf{XT_i}$: Transportation characteristic vector in zone i (except for accessibility)

$\mathbf{XZ_i}$: Non-transportation zonal characteristic vector in zone i (including average building age in zone i)

RH_i : Residential land price in zone i

p_Z : Composite price

Ω : Generalized disposable income

θ : Logit parameter

Residential floor rent is considered as important factors to make the choice. Employees (commuting convenience) and service employees (commercial convenience) seem to be appropriate targets of household accessibility which is calculated from the transportation conditions for the previous period.

Household indirect utility function is specified as follows.

$$v_{li} = \alpha'_{l1} p_Z + \boldsymbol{\alpha}'_{l2}\mathbf{ACC_{l'i}} + \boldsymbol{\alpha}'_{l3}\mathbf{XT_i} + \boldsymbol{\alpha}'_{l4}\mathbf{XZ_i} + \alpha'_{l5} RH_i + \alpha'_{l6}\Omega \tag{24}$$

$\alpha'_{l1}, \alpha'_{l5}, \alpha'_{l6}$: Parameters

$\boldsymbol{\alpha}'_{l2}, \boldsymbol{\alpha}'_{l3}, \boldsymbol{\alpha}'_{l4}$: Parameter Vectors

In explanatory variables of the indirect utility function above, composite price and generalized disposable income are assumed to be constant in each zone. Then, the composite price and the generalized disposable income are offset by the numerator and denominator of the formula, and transportation conditions, zonal land condition and land price is remain in the formula as the location choice factors as follows.

$$P_{li}^{H} = \frac{\exp(\alpha'_{l1} p_Z + \boldsymbol{\alpha}'_{l2}\mathbf{ACC_{l'i}} + \boldsymbol{\alpha}'_{l3}\mathbf{XT_i} + \boldsymbol{\alpha}'_{l4}\mathbf{XZ_i} + \alpha'_{l5} RH_i + \alpha'_{l6}\Omega)}{\sum_i \exp(\alpha'_{l1} p_Z + \boldsymbol{\alpha}'_{l2}\mathbf{ACC_{l'i}} + \boldsymbol{\alpha}'_{l3}\mathbf{XT_i} + \boldsymbol{\alpha}'_{l4}\mathbf{XZ_i} + \alpha'_{l5} RH_i + \alpha'_{l6}\Omega)}$$

$$= \frac{\exp(\alpha'_{l1} p_Z + \alpha'_{l6}\Omega)\exp(\boldsymbol{\alpha}'_{l2}\mathbf{ACC_{l'i}} + \boldsymbol{\alpha}'_{l3}\mathbf{XT_i} + \boldsymbol{\alpha}'_{l4}\mathbf{XZ_i} + \alpha'_{l5} RH_i)}{\exp(\alpha'_{l1} p_Z + \alpha'_{l6}\Omega)\sum_i \exp(\boldsymbol{\alpha}'_{l2}\mathbf{ACC_{l'i}} + \boldsymbol{\alpha}'_{l3}\mathbf{XT_i} + \boldsymbol{\alpha}'_{l4}\mathbf{XZ_i} + \alpha'_{l5} RH_i)}$$

$$= \frac{\exp(\boldsymbol{\alpha}_{l1}\mathbf{ACC_{l'i}} + \boldsymbol{\alpha}_{l2}\mathbf{XT_i} + \boldsymbol{\alpha}_{l3}\mathbf{XZ_i} + \alpha_{l4} RH_i)}{\sum_i \exp(\boldsymbol{\alpha}_{l1}\mathbf{ACC_{l'i}} + \boldsymbol{\alpha}_{l2}\mathbf{XT_i} + \boldsymbol{\alpha}_{l3}\mathbf{XZ_i} + \alpha_{l4} RH_i)} \tag{25}$$

$\boldsymbol{\alpha}_{l1}, \boldsymbol{\alpha}_{l2}, \boldsymbol{\alpha}_{l3}$: Parameter Vectors

α_{l4} : Parameter

where, if $RH_i < FR_{hi}^{\min}$ then $RH_i = FR_{hi}^{\min}$.

$FR_{hi}^{\min}$: Lower limit of residential floor rent in zone i

Number of locating household in each zone for the present period is given by adding the number of non-migration household to the number of location choice household that is given by applying location choice probability for the number of location choice target household.

$$NH_{li} = NH_l^C \cdot P_{li}^H + NH_{li}^{NM} \tag{26}$$

NH_{li} : Number of household by type l in zone i

Floor rent is given from floor supply area and total number of household in each zone as follows. Apply the given floor rent to equation (26), and keep computing to adjust until convergence with floor rent and number of residents,

$$NH_i = \sum_l NH_{li} \tag{27}$$

$$RH_i = \max(\omega^H \exp(-\varpi^H q_i^H), FR_{hi}^{\min}) \tag{28}$$

where, if $RH_i > FR_{gi}^{\min}$ then $q_i^H = \dfrac{FLS_i^H}{NH_i}$, and if $RH_i = FR_{hi}^{\min}$ then $q_i^H = -\dfrac{1}{\varpi^H} \cdot \ln\left(\dfrac{FR_{hi}^{\min}}{\omega^H}\right)$.

NH_i : Number of household in zone i

RH_i : Residential floor rent in zone i

q_i^H : Consumed floor area per household in zone i (endogenous)

FLS_i^H : Residential floor supply area in zone i

$FR_{hi}^{\min}$: Lower limit of residential floor rent in zone i

ω^H, ϖ^H : Parameters

2.3.8 Population conversion model

Population distribution is calculated by applying conversion coefficient of population to household distribution as follows.

$$NJ_{hi} = \sum_l (NH_{li} \cdot \kappa_{lh}) \tag{29}$$

NJ_{hi} : Population by age h in zone i

κ_{lh} : Conversion coefficient of population for age h of type l

2.3.9 Firm location choice model

The number of employees which is the target of location choice behavior is only subject to service employees. Total number of employees, the employee distribution of basical industry and number of employees of large-scale retail stores for the present period are given exogenously. Therefore, total number of service employee (except for large-scale retail stores) distribution to each zones is only considered in the location choice behavior,.

$$TNJ = TNS + \sum_i NB_i \tag{30}$$

$$NB_i = NA_i + NI_i + NCB_i + NSB_i \tag{31}$$

TNJ : Total number of employees (exogenous)

TNS : Total number of service employee (except for large-scale retail stores)

NB_i : Number of employees in basical industry in zone i (exogenous)

NA_i : Number of employees in primary industry in zone i (exogenous)

NI_i : Number of employees in secondary industry in zone i (exogenous)

NCB_i : Number of employees in tertiary industry excepting service employees (included basical industry) in zone i (exogenous)

NSB_i : Number of employees in large-scale retail stores in zone i (exogenous)

Also in firm location choice model, locational attractiveness to the zone i is composed with deterministic and stochastic terms, as well as the household.

$$\Pi_i = \pi_i + \varepsilon_i \tag{32}$$

π_i : Utility of firms by location in zone i

ν_i : Deterministic term (indirect utility function)

ε_i : Stochastic term (immeasurable factors)

Although the stochastic term ε_{li} is not observed specific coefficients for each firm and observed as if it is a random, the firm location choice probability for zone i is represented by the following logit model as follows.

$$P_i^S = \frac{\exp(\theta\pi_i)}{\sum_i \exp(\theta\pi_i)} = \frac{\exp(\pi_i[p_Z, \mathbf{ACC_{li}}, \mathbf{XT_i}, \mathbf{XZ_i}, RC_i, G])}{\sum_i \exp(\pi_i[p_Z, \mathbf{ACC_{li}}, \mathbf{XT_i}, \mathbf{XZ_i}, RC_i, G])} \tag{33}$$

P_i^S : Location choice probability of firm (employees) in zone i

$\mathbf{ACC_{li}}$: Accessibility characteristic vector for locator l in zone i

$\mathbf{XT_i}$: Transportation characteristic vector in zone i (except for accessibility)

$\mathbf{XZ_i}$: Non-transportation zonal characteristic vector in zone i (including average building age in zone i)

RC_i : Commercial land price in zone i

p_Z : Composite price

G : lump sum asset tax for private enterprise

θ : Logit parameter

Commercial floor rent is considered as important factors to make the choice. Population (customer attractiveness) and service employees (agglomeration preference of service industry) seem to be appropriate targets of firm accessibility which is calculated from the transportation conditions for the previous period

Firm (employees) indirect utility function is specified as follows.

$$\pi_i = \beta'_1 p_Z + \boldsymbol{\beta'_2}\mathbf{ACC_{li}} + \boldsymbol{\beta'_3}\mathbf{XT_i} + \boldsymbol{\beta'_4}\mathbf{XZ_i} + \beta'_5 RC_i + \beta'_6 G \tag{34}$$

$\beta'_1, \beta'_5, \beta'_6$: Parameters

$\boldsymbol{\beta'_2}, \boldsymbol{\beta'_3}, \boldsymbol{\beta'_4}$: Parameter Vectors

In explanatory variables of the indirect utility function above, composite price and the lump sum asset tax are assumed to be constant in each zone. Then, the composite price and the lump sum asset tax are offset by the numerator and denominator of the formula, and transportation conditions, zonal land condition and land price is remain in the formula as the location choice factors by the following equation,

$$\begin{aligned} P_i^S &= \frac{\exp(\beta'_1 p_Z + \boldsymbol{\beta'_2}\mathbf{ACC_{li}} + \boldsymbol{\beta'_3}\mathbf{XT_i} + \boldsymbol{\beta'_4}\mathbf{XZ_i} + \beta'_5 RC_i + \beta'_6 G)}{\sum_i \exp(\beta'_1 p_Z + \boldsymbol{\beta'_2}\mathbf{ACC_{li}} + \boldsymbol{\beta'_3}\mathbf{XT_i} + \boldsymbol{\beta'_4}\mathbf{XZ_i} + \beta'_5 RC_i + \beta'_6 G)} \\ &= \frac{\exp(\beta'_1 p_Z + \alpha'_6 G)\exp(\boldsymbol{\beta'_2}\mathbf{ACC_{li}} + \boldsymbol{\beta'_3}\mathbf{XT_i} + \boldsymbol{\beta'_4}\mathbf{XZ_i} + \beta'_5 RC_i)}{\exp(\beta'_1 p_Z + \alpha'_6 G)\sum_i \exp(\boldsymbol{\beta'_2}\mathbf{ACC_{li}} + \boldsymbol{\beta'_3}\mathbf{XT_i} + \boldsymbol{\beta'_4}\mathbf{XZ_i} + \beta'_5 RC_i)} \\ &= \frac{\exp(\boldsymbol{\beta_1}\mathbf{ACC_{li}} + \boldsymbol{\beta_2}\mathbf{XT_i} + \boldsymbol{\beta_3}\mathbf{XZ_i} + \beta_4 RC_i)}{\sum_i \exp(\boldsymbol{\beta_1}\mathbf{ACC_{li}} + \boldsymbol{\beta'_2}\mathbf{XT_i} + \boldsymbol{\beta_3}\mathbf{XZ_i} + \beta_4 RC_i)} \end{aligned} \tag{35}$$

$\boldsymbol{\beta_1}, \boldsymbol{\beta_2}, \boldsymbol{\beta_3}$: Parameter vectors

β_4 : Parameter

where, if $RC_i < FR_{ci}^{\min}$ then $RC_i = FR_{ci}^{\min}$.

$FR_{ci}^{\min}$: Lower limit of commercial floor rent in zone i

Number of locating service employees for each zone is given by applying the location choice probability for the total number of service employees.

$$NS_i = TNS \cdot P_i^S \tag{36}$$

NS_i : Number of service employees in zone i

Number of commercial employees (tertiary industry) for each zone is given by adding their distribution to the number of employees in tertiary industry excepting for service employees that are exogenously given.

$$NC_i = NS_i + NCB_i \tag{37}$$

NC_i : Number of commercial employees in zone i

Floor rent is given from floor supply area and total number of commercial employees as follows. Apply the given floor rent to equation (37), and keep computing to adjust until convergence with floor rent and number of residents.

$$RC_i = \max(\omega^C \exp(-\varpi^C q_i^C), FR_{ci}^{\min}) \tag{38}$$

where, if $RC_i > FR_{ci}^{\min}$ then $q_i^C = \dfrac{FLS_i^C}{NC_i}$, and if $RC_i = FR_{ci}^{\min}$ then $q_i^C = -\dfrac{1}{\varpi^C} \cdot \ln\left(\dfrac{FR_{ci}^{\min}}{\omega^C}\right)$.

NC_i : Number of commercial employees in zone i

RC_i : Commercial floor rent in zone i

q_i^C : Consumed floor area per employee in zone i (endogenous)

FLS_i^C : Commercial floor supply area in zone i

$FR_{ci}^{\min}$: Lower limit of commercial floor rent in zone i

ω^C, ϖ^C : Parameter

2.3.10 Land price model

Land price is determined by land price function that consider the result of location distribution in the end of the term. It is not adopted that the transformation method in which locator's land demand and landlord's land supply is adjusted through the land price. Then the land price structure in market is determined by consumed land area per capita as an explanatory variable as follows. Therefore, , the structure change consisted of the land supply-demand balance and land price is considered endogenously in the model.

$$R_{gi} = \omega_g \exp(-\varpi_g q_{gi} + c) \tag{39}$$

$$q_{gi} = \frac{L_{gi}}{N_{gi}} \tag{40}$$

R_{gi} : Land price for use type g (residential, commercial) in zone i

q_{gi} : Consumed land area per capita by use type g in zone i

L_{gi} : Land supply area by use type g in zone i

$N_{gi} = \{NH_i, NC_i\}$: Number of locator by use type g in zone i (number of households, number of commercial employees)

ω_g, ϖ_g, c : Parameter

2.4 Detail design of Transportation model

2.4.1 Trip generation model

Production trip is the total trip (zone inside and zone inside-outside) from people who live in the target area by the locators who live in the zone. Generally, it is estimated by purpose (commuting, school, private affairs, business, and go home) using the method of trip production rate as follows. The total population in target area by attribute category (according to state of commuting work and school, employment sector and licenses holding etc.) is given exogenously because of being assumed Closed City here.

$$T_m = \sum_l \alpha_{ml} X_l \tag{41}$$

T_m : Production trip of purpose m

X_l : Population of attribute category l

α_{ml} : Trip production rate of purpose m in attribute category l

Generation and attraction trip in each zone is basically estimated by linear multiple regression model for different purposes using population, number of employees and so on. The output of Land use model is used for the population and the number of employees by industry.

$$GT_{im} = \alpha_{m0} + \sum_l \alpha_{ml} X_{li}, AT_{im} = \beta_{m0} + \sum_l \beta_{ml} Y_{li} \tag{42}$$

GT_{im} : Generation trip of purpose m in zone i

AT_{jm} : Attraction trip of purpose m in zone j

X_{li} : Population of attribute category l (set by employment condition and sector etc.) in zone i

Y_{li} : Number of employees of attribute category l (set by industry sector etc.) in zone i

$\alpha_{m0}, \alpha_{ml}, \beta_{m0}, \beta_{ml}$: Parameter

2.4.2 Trip distribution model

Trip distribution model estimate the OD trip. There are many kind of models in Trip distribution model, such as Present pattern model, Gravity model and Probability model. The following equations show the Gravity model method which is often used generally.

$$Q_{ijm} = \gamma_m \cdot GT_{im}^{\alpha_m} \cdot AT_{jm}^{\beta_m} \cdot f(c_{ij}) \tag{43}$$

Q_{jim} OD trip of purpose m between zone i and j

GT_{im} : Generation trip of purpose m from zone i

AT_{jm} : Attraction trip of purpose m to zone j

c_{ij} : Time distance or generalized trip cost between zone i and j

$\gamma_m, \alpha_m, \beta_m$: Parameters

$f(c_{ij})$ is the function that represent a spatial distance between zone i and j. In general, following power type, exponential type and Turner type etc. are used.

Power type $f(c_{ij}) = c_{ij}^{-\lambda}$ (44)

Exponential type $f(c_{ij}) = \exp(-\lambda c_{ij})$ (45)

Turner type $f(c_{ij}) = c_{ij}^{\theta} \exp(-\lambda c_{ij})$ (46)

c_{ij} : Time distance or generalized trip cost between zone i and j

λ, θ : Parameter

c_{ij} is a generalized trip cost or time distance between zone i and j. Without performing feedback time distance of Trip distribution model, the weighted average of generalized trip cost processed by present time distance is used. When performing feedback, the weighted average value processed by estimated result of trip distribution is used.

2.4.3 Mode choice model

1) Summery of Model

Mode choice model predict the OD trip by transit mode, in which the OD table by purpose that estimated in Trip distribution model are shared to each transit mode. The table below shows an example of segment of a representative transportation in the mode choice model.

Table 2. Example of segmentation of a representative traffic mode

Model segmentation	Walk, Bicycle	Car	Bus	Railway
Traffic Mode	Walk, Bicycle, Motor cycle	Light automobile, Automobile	Bus	Automated guideway transit, Monorail, Subway, Railway

2) Zone inside mode choice

The present modal share is usually used for the zone inside mode choice because it is considered that the hardness to calculate the time distance in next step of traffic assignment, the difficulty to specify the reason of zone inside mode choice, and no influence of modal share by infrastructure development.

3) Zone inside-outside mode choice

The zone inside-outside mode choice is mostly modeled by the aggregate logit model in which a service level for each mode choice (time distance or cost) is used as the explanatory variables. There are several models, for example, Binary choice model divides the mode choice into two stages stepwise assuming the choice structure, Multi choice model estimates the trip mode choice at one time, and Mixed model is the mixture of those two. The following figure shows an example of the selection structure assumed by each model.

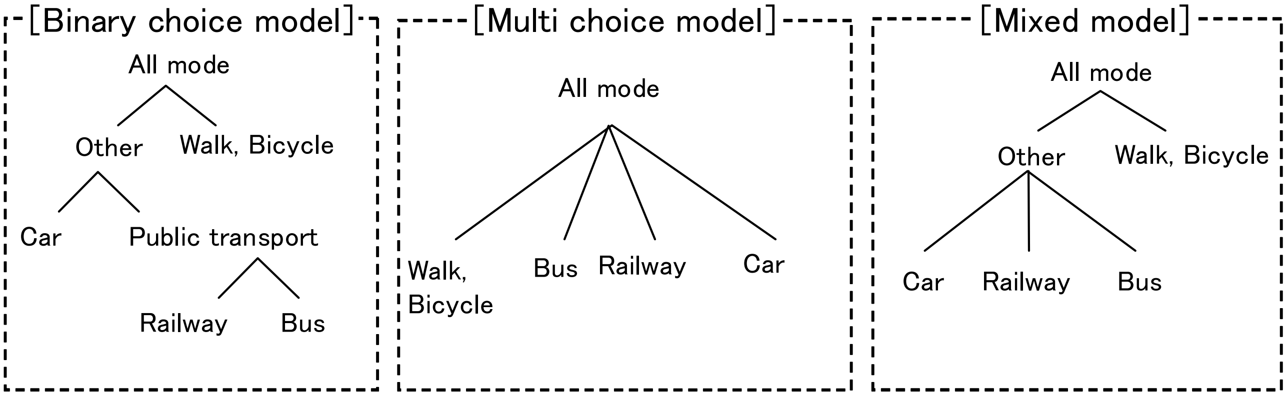

Figure 5. Example of choice structure assumption

In these models, the modal share is calculated for each stage and the trip mode is chosen step by step. The modal share of Binary choice model and Multi choice model can be formulated as follows.

[Binary choice model]

$$P_{ij}^{1} = \frac{\exp(V_{ij}^{1})}{\exp(V_{ij}^{1}) + \exp(V_{ij}^{2})} \quad (47)$$

$$P_{ij}^{2} = 1 - P_{ij}^{1} \quad (48)$$

$$V_{ij}^{1} = \alpha t_{ij}^{1} + \sum_{h} \beta_{h}^{1} TX_{ijh}^{1} + c \quad (49)$$

$$V_{ij}^{2} = \alpha t_{ij}^{2} + \sum_{h} \beta_{h}^{2} TX_{ijh}^{2} \quad (50)$$

P_{ij}^{1}, P_{ij}^{2} : Mode choice probability of mode 1 and 2 between zone i and j

V_{ij}^{1}, V_{ij}^{2} : Utility of mode 1 and 2 between zone i and j

t_{ij}^{1}, t_{ij}^{2} : Time distance of mode 1 and 2 between zone i and j

$TX_{ijh}^{1}, TX_{ijh}^{2}$: Explanatory variable of choice factor h (cost, access and egress time, distance, station density, and so on) except for time distance of mode 1 and 2 between zone i and j

$\alpha, \beta_{h}^{1}, \beta_{h}^{2}, c$: Parameters

[Multi choice model]

$$P_{ij}^{k} = \frac{\exp(V_{ij}^{k})}{\sum_{k'} \exp(V_{ij}^{k'})} \quad (51)$$

$$V_{ij}^{k} = \alpha t_{ij}^{k} + \sum_{h} \beta_{h}^{k} TX_{ijh}^{k} + c^{k} \quad (52)$$

P_{ij}^{k} : Mode choice probability of mode $k (\in k')$ between zone i and j

V_{ij}^{k} : Utility of mode k between zone i and j

t_{ij}^{k} : Time distance of mode k between zone i and j

TX_{ijh}^{k} : Explanatory variable of choice factor h (cost, access and egress time, distance, station density, and so on) except for time distance of mode k between zone i and j

α, β_h^k, c^k : Parameter

2.4.4 Route assignment model

In the route assignment model, OD trip is assigned to network by transit such as railway, bus and car. The incremental assignment method with QV equation and user equilibrium assignment is used in this assignment model. The user equilibrium allocation model represents a steady state in which any user can not reduce the cost to change the route by him and this is the extended theory of Wardrop equilibrium. In recent years, Person Trip Survey uses this model in many scenes. The assignment calculation is carried out with schemes that correspond to the challenges of public transport planning in each urban area. For the calculation, the Railway route selection model and the model which assign the trip to shortest route considering the bus network etc is mainly used.

2.5 Data availability

The data sources and model parameter setting methods used in each sub-models are following.

1) Accessibility Model

- Population distribution by age

  The Population distribution which is aggregated by age and zone is obtained from the Basic Resident Register and small area statistics of Census.

- Household distribution by type

  Household distribution which is aggregated by type is obtained from the Basic Resident Register and small area statistics of Census. The estimation is needed by IPF method or Monte Carlo sampling method when the household type of Census is limited and different from that for the sub-models. In that case, the accuracy of the estimation is improved by the aid of individual households sample of questionnaires survey.

- Employee distribution by industry

  Employee distribution is obtained by aggregation by sector that corresponded to set and the aggregate value from firm survey is available to be used.

2) Land supply model

- Land price by use type

  Land price by use type is obtained from the Notice of land prices, land prices point data of land prices survey and roadside land prices data. It is necessary to estimate and complement in the case of no land price point exist for setting zone because land price point density decrease in the suburban.

- Inhabitable land area, Land area by use type

  Inhabitable land area and land area by use type is obtained from the site area by use type of Basic City Planning Survey.

- Land supply model parameter

  Land supply model parameter is estimated and set corresponding to model equation from land price by use type, use zoning dummy and land area by use type

3) Floor supply model

- Designated floor area ratio, Building coverage ratio, Use zoning dummy

  Those are set from use zoning data in Basic City Planning Survey. It is set that designated floor area ratio, building coverage ratio and use zoning dummy of the typical zone. Otherwise, if the data are available in the detailed zone, designated floor area ratio and building coverage ratio are weighted by use zoning area and set as the zone weighted average.

- Floor area by use type

  Floor area by use type is aggregated from floor area of Basic City Planning Survey and set.

・Floor supply model parameter

Floor supply model parameter is estimated and set from floor area by use type, land area by use type and building coverage ratio.

4) Household Type transition Model

・Household type transition probability

The parameters are set by repeating the Monte Carlo simulation until the probability convergence in which the probability of occurrence of the individual life event (age, death, birth, marriage, leaving home, etc.) from existing statics is applied to the sample of households that include the information about the family members of the household obtained from such as questionnaires.

5) Migration Rate Model

・Reservation rate by household type

Reservation rate by household type is obtained from parameter estimation with migration household within period obtained from such as questionnaires.

6) Number of Location Choice Target Households

・Total population by age

Total population by age is obtained from Census and the Population projection of National Institute of Population and Social Security Research.

・Population conversion coefficient

Population conversion coefficient is set as the parameter that given by calculation the population distribution by age that consists of each household type from household sample.

7) Household Location Choice Model

・Household location choice model parameter

Household location choice model parameter is estimated by extraction of migration household within period obtained from such as questionnaires and using the parameter that is both results and reasons of zone selection for disaggregate sample from present residence to extract.

8) Population Conversion

・Population distribution by age

Population distribution by age is obtained from Census.

9) Firm Location Choice Model

・Total of employee (by sector)

It is available to use the aggregate value from firm survey.

・Firm location choice model parameter

Firm location choice model parameter is obtained by estimating in which the estimated parameter of number of commercial employees parameter to each zones are processed with the results and reasons of zone selection for aggregated sample as the parameter.

10) Land Price Model

・Land price model parameter

Land price model parameter is set by estimating from the number of locator and the land area in each zone.

11) Trip Generation Model

・Trip production rate

Trip production rate is set from trip generation status in person sample of Person trip survey.

12) Trip Distribution Model

・Distribution trip by purpose

Distribution trip by purpose is obtained by using the OD data by purpose of Person trip survey.

・Trip Distribution Model parameter

Trip distribution model parameter is obtained by using the distribution trip by purpose and time distance between zones etc. of Person trip survey.

13) Mode Choice Model

・Modal share

Modal share is obtained by using the OD data by purpose of Person trip survey.

・Transit mode choice model parameter

Transit mode choice model parameter is estimated by using OD trip by purpose, time distance between zones and the cost data etc. of Person trip survey.

14) Route Assignment Model

・Road network

Road network is prepared from DRM (Digital Road Map).

・Public transport network and cost etc.

Public transport network and cost etc. is prepared from the route map and the price list etc.

2.6 Parameter estimation method

The estimation method for the parameters of each sub-model is shown as follows. Parameter estimation is performed using a database that is based on specific year.

1) Land supply model

Logit model parameters for the use zoning dummy variables and land price by use type in previous term are estimated by maximum likelihood estimation using the each zone as sample. Ratio of land supply by use type is set by inhabitable land area and land area by use type. The residential land price and the commercial land price from the Officially Published Land Price are used as the land price by use type. Basic City Planning Survey data is used for inhabitable land area, land area by use type, and use zoning.

2) Floor supply model

Logit model parameters for the use zoning dummy variables and land price by use type in previous term is estimated by maximum likelihood estimation using the each zone as sample. The filling rate for designated floor area ratio is set by land area by use type and the floor capacity by use type that calculated from land area by use type, building coverage ratio, and designated floor area ratio. The residential land price and the commercial land price from the Officially Published Land Price are used as the land price by use type. Basic City Planning Survey data is used for Land area by use type, building coverage ratio, designated floor area ratio, and use zoning.

3) Household Type transition Model

The probability parameter of type transition, generation, and disappear in Household type transition model is estimated by the micro-simulation using the disaggregate sample households including the information of household members. The household type of 5 years later is determined by repeating the micro simulation until the transition probability convergence in which the marriage rate by age, the birth rate by age, and death rate by age is applied to each member of the disaggregate household sample. The disaggregated households and the members sample are prepared from Person Trip survey. The marriage rate, the birth rate, and death rate is obtained from the Health Statistics Yearbook.

4) Migration Rate Model

The reservation rate by household type of migration rate model is obtained by using the disaggregate household sample. The reservation rate by household type for 5 years is set by aggregating the residential period in previous residence of disaggregate household sample. The disaggregate household sample is obtained from the questionnaire survey.

5) Location Choice Target Household Adjustment and Population Conversion

The Population conversion coefficient of location choice target household adjustment and population conversion is set by using the disaggregate sample household including the information of household members. The Population conversion coefficient by household type and age is set from the age and the type of the disaggregate sample household member. The disaggregated household member sample is prepared by using the survey paper of the Person Trip survey.

6) Household Location Choice Model

The upper limit of floor rent parameter of floor rent function for Household Location Choice Model is set exogenously. And the parameter for consumed floor capacity per household is estimated by setting the consumed floor capacity per household from floor area by use type and the amount of number of locators by use type. The parameter for zonal traffic and land-use attribute (accessibility etc) in utility function is estimated by using the disaggregate household sample. The Parameters are estimated by setting the zone selection probability of extracted sample that is the migration household sample for 5 years from the residential period in previous residence of disaggregate household sample. The accessibility is prepared by inputting the present time distance between zones by transportation model to accessibility model. The transportation characters in each zone are prepared from transportation model output or traffic facility data. The zonal character except for transportation is prepared from Basic City Planning Survey data and city planning map etc. The amount of residential floor supply is obtained from Basic City Planning Survey data. The residential floor rent is set in consideration of the realized floor area ratio capacity ratio that is calculated by the land price of the Officially Published Land Price and the residential land area and residential floor capacity of Basic City Planning Survey. The consumed floor capacity by household type is set by the residential floor capacity of the Basic City Planning Survey and the number of household by type of the Census. The probability of household location choice by type is obtained from the questionnaire survey.

7) Firm Location Choice Model

The upper limit of floor rent parameter of floor rent function for Commercial Location Choice Model is set exogenously. And the parameter for consumed floor area per employee is estimated by setting the consumed floor area per employee from floor area by use type and the amount of number of locators by use type. The parameter for zonal traffic and land-use attribute (accessibility etc) in utility function is estimated by setting the probability of location zone choice from the commercial employee distribution. The accessibility is prepared by inputting the present time distance between zones by transportation model to accessibility model. The transportation character in each zone is prepared from transportation model output or traffic facility data. The zonal character except for transportation is prepared from Basic City Planning Survey data and city planning map etc. The amount of commercial floor supply is obtained from Basic City Planning Survey data. The commercial floor rent is set in consideration of the floor capacity ratio that is calculated by the land price of the Officially Published Land Price and the commercial location area and commercial floor capacity of Basic City Planning Survey. The consumed floor capacity by employee is set by the commercial floor capacity of Basic City Planning Survey. and the number of commercial employee by type of the Statistics on Business. The probability of location zone choice is prepared from the commercial employee distribution of the Statistics on Business.

8) Land Price Model

The upper limit of floor rent parameter is set exogenously from data. And the parameter for consumed land area per locator is estimated by setting the consumed land area per locator from Land area by use type and the amount of number of locators by use type. The Land area by use type is obtained from Basic City Planning Survey data. The number of household by type is obtained from the Census and the number of commercial employee by type is obtained from the Statistics on Business. The Land price by use type is obtained from the residential and commercial land price of the Officially Published Land Price.

9) Trip Production, Generation and Attraction Model

The trip rate of trip production, generation and attraction is set by the trip production status of person sample. The parameter for the population by attribute and the number of employee by industry is set by using generation and attraction trip of the Person Trip survey. The population by attribute is obtained from the Census and the number of employee by industry is obtained from the data of Statistics on Business. The Generation and attraction trip by purpose is obtained from the Person Trip survey.

10) Trip Distribution Model

The parameter of trip distribution model is estimated from generation and attraction trip, and OD trip, present time distance between zones. The Generation and attraction trip by purpose and OD trip by purpose is obtained from the Person Trip survey. The time distance between zones is prepared from Route assignment model.

11) Mode Choice Model

The parameter of mode choice model is set in consideration of the mode choice factor such as present time distance between zones and cost for the present modal share which prepared from OD trip by purpose. The OD trip by purpose and OD trip by mode is obtained from the Person Trip survey. The time distance between zones by mode is prepared from route assignment model. Another mode choice factor is prepared from traffic facility data.

12) Route Assignment Model

For the car route assignment model, the parameters are set one by one such as road type and structure. The parameters are set arbitrarily considering of the walk speed and vehicle speed for walk, bus and tram, and railway.

3. Zone-size Transformation Tool

3.1 Outline and composition of Zone-size Transform Tool

3.1.1 Necessity of zone-size transformation

The method to set a large zone-size to contain all zone sizes, such as for land-use condition setting, or land-use and transportation analysis, is stable for predicting the broad trends of urban structure. However, as shown in Figure 6, sometimes the PT small zone is different from that of Basic City Planning Survey zone especially in regional cities. Therefore, in Policy making, there are several problems such as the limitation (e.g. difficulty to introduce a land use policy immediately etc) or the shortage of sufficiency for sensitivity.

The Zone-size Transformational Tool provide a mechanism that can handle the case of the zone-size for land-use is different from that of transportation. This tool is so useful to correspond to applying more detailed policy (e.g. land-use related policies such as residential measure for city core or boundary line making) than zone-size for analysis.

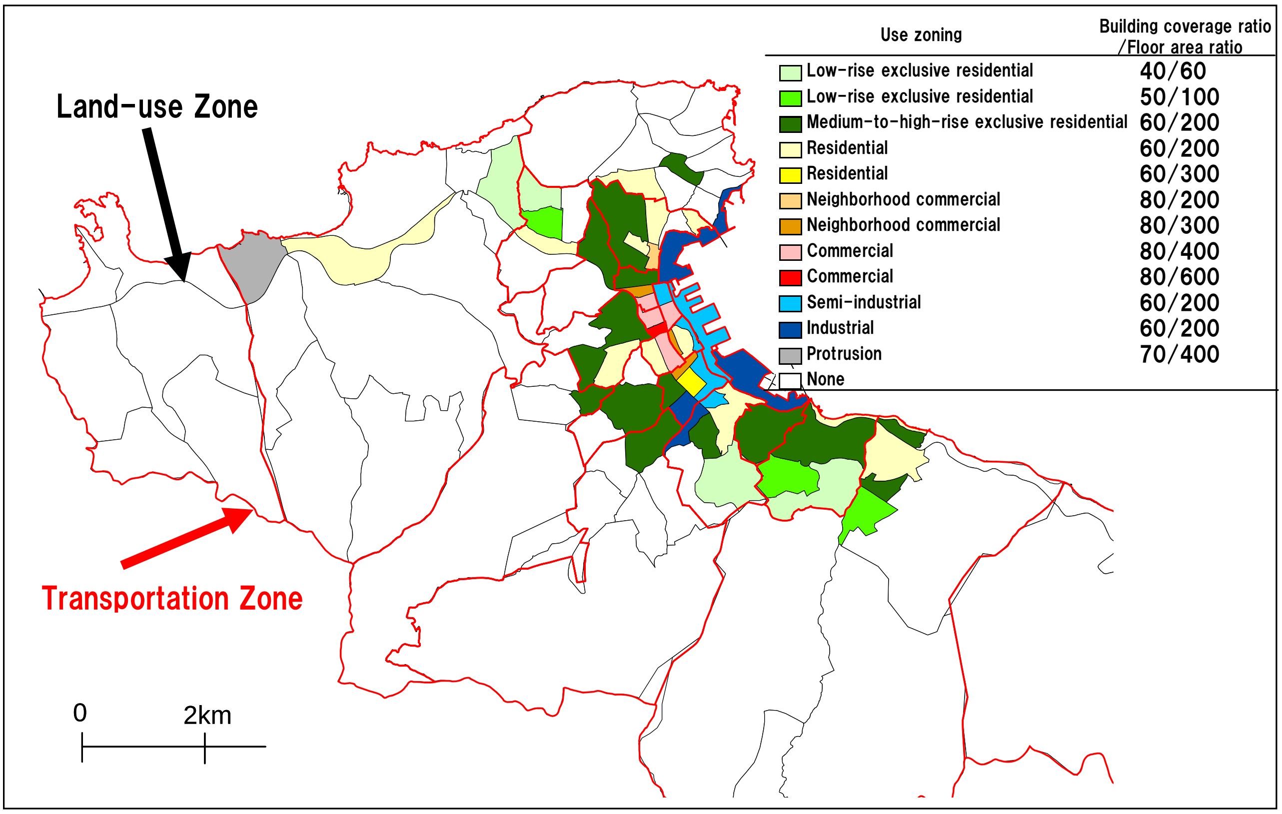

Figure 6. Example of Land Use Zones and Transportation Zones

3.1.2 Classification and generalization of zone-size transformation

As the zone of the Future Urban Structure Estimation model, it can be set arbitrarily that 3 zones to analyze, Land-Use Measure Zone, Land-Use Analysis Zone, and Transportation Analysis Zone and 1 kind of transportation network. Two kind of zone shape, Land-Use Measure Zone, Land-Use Analysis Zone, are set as the Land-use zone, because if the zone for measure input and result output is relatively small, the model analysis may be difficult according to the calibration or the calculation execution. Transportation measure is inputted for the transportation network and is intended only for transportation analysis zone in which the traffic volume and time distance between OD is regulated. Those above are required in view of the specification of the model, but also mean complexity of the model. Then, when the zones used in the Future Urban Structure Estimation Model are organized, the required Zone-size Transformational functions are 7 cases as follows and shown in Figure 7.

・Process in inputting the measures to model (Batch processing the multiple annual)

(1) Conversion from Land-Use Measure Zone to Land-Use Analysis Zone

Convert the data about Land-Use Measure such as use zoning, floor area ratio, inhabitable land area to the analysis unit of land-use model.

(2) Conversion from Land-Use Measure Zone to Transportation Analysis Zone

Convert the Land area by use type and student distribution to the analysis unit of transportation model.

・Repetitive process for each year in running the model simulation

(3) Conversion from Transportation Network to Land-use Analysis Zone

Convert the time distance between zones to the analysis unit of land-use model.

(4) Conversion from Land-use Analysis Zone to Transportation Analysis Zone

Convert the population, number of employees by use type to the analysis unit of transportation model.

・Process in outputting (Batch processing the multiple annual)

(5) Conversion from Land-use Analysis Zone to Land-use Measure Zone

Convert the analysis results by land-use model such as number of household, population, number of employees, land area, and land price, to output per Land-use Measure zone.

(6) Conversion from Transportation Analysis Zone to Land-use Measure Zone

Convert the analysis results of OD traffic volume by transportation model to output per Land-use Measure zone.

(7) Conversion from Transportation Network to Land-use Measure Zone

Convert the time distance between zones of transportation model to output per Land-use Measure zone.

Based on the above, the zone-size transformational case that corresponds to the input and output of each model of land use and transportation in the Future Urban Structure Estimation model is determined. Table 3 shows the zone-size transformation cases and functions

In the case except for (7) which is a process with the network, the generalization for each case are developed as shown in Figure 8, because it is rare that the spatial including relation between the different zone size is guaranteed, and to correspond these situation, the intermediate zone which take the spatial difference in each zone is configured. Furthermore, since the flattening process that is required during the conversion zone is different by data types (aggregate value, continuous property value, discrete property value), then the distribution indicator especially in distributed processing is examined. Through these studies, the Zone-size Transformational Tool is developed and implemented as the function of Future Urban Structure Estimation Model to correspond to each transformational case.

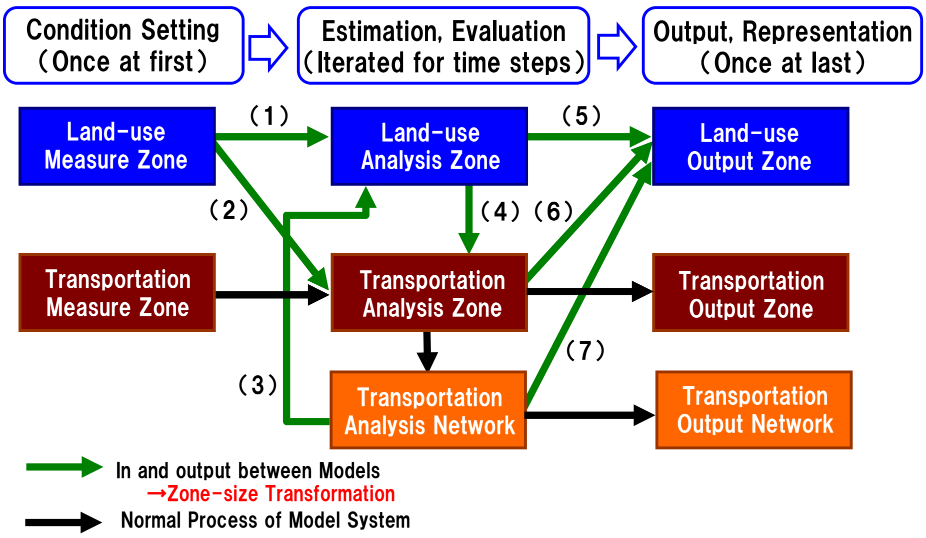

Figure 7. Zone-size Transformation cases

Table 3. Zone-size Transformation cases and functions

A. Process in inputting the measures to model (Batch processing the multiple annual)		
	(1) Conversion from Land-Use Measure Zone to Land-Use Analysis Zone	Convert the data about Land-Use Measure such as use zoning, floor area ratio, inhabitable land area to the analysis unit of land-use model.
	(2) Conversion from Land-Use Measure Zone to Transportation Analysis Zone	Convert the Land area by use type and student distribution to the analysis unit of transportation model.
B. Repetitive process for each year in running the model simulation		
	(3) Conversion from Transportation Network to Land-use Analysis Zone	Convert the time distance between zones to the analysis unit of land-use model.
	(4) Conversion from Land-use Analysis Zone to Transportation Analysis Zone	Convert the population, number of employees by use type to the analysis unit of transportation model.
C. Process in outputting (Batch processing the multiple annual)		
	(5) Conversion from Land-use Analysis Zone to Land-use Measure Zone	Convert the analysis results by land-use model such as number of household, population, number of employees, land area, and land price, to output per Land-use Measure zone.
	(6) Conversion from Transportation Analysis Zone to Land-use Measure Zone	Convert the analysis results of OD traffic volume by transportation model to output per Land-use Measure zone.
	(7) Conversion from Transportation Network to Land-use Measure Zone	Convert the time distance between zones of transportation model to output per Land-use Measure zone

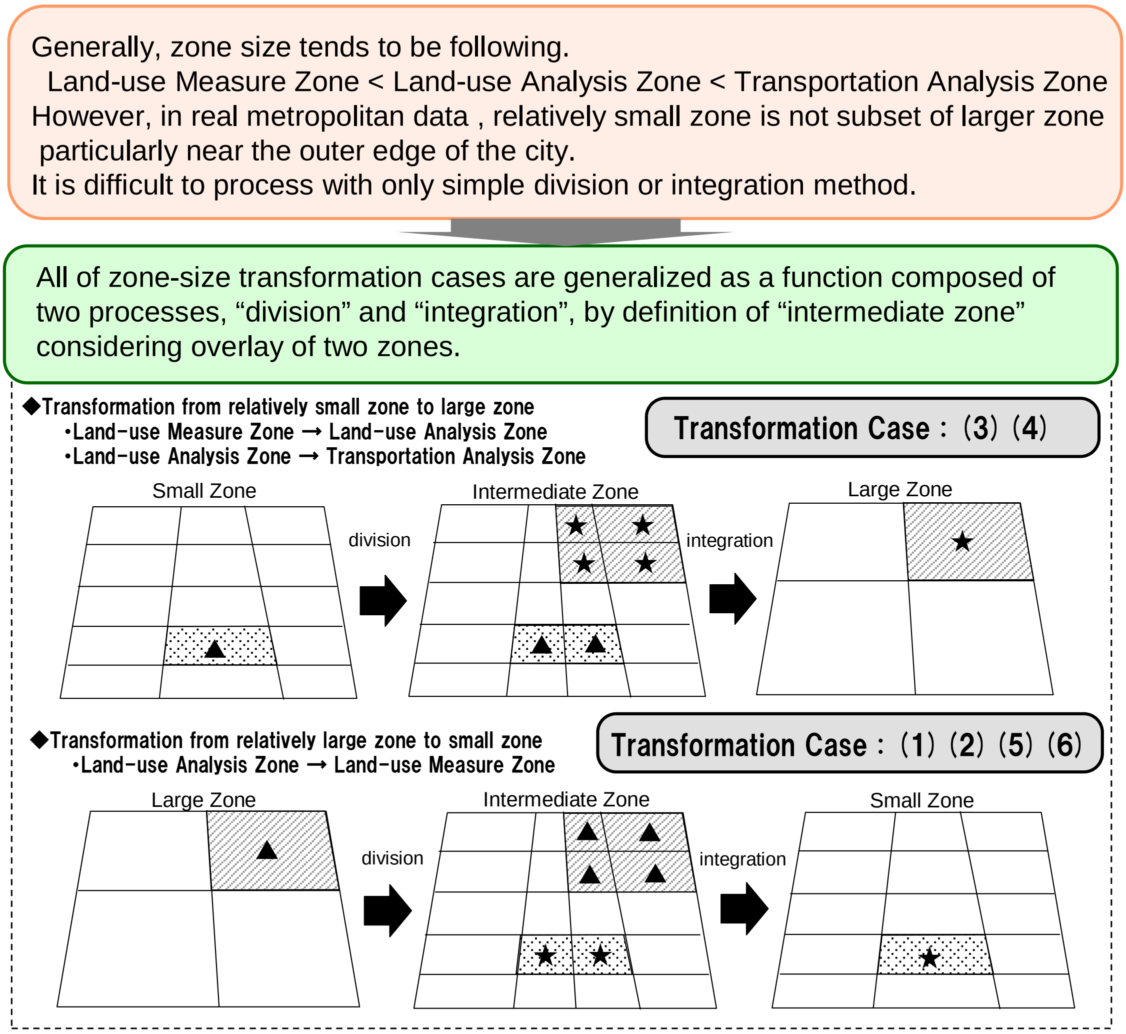

Figure 8. Consideration of intermediate zone to Zone-size Transformation

3.2 Detail of the designation for Zone-size Transformation Tool

3.2.1 Target data and transformation process

The target data flattening process that is required during the conversion zone is different from each other by the data types (aggregate value, continuous property value, discrete property value). In the process of the zone-size transformation from transportation to land-use analysis, the other processing function (route search on the network) that is different from the generalized process of zone-size transformation, because the zone data is developed from the network The process type of what can be a target data of the handled by Future Urban Structure Estimation Model is organized as Table 4 to 6.

Table 4. Target data and process type of each transformation case (1)

・Case(1): Land–Use Measure Zone to Land–Use Analysis Zone

Target Data File	Target data	Zone Division	Zone Integration	Process Type	Distribution Indicator
Zone land condition	Inhabitable land area	Distribution	Aggregation	1	Inhabitable land area
	Industrial land area				Inhabitable land area * Industrial distribution rate
Zone condition	Number of bus stops	Distribution	Aggregation	1	Inhabitable land area
	designated floor area ratio building coverage ratio Building age Distance to nearest station Average bus service Density of bus stop Bus service Maximum bus service	Same value	Weighted average	2	Inhabitable land area
	Use zoning dummy	Same value	Representative value	3	Inhabitable land area

・Case(2): Land–Use Measure Zone to Transportation Analysis Zone

Target Data File	Target data	Zone Division	Zone Integration	Process Type	Distribution Indicator
Zone land condition	Inhabitable land area	Distribution	Aggregation	1	Inhabitable land area
	Industrial land area				Inhabitable land area * Industrial distribution rate
Student distribution	Number of student under 15years old	Distribution	Aggregation	1	Elementary and junior high school site dummy
	Number of student over 15years old				High school and college sites dummy

・Case(3): Transportation Network to Land–Use Analysis Zone

Target Data File	Target data	Zone Division	Zone Integration	Process Type	Distribution Indicator
Car traffic volume	Time distance by car	Route search		5	—
Bus and tram traffic volume	Time distance by public transport	Route search		5	—
Railway traffic volume					

Table 5. Target data and process type of each transformation case (2)

・Case(4): Land-Use Analysis Zone to Transportation Analysis Zone

Target Data File	Target data	Zone Division	Zone Integration	Process Type	Distribution Indicator
Population distribution by age	Population by age	Distribution	Aggregation	1	Inhabitable land area * Residential distribution rate
Student distribution	Employees in primary industry	Distribution	Aggregation	1	Inhabitable land area
	Employees in secondary industry				Inhabitable land area * Industrial distribution rate
	Employees in tertiary industry excepting service employees Service employee Employees in tertiary industry				Inhabitable land area * commercial distribution rate

・Case(5): Land-Use Analysis Zone to Land-Use Measure Zone

Target Data File	Target data	Zone Division	Zone Integration	Process Type	Distribution Indicator
Land area by use type	Residential land area	Distribution	Aggregation	1	Inhabitable land area * Residential distribution rate
	Commercial land area				Inhabitable land area * commercial distribution rate
Floor area by use type	Residential floor area	Distribution	Aggregation	1	Inhabitable land area * Residential distribution rate
	Commercial floor area				Inhabitable land area * commercial distribution rate
Household distribution by type	Household by type	Distribution	Aggregation	1	Inhabitable land area * Residential distribution rate
Residential floor rent	Residential floor rent	Same value	Weighted average	2	Inhabitable land area * Residential distribution rate
Residential floor area	Residential floor area per household	Same value	Weighted average	2	Inhabitable land area * Residential distribution rate
	Residential floor area Residential vacant floor area	Distribution	Aggregation	1	Inhabitable land area * Residential distribution rate
Population distribution by age	Population by age	Distribution	Aggregation	1	Inhabitable land area * Residential distribution rate
Employee distribution by industry	Employee by industry	Distribution	Aggregation	1	Inhabitable land area * commercial distribution rate
Commercial floor rent	Commercial floor rent	Same value	Weighted average	2	Inhabitable land area * commercial distribution rate
Commercial floor area	Consumed floor area per employee	Same value	Weighted average	2	Inhabitable land area * commercial distribution rate
	Commercial floor area Commercial vacant floor area	Distribution	Aggregation	1	Inhabitable land area * commercial distribution rate
Land price by use type	Residential land price	Distribution	Aggregation	1	Inhabitable land area * Residential distribution rate
	Commercial land price	Same value	Weighted average	2	Inhabitable land area * commercial distribution rate

Table 6. Target data and process type of each transformation case (3)

・Case(6): Transportation Analysis Zone to Transportation Analysis Zone

Target Data File	Target data	Zone Division	Zone Integration	Process Type	Distribution Indicator
Trip by mode and purpose	Number of OD trip by mode and purpose	Distribution (2–D)	Aggregation (2–D)	4	Inhabitable land area

・Case(7): Transportation Network to Land–Use M Zone

Target Data File	Target data	Zone Division	Zone Integration	Process Type	Distribution Indicator
Walk traffic volume	Time distance by walk	Route search		5	—
Bus and tram traffic volume	Time distance by bus and tram	Route search		5	—
Railway traffic volume	Time distance by railway	Route search		5	—
Car traffic volume	Time distance by car	Route search		5	—

3.2.2 Arrangement of transformation process type

Process types for each data are aggregated into the following five.

1: Distribution → Aggregation

2: Same value → Weighted average

3: Same value → Representative value

4: Distribution (2-Dimension) → Aggregation (2-Ddimension)

5: Route search

Although the processing about OD data is 2-dimension, it is possible to correspond by applying the processing functions above in zone O and D, respectively.

The process functions are generalized in into the following 5 types.

a) Distribution

b) Same value

c) Aggregation

d) Weighted average

e) Representative value

The processing using a distribution indicator is applied to a) Distribution, d) Weighted average, and e) Representative value.

3.2.3 Outline of transformation processes

The Outline of transformation processes for each of a) to e) are followings.

a) Distribution

- For aggregate value, assign the original zone value to multiple zones.
- Calculate the value in each zone weighting with the ratio of the index.
- It is considered of the Distribution by Logit model etc but not practical because of necessity for the parameter estimation for each distribution indicator.

b) Same value

- For continuous property value and discrete property value, the original zone value is set as the identical values for multiple zones.

c) Aggregation

- For aggregate value, the value of the integration target zone is set by summing up the values of multiple zones.

d) Weighted average

- For continuous property value, the value of the integration target zone is set by weighted average with weighting by distribution indicator of the multiple zones.

e) Representative value

- For discrete property value, the value of the integration target zone is set by selecting the value in which the sum of distribution indicator is max from values of multiple zones.

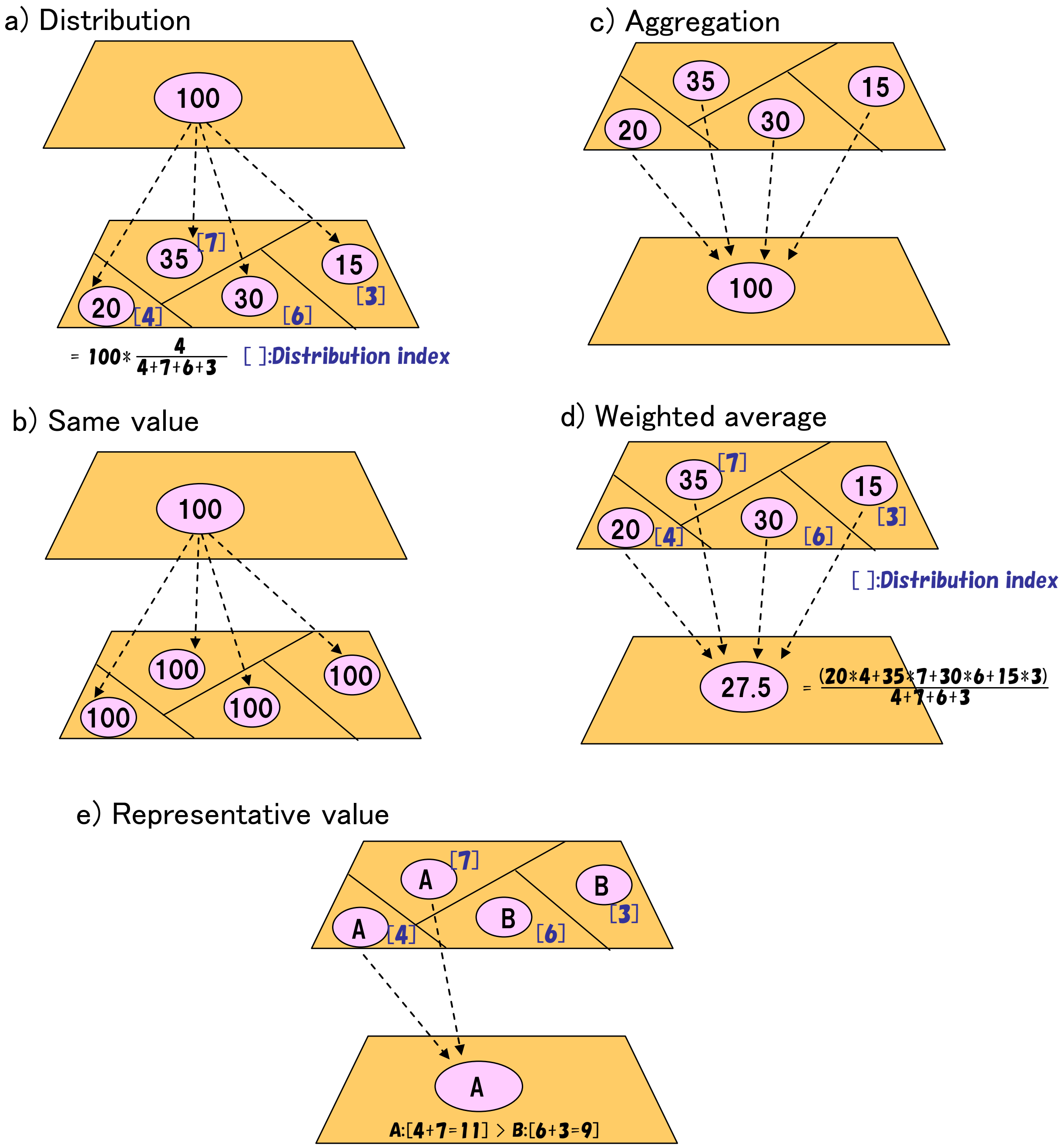

Figure 9. Outline of transformation process

3.2.4 Setting of distribution indicator

When the split process is performed, it is necessary for the reference data to determine the split value, such as the apportioning by the area. The reference data is defined as distribution indicator.

As the distribution indicator for the typical data, the inhabitable land area is mainly used, but otherwise, the residential area and commercial area is used according to the data content. However, in the Future Urban Structure Estimation model, other than the inhabitable land area is an endogenous value that is calculated for each year and for each alternative. Therefore, it is difficult to set them exogenously in the every intermediate zone, if set, the inconsistent occur with the model calculations. Further, if the distributed value developed endogenously is used, another indicator is needed for it, and if the endogenously calculated value is distributed for inhabitable land, the obtained result is as same as using the inhabitable land.

Then, the foundation of the distribution indicator is the inhabitable land that is set exogenously for each alternative and each year. Moreover, distribution ratio of industrial / commercial / residential of each intermediate zone is set exogenously. As a result, the conversion is performed using the distribution indicator that is consisted from the product of the inhabitable land area and these distribution ratios. In addition, two dummy variables of the school locations (elementary and middle schools placement, high schools and college placement) that represent the student distribution are set as the data of distribution indicator.

Based on the above, the distribution indicator data is defined as follows;

1) Inhabitable land area
2) Residential distribution ratio
3) Commercial distribution ratio
4) Industrial distribution ratio
5) Elementary and junior high school sites
6) High school and college sites

And the distribution indicator that is used in conversion process is follows;

- Inhabitable land area
- Inhabitable land area * Residential distribution ratio
- Inhabitable land area * Commercial distribution ratio
- Inhabitable land area * Industrial distribution ratio
- Elementary and junior high school sites
- High school and college sites

4. Future Urban Structure Evaluation Model

4.1. Outline and composition of Future Urban Structure Evaluation Model

The Future Urban Structure Evaluation Model is developed to calculate the evaluation indicator that carry out the evaluation about the future urban structure of each alternative measures, by using the data about the transportation situation and population distribution of future that output by the Future Urban Structure Estimation Model described above. This model is responsible for the function to calculate the indicators about the evaluation of urban structure as follows.

- The indicators that may help to compare the advantages and disadvantages of alternatives about the future urban and regional vision and measures
- The indicators to achieve the city where is sustainable under the constraints of such a declining population in the future, at the level of each local city.
- Indicators to understand whether getting closer or not to the aim of future vision in feasible from a long-term perspective

In this model select the indicators about living, safety, environment, energy, and administrative service costs as shown in Table 7 with considering to the existing research and the calculation availability of the data from output of the Future Urban Structure Estimation Model. And also this model builds up a concrete calculation formula and the calculation tool to calculate the indicators which include not only the indicators for evaluating the usability but also the indicators of future administrative service costs from the point of view of the efficiency and sustainability of urban structure, so a multi-faceted evaluation is possible.

Table 7. Indicators of Future Urban Structure Evaluation Model

Indicator No.	Category		Indicator
1	Life: L	Housing: H	Residents around city center
2			Floor area per capita
3			Housing cost per capita
4		Transportation: T	Time distance by mode
5			Time distance by purpose
6			Modal share
7			Public transport user
8			Accessibility to Public Transport
9			Rode congestion rate
10			Traffic accident victims
11			Accessibility to city center
12			Accessibility of elderly to public transport
13			Accessibility of elderly to city center by public transport
14		Infrastructure: I	Sewage served population rate
15			Park and green area per capita
16		Communication: C	Balance of population attribute composition
17	Safety: S	Disaster mitigation: D	People with difficulty returning home in case of disasters
18			Residents in difficult area of fire-fighting
19			Initial response time of fire-fighting
20			Length of wide road
21			Residents in disaster hazard area
22		Medical services: M	Population in accessible area to medical facilities
23			Accessibility of elderly to medical facilities by public transport
24	Environment: E	Global environment: E	CO2 emissions by transportation sector
25			CO2 emissions by private and industrial sector
26			Amount of fixed CO2 by green
27		Air pollution: A	NOx emissions
28		Nature: G	Green and agricultural land coverage rate
29		Resources and energy: R	Fuel consumption by transportation sector
30			Fuel consumption by private and industrial sector
31	Vitality: V	Activity distribution: A	Employee
32		Industrial activities: I	Average time distance of trips
33			Visitors to central commercial area
34			Accessibility between sightseeing spots
35		Economic impact: E	Total value of land price
36	Cost of administrative services: C	Facilities: F	Road maintenance cost
37		Services: S	Elder care service cost
38			Public transport cost
39			Elementary and junior high school cost

4.2. Approach for selection of evaluation indicators

In the past, since the accumulation of a variety of studies what is referred to as evaluation method for urban structure have been made, it is a reality that its numerical and indicators such as explained in this model are not shown in the future planning of the city like a urban master plan. Therefore, a group of metrics which were commonly available in the assessment of local governments were organized and developed the tools to calculate them.

First, the candidate of evaluation indicators were extracted with reference to the various existing planning initiatives and indicators of related research. Next, we considered how to take advantage of two assessments, Predictive and Declarative type, that concern about the usability in order to compare and evaluate the draft future urban structure in the local city where the population was declining. Predictive type assessment based on the predicted results about future urban structure, and Declarative type assessment in which the urban structure was declared as a policy-making (setting) value. In these studies, the summarized indicators was over 100. About the indicator candidate for the Declarative type assessment, the possibility of calculation was investigated if the indicator of conditions of transportation network, population distribution in daytime and nighttime , and land use were changed, then different calculated value output come out or not. About the indicator candidate for the Predictive type assessment, the availability of calculation by using the Future Urban Structure Estimation Model was investigated. The indicators were narrowed down by examining the balance between indicators, and the indicator were also examined whether shared or not in many thesis such as investigated results, plans, and research reviews. Result of reference on indicator is summarized as shown in Table 8.

Table 8. Referenced works, plans, and studies for indicator selection

<table>
<tr><td colspan="3">◇Evaluation contents and indicator in the related planning by Ministry of Land, Infrastructure and Transport</td></tr>
<tr><td colspan="3">(1) Evaluation contents and indicator in “Priority Plan for Social Infrastructure Development”</td></tr>
<tr><td colspan="3">(2) Evaluation contents and indicator in “Low Carbon City Development Guidance”</td></tr>
<tr><td colspan="3">◇Description in the plans of local governments</td></tr>
<tr><td colspan="2">(1) Indicator of urban planning master plan described by concrete target value</td><td>Kasugai, Kashiwa, Matsudo, Yachiyo, Ise</td></tr>
<tr><td colspan="2">(2) Objective of urban planning master plan etc.</td><td>Sapporo, Toyama, Akita, Aomori, Hitachi etc.</td></tr>
<tr><td colspan="3">◇Evaluation contents and indicator in the researches and studies</td></tr>
<tr><td rowspan="5">(1) Example of monitoring indicator (Ex-post Evaluation indicator)</td><td colspan="2">“Renovation Program” (Ministry of Land, Infrastructure and Transport)</td></tr>
<tr><td colspan="2">“General Support for City Planning” (Ministry of Land, Infrastructure and Transport)</td></tr>
<tr><td colspan="2">“Sustainable Development Indicator” (United Nations)</td></tr>
<tr><td colspan="2">“The Global City Indicators Facility” (World Bank)</td></tr>
<tr><td colspan="2">“Sustainable development indicators” (Department for Environment, Food and Rural Affairs, England)</td></tr>
<tr><td rowspan="6">(2) Example of assessment indicator (Pre-estimation indicator)</td><td>Transportation model (Person Trip Survey)</td><td>“Report of the research on role and utilization of the Person trip Survey” (National Institute for Land and Infrastructure Management), 2005</td></tr>
<tr><td rowspan="2">Foreign land-use transportation model application project</td><td>SPARTACUS</td></tr>
<tr><td>PROPOLIS</td></tr>
<tr><td rowspan="2">Foreign example of land-use transportation model</td><td>Cambridge Futures</td></tr>
<tr><td>“The Netherland in the Future” (The Netherland Environmental Assessment Agency), etc.</td></tr>
<tr><td>Output indicator of land-use transportation model in domestic and overseas</td><td>“URBANSIM”, “DELTA”, “IRPUD”, “NYMTC-LUM”, “VMcue”, “RURBAN”</td></tr>
<tr><td rowspan="3">(3) Existing study paper</td><td colspan="2">Mihoko TAKAHASHI et al.: Method for Cost-Benefit Evaluation System of Impact by Forming Compact City, Papers on city planning, 2007.</td></tr>
<tr><td colspan="2">Takeshi KUROKAWA et al: Cost of Infrastructure Improvement on Sprawl Area, Papers on city planning, 1995.</td></tr>
<tr><td colspan="2">Takehito UJIHARA et al: Ecological Footprint of Urban Retreat considering Development Methods : Case Study of Maintenance of Urban Infrastructure Network in Residential Zones, Papers on city planning, 2007.</td></tr>
</table>

It is organized in the criteria shown in Table 9 whether the indicator can be calculated in future urban vision assessment from the relevance of the policy measure variable, and the affinity for the prediction model and urban structure, for the urban structure evaluation indicators. In addition, it is organized by the criteria shown in Table 10 whether indicator value is analyzed by zone based or entire city. Finally, indicators of future urban structure evaluation were selected as shown in Table 11.

Table 9. Criteria of calculation possibility

Type of assessment method	Criteria of calculation possibility
Predictive type assessment	The availability of calculation by using Future Urban Structure Estimation Model is evaluated as bellow 4 categories. ● : Indicators can be calculated by using present Future Urban Structure Estimation Model. △ : Indicators have possibility of calculation in case of Model improved. □ : Indicators are set as exogenous variables such as the policy measure variable. — : Indicators have difficulty to predict or calculate.
Declarative type assessment	The possibility of make difference for calculation result if the indicator of conditions of transportation network, population distribution in daytime and nighttime , and land use were changed. ● : Difference occur, or possible to occur — : No difference

Table 10. Criteria of calculation spatial unit

	Criteria of calculation spatial unit
Zone based indicator calculation	● : Indicators can be calculated by zone and have the ability to evaluate the urban structure from the view point of fairness for among zones and appropriateness of assignment. △ : Indicators can be calculated by zone, but have no meaning to do because of difficulty of evaluation from the view point of fairness among zones and appropriateness of assignment. — : Indicators cannot be calculated.
Entire city based indicator calculation	● : Indicators can be calculated for the entire city. △ : Indicators should be evaluate from the view point of fairness among zones and appropriateness of assignment. — : Indicators cannot be calculated.

Table 11. Result of Future Urban Structure Evaluation Indicators selection

Categories			NO	Indicator	calculation possibility		calculation spatial unit		Selected Indicator
					Predictive	Declarative	Zone	Entire city	
Life	Housing	Habitants	1	Residents around city center	●	●	─	●	●
		Quality of Housing	2	Floor area per capita	●	─	●	●	●
		Housing cost	3	Housing cost per capita	●	─	●	●	●
	Transportation	Transportation characteristics	4	Time distance by mode	●	─	●	●	●
			5	Time distance by purpose	●		●	●	●
			6	Modal share	●	─	●	●	●
		Public transport	7	Public transport user	●	─	●	●	●
			8	Accessibility to Public Transport	●	●	●	●	●
		Congestion	9	Rode congestion rate	●	─	●	●	●
		Traffic accident	10	Traffic accident victims	●	─	●	●	●
		Accessibility	11	Accessibility to city center	●	─	●	●	●
		Accessibility of elderly	12	Accessibility of elderly to public transport	●	─	●	●	●
			13	Accessibility of elderly to city center by public transport	●	─	●	●	●
	Infrastructure	Sewage	14	Sewage served population rate	□	●	●	●	●
		Park and green	15	Park and green area per capita	□	●	●	●	●
	Communication	Community	16	Balance of population attribute composition	●	─	●	△	●
Safety	Public security	Public security	17	Crimes, crime occurring rate	─	─	─	─	─
	Disaster mitigation	Disaster mitigation	18	People with difficulty returning home in case of disasters	●	─	●	●	●
			19	Residents in difficult area of fire-fighting	●	─	●	●	●
			20	Initial response time of fire-fighting	●	─	●	●	●
			21	Length of wide road	□	●	─	●	●
			22	Residents in disaster hazard area	●	●	●	●	●
			23	High earthquake-resistance facilities rate	△	─	─	─	─
	Medical services	Medical services	24	Population in accessible area to medical facilities	●	─	●	●	●
		Medical services for Elderly	25	Accessibility of elderly to medical facilities by public transport	●	─	●	●	●
Environment	Global environment	Global warming	26	CO2 emissions by transportation sector	●	─	△	●	●
			27	CO2 emissions by private and industrial sector	●	─	●	●	●
			28	Amount of fixed CO2 by green	□	●	△	●	●
	Air pollution	Emissions	29	NOx emissions	●	─	●	●	●
	Nature	Green	30	Green and agricultural land coverage rate	□	●	△	●	●
	Resources and energy	Fuel	31	Fuel consumption by transportation sector	●	─	△	●	●
			32	Fuel consumption by private and industrial sector	●	─	●	●	●
	Waste	Waste	33	Waste generation per capita	△	─	─	─	─
Vitality	Activity distribution	Industry	34	Employee	●	─	●	△	●
	Industrial activities	Distribution cost	35	Average time distance of trips	●	─	─	●	●
		Commercial	36	Visitors to central commercial area	●	─	─	●	●
		Sightseeing	37	Accessibility between sightseeing spots	●	─	─	●	●
	Economic grows	GDP・GRP	38	GDP, GDP per capita	△	─	─	─	─
	Economic impact	土地価格	39	Total value of land price	●	─	●	●	●

In addition, the calculating method of the administrative service costs for the future was also considered because the cost is an essential element and important in order to evaluate and determine the efficiency and sustainability of urban structure. In this review, the cost was limited as the maintenance cost for the future urban structure.

From the preceding example of calculation about the administrative service costs, the offering density of service items and the set criteria of cost per unit is organized and shown in table below.

About the setting criteria of offering density, "elementary and junior high school, feeding centers, park, kindergarten, nursery center, community center, fire and ambulance station" are similar because they are located on the basis of criteria such as the desired alignment in manual. In this case, fire and ambulance station and elementary and junior high schools use a calculation equation that uses population by area etc. as the cost per unit area. And the equation for elementary and junior high school is more direct and clear. Therefore, it is assumed that the calculation of the elementary and junior high schools represent of the other such as feeding center, park, kindergarten, nursery center, community center, fire and ambulance station. In addition, Public transport, sewer, and road have set the offering density from the regression equation of each city data, and it is similar to the standard-setting process to the calculation of the cost per unit in the sewer and road, so sewer can be determined by the road calculation.

Table 12. Foundation of criteria setting of administrative service cost in existing case study

	Setting foundation	Service contents
Standard setting of administrative service arrangement density	Manual (desirable layout criterion)	Elementary and junior high school, Feeding center, park, Kindergarten, Nursery school, Community center, Fire and ambulance station
	National average	Water and sewage
	Regression equation by data of each city	Road, Sewage, Public transport
	Specific actual result, No criterion	Elder care service, Waste collection
Standard setting of administrative service unit cost	National average	Road, Sewage, Water supply, Community center
	Calculation equation	Elementary and junior high school, Fire and ambulance station
	Regression	Waste collection, Park, Nursery school, Kindergarten, Public transport
	Specific actual result	Elder care service

From the reviews of the previous calculation method and grasp of study state in local governments, the concrete methods for calculation that is implemented on assessment tool were organized by dividing two types that consist of "base type" and "network type". The organized linkage of land use and transportation model by service item is shown in the table below. As the indicator reflects the status of Aging (population by age group), public transport, Elementary and Junior High School, and Elder care service is given. In addition, in the calculation of elementary and junior high school and public transportation, the indicator is considered to be related to "population distribution by zone strongly. Therefore, elementary and junior high school, public transport, Elder care service, and road is selected as an indicator for an administrative service costs. They can represent a method for calculating the items of other services and reflect the population distribution due to the changes in urban structure and aging and low birth rate, by utilizing the land use transportation model.

Table 13. Calculation method of administrative service costs

Service style	Target administrative service	Linkage of land-use transportation model		Necessity of local government data	Setting contents as policy measure variables
		Decreasing birthrate and aging population (Age composition by zone)	Population distribution (Population by zone)		
Network type	Road		○※1※2	—	City Planning Area
	Water supply			—	Urbanization Promotion Area
	Sewage		○[1]	—	
	Waste collection		○[3]	—	
	Visiting care service	○		Need[4]	
	Public transport	○[5]	○[5]	—	
Position type	Park		○[2]	—	Service level[6]
	Elementary and junior high school	○[7]	○[7]	—	Service level[6]
	Feeding center	○	○	—	Service level[6]
	Kindergarten	○	○	—	Service level[6]
	Nursery school	○	○	—	Service level[6]
	Community center			—	Service level[6]
	Fire and ambulance station			—	Service level[6]

1) Road density is set by the function of population density of inhabitable area. Length of sewage culvert is set by the linear expression of road length.

2) Unit cost is set by the function of area, degree of urbanization (DID population / total population), population density in inhabitable area

3) Unit cost is set by the function of degree of urbanization (DID population / total population), population density in inhabitable area

4) Specific actual result of utilization rate and care payment by visiting care service type

5) Decreasing birthrate and aging population and population distribution are considered by model simulation, because the number of public transport user is calculated by land-use transportation model in this study.

6) Service level is basically sufficient the proper service level defined by the related laws or manuals, it can be set flexibly according to the actual condition of local government.

7) Cost per a school is also changed according to the school size.

4.3. Method of calculating Life indicators

The Method of calculating the indicator for life is as follows.

(1) Residents around city center

1) Total population by zone

Total population by age is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{53}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Population by age h in zone i

2) Target population

Target population is calculated as a sum of population multiplied by the target flag for all zone.

$$TNJ = \sum_i (ZNJ_i \times FLG_i) \tag{54}$$

ZNJ_i : Population in zone i

FLG_i : Flag for zone around city center zone (if zone i is target: 1, the other: 0)

TNJ : Target population

3) Ratio of target residents

Ratio of target residents is calculated as the proportion of target population to total population of entire urban area.

$$RTNJ = \frac{TNJ}{\sum_i ZNJ_i} \tag{55}$$

TNJ : Target population

$RTNJ$: Ratio of target residents

(2) Floor area per capita

1) Total population by zone

Total population by age is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{56}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Population by age h in zone i

2) Floor area per capita by zone

Floor area per capita is calculated by the following equation by zone.

$$HFANJ_i = HFA_i / ZNJ_i \tag{57}$$

ZNJ_i : Population in zone i

HFA_i : Residential floor area in zone i

$HFANJ_i$: Floor area per capita in zone i

3) Floor area per capita

Weighted average of floor area per capita is calculated by using population in zone as follows.

$$RHFANJ = \frac{\sum_i HFA_i}{\sum_i ZNJ_i} \tag{58}$$

$RHFANJ$: Floor area per capita

(3) Housing cost per capita

1) Total population by zone

Total population by age is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{59}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Population by age h in zone i

2) Housing cost by zone

Housing cost by zone is calculated by the following equation.

$$HFAFR_i = HFA_i \times HFR_i \tag{60}$$

HFR_i : Residential floor rent in zone i

HFA_i : Residential floor area in zone i

$HFAFR_i$: Housing cost in zone i

3) Total housing cost

Total housing cost is calculated by the following equation.

$$THFAFR = \sum_i HFAFR_i \tag{61}$$

$THFAFR$: Total housing cost

4) Averaged housing cost

Weighted average of housing cost per capita is calculated by using population in zone as follows.

$$RHFAFR = \frac{THFAFR}{\sum_i ZNJ_i} \tag{62}$$

$RHFAFR$: Weighted average of housing cost per capita

(4) Time distance by mode

1) Time distance by mode by zone

Time distance by mode by zone is calculated by the following equation.

$$SZATRPT_{si} = \frac{\sum_m \sum_j \left(OD_{msij} \times T_{sij}\right)}{\sum_m \sum_j OD_{msij}} \tag{63}$$

OD_{msij} : Trips of purpose m by mode s between zone i and j

T_{sij} : Time distance by mode s between zone i and j

$SZATRPT_{si}$: Averaged time distance by mode s in zone i

2) Averaged time distance by mode

Averaged time distance by mode is calculated by the following equation.

$$SATRPT_s = \frac{\sum_m \sum_i \sum_j \left(OD_{msij} \times T_{sij}\right)}{\sum_m \sum_i \sum_j OD_{msij}} \qquad (64)$$

$SATRPT_s$: Averaged time distance by mode s

(5) Time distance per purpose

1) Time distance by purpose by zone

Time distance by purpose by zone is calculated by the following equation.

$$MZATRPT_{mi} = \frac{\sum_s \sum_j \left(OD_{msij} \times T_{sij}\right)}{\sum_s \sum_j OD_{msij}} \qquad (65)$$

OD_{msij} : Trips of purpose m by mode s between zone i and j

T_{sij} : Time distance by mode s between zone i and j

$MZATRPT_{mi}$: Averaged time distance of purpose m in zone i

2) Averaged time distance by purpose

Averaged time distance by purpose is calculated by the following equation.

$$MATRPT_m = \frac{\sum_s \sum_i \sum_j \left(OD_{msij} \times T_{sij}\right)}{\sum_s \sum_i \sum_j OD_{msij}} \qquad (66)$$

$MATRPT_m$: Averaged time distance of purpose m

(6) Modal share

1) Modal share by origin zone

Modal share by origin zone is calculated by the following equation.

$$ROZTR_{si} = \frac{\sum_m \sum_j OD_{msij}}{\sum_s \sum_m \sum_j OD_{msij}} \qquad (67)$$

OD_{msij} : Trips of purpose m by mode s between zone i and j

$ROZTR_{si}$: Modal share by mode s in origin zone i

2) Modal share by destination zone

Modal share by destination zone is calculated by the following equation.

$$RDZTR_{sj} = \frac{\sum_m \sum_i OD_{msij}}{\sum_s \sum_m \sum_i OD_{msij}} \qquad (68)$$

$RDZTR_{sj}$: Modal share by mode s in destination zone j

3) Modal share

Modal share is calculated by the following equation.

$$RTR_s = \frac{\sum_m \sum_i \sum_j OD_{msij}}{\sum_s \sum_m \sum_i \sum_j OD_{msij}} \tag{69}$$

RTR_s : Modal share by mode s

(7) Public transport user

1) Public transport user by zone

Public transport user by zone is calculated by the following equation.

$$ZPUBOD_i = \sum_{s=s\_bus, s\_train} \sum_m \left(\sum_j OD_{msij} + \sum_j OD_{msji}\right) \tag{70}$$

OD_{msij} : Trips of purpose m by mode s between zone i and j

s_bus : Mode number of bus

s_train : Mode number of railway

$ZPUBOD_i$: Public transport user in zone i

2) Public transport user

Public transport user is calculated by the following equation.

$$TPUBTOD = \sum_i ZPUBOD_i / 2 \tag{71}$$

$TPUBTOD$: Public transport user

(8) Accessibility to Public Transport

1) Total population by zone

Total population by age is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{72}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Population by age h in zone i

2) Time distance accessing to station by walk by zone is calculated by the following equation.

Time distance accessing to station by walk by zone is calculated by the following equation.

$$ZACCT_i = STDIST_i / WSP \tag{73}$$

$STDIST_i$: Distance to nearest station in zone i (km)

WSP : Walking speed = 0.08 (km/min)

$ZACCT_i$: Time distance accessing to station by walk by zone (min)

3) Total of time distance accessing to station by walk by zone

Total of time distance accessing to station by walk by zone is calculated by the following equation.

$$TZACCT_i = ACCT_i \times ZNJ_i \tag{74}$$

$TZACCT_i$: Total of time distance accessing to station by walk by zone

4) Total of time distance accessing to station by walk

Total of time distance accessing to station by walk is calculated by the following equation.

$$TTACCT = \sum_i TZACCT_i \tag{75}$$

$TTACCT$: Total of time distance accessing to station by walk (min)

5) Averaged time distance accessing to station by walk

Weighted average of time distance accessing to station by walk is calculated by using population in zone as follows.

$$ATACCT = \frac{TTACCT}{\sum_i ZNJ_i} \tag{76}$$

$ATACCT$: Averaged time distance accessing to station by walk (min)

(9) Rode congestion rate

1) Rode congestion rate by link

Rode congestion rate by link is calculated by the following equation.

$$ALTJ_l = \frac{KU_l \cdot TJU_l + KD_l \cdot TJD_l}{KU_l + KD_l} \tag{77}$$

KU_l, KD_l : Inbound and outbound traffic volume in link l

TJU_l, TJD_l : Inbound and outbound rode congestion rate in link l

$ALTJ_l$: Rode congestion rate in link l

2) Averaged rode congestion rate (weighted average by traveler km)

Averaged rode congestion rate is calculated by the following equation.

$$ATJ = \frac{\sum_l ((KU_l \cdot TJU_l + KD_l \cdot TJD_l) \times LL_l)}{\sum_l ((KU_l + KD_l) \times LL_l)} \tag{78}$$

LL_i : Length of link l

ATJ : Averaged rode congestion rate

3) Vehicle-km of link with road congestion rate over 1

Vehicle-km of link with road congestion rate over 1 is calculated by the following equation

$$TTL = \sum_l (KU_l \times LL_l) + \sum_l (KD_l \times LL_l) \tag{79}$$

subject to link l with $TJU_l > 1$ or $TJD_l > 1$

TTL : Traveler kilometer with road congestion rate over 1

4) Averaged rode congestion rate by zone

Averaged rode congestion rate by zone is calculated by the following equation, by aggregating links l included in zone i.

$$AZTJ_i = \frac{\sum_{l \in i} ((KU_l \cdot TJU_l + KD_l \cdot TJD_l) \times LL_l)}{\sum_{l \in i} ((KU_l + KD_l) \times LL_l)} \tag{80}$$

$AZTJ_i$: Averaged rode congestion rate in zone i

(10) Traffic accident victims

1) Traffic accident victims by link

Traffic accident victims is calculated by the following equation.

$$LA_l = \frac{(KU_l + KD_l) \times (LL_l \times LPL_{h,l} + LPN_{h,l})}{1000} \tag{81}$$

KU_l, KD_l : Inbound and outbound traffic volume in link l

LL_l : Length of link l

$LPL_{h,l}$: Accident coefficient for length of type h in link l (per 1000 vehicle-km)

$LPN_{h,l}$: Accident coefficient for crossroad of type h in link l (per 1000 vehicle)

LA_l : Traffic accident victims in link l

Accident coefficient for length and crossroad are given by type and class of link which is specified by link capacity.

2) Traffic accident victims

Traffic accident victims is calculated by the following equation.

$$LTA = \sum_l LA_l \tag{82}$$

LTA : Traffic accident victims

3) Traffic accident victims by zone

Traffic accident victims by zone is calculated by the following equation, by aggregating links l included in zone i.

$$TZA_i = \sum_{l \in i} LA_l \tag{83}$$

TZA_i : Traffic accident victims in zone i

(11) Accessibility to city center

1) Total population by zone

Total population in zone is calculated as a sum of population by age in zone.

$$ZNJ_i = \sum_h NJ_{hi} \tag{84}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Total population in zone i

2) Time distance accessing to city center by zone

Time distance accessing to city center by zone is calculated by the following equation.

$$MINTKYOTEN_i = \min_{s,n}\{T_{s,i,n}\} \tag{85}$$

$T_{s,i,n}$: Time distance accessing to city center n by mode s in zone i

$MINTKYOTEN_i$: Time distance accessing to city center by zone

3) Total of time distance accessing to city center by zone

Total of time distance accessing to city center by zone is calculated by the following equation.

$$TJKYOTEN_i = MINTKYOTEN_i \times ZNJ_i \tag{86}$$

$TJKYOTEN_i$: Total of time distance accessing to city center by zone

4) Total of time distance accessing to city center

Total of time distance accessing to city center by zone is calculated by the following equation.

$$TTJKYOTEN = \sum_{i} TJKYOTEN_i \tag{87}$$

$TTJKYOTEN$: Total of time distance accessing to city center

5) Averaged time distance accessing to city center

Weighted average of time distance accessing to city center is calculated by using population in zone as follows.

$$ATJKYOTEN = \frac{TTJKYOTEN}{\sum_{i} ZNJ_i} \tag{88}$$

$ATJKYOTEN$: Averaged time distance accessing to city center

(12) Accessibility of elderly to public transport

1) Number of elderly by zone

Number of elderly by zone is calculated as a sum of population over 65.

$$ZONJ_i = \sum_{h'} NJ_{h'i} \tag{89}$$

$NJ_{h'i}$: Population of over 65 age category h' in zone i

$ZONJ_i$: Population of over 65 in zone i

2) Time distance accessing to nearest public transport by zone

Time distance by walk accessing to nearest public transport by zone is calculated by the following equation.

$$MINTPT_i = \min_{n}\{T_{walk,i,n}\} \tag{90}$$

$T_{walk,i,n}$: Time distance by walk accessing to nearest bus stop or station n in zone i

$MINTPT_i$: Time distance accessing to nearest public transport in zone i

3) Number of elderly in accessible area to public transport by zone

Number of elderly in accessible area to public transport by zone is calculated by the following equation.

$$ACCONJPT_i = ZONJ_i \times FLGPT_i \tag{91}$$

$ACCONJPT_i$: Number of elderly in accessible area to public transport by zone

$TLMTPT$: Upper limit of public transport access time distance

$FLGPT_i$: Public transport accessible flag

(in case $MINTIPT_i \leq TLMTPT$: 1, the other: 0)

4) Number of elderly in accessible area to public transport

Number of elderly in accessible area to public transport is calculated by the following equation.

$$TACCONJPT = \sum_{i} ACCONJPT_i \tag{92}$$

$TACCONJPT$: Number of elderly in accessible area to public transport

5) Ratio of elderly in accessible area to public transport

Ratio of elderly in accessible area to public transport is calculated by the following equation.

$$RACCONJPT = \frac{TACCONJPT}{\sum_{i} ZONJ_i} \tag{93}$$

$RACCONJPT$: Ratio of elderly in accessible area to public transport

(13) Accessibility of elderly to city center by public transport

1) Number of elderly by zone

Number of elderly by zone is calculated as a sum of population over 65.

$$ZONJ_i = \sum_{h'} NJ_{h'i} \tag{94}$$

$NJ_{h'i}$: Population of over 65 age category h' in zone i

$ZONJ_i$: Population of over 65 in zone i

2) Time distance accessing to city center by public transport by zone

Time distance accessing to city center by public transport by zone is calculated by the following equation.

$$MINPTKYOTEN_i = \min_n \{T_{bus,i,n}, T_{train,i,n}\} \tag{95}$$

$T_{bus,i,n}$: Time distance accessing to city center n by bus in zone i

$T_{train,i,n}$: Time distance accessing to city center n by railway in zone i

$MINPTKYOTEN_i$: Time distance accessing to city center by public transport in zone i

3) Total of time distance of elderly accessing to city center by public transport by zone

Total of time distance of elderly accessing to city center by public transport by zone is calculated by the following equation.

$$PTONJKYOTEN_i = MINPTKYOTEN_i \times ZONJ_i \tag{96}$$

$PTONJKYOTEN_i$: Total of time distance of elderly accessing to city center by public transport by zone

4) Total of time distance of elderly accessing to city center by public transport

Total of time distance of elderly accessing to city center by public transport is calculated by the following equation.

$$TPTONJKYOTEN = \sum_i PTONJKYOTEN_i \tag{97}$$

$TPTONJKYOTEN$: Total of time distance of elderly accessing to city center by public transport

5) Averaged time distance of elderly accessing to city center by public transport

Weighted average of time distance of elderly accessing to city center by public transport is calculated by using number of elderly in zone by the following equation.

$$APTONJKYOTEN = \frac{TPTONJKYOTEN}{\sum_i ZONJ_i} \tag{98}$$

$APTONJKYOTEN$: Averaged time distance of elderly accessing to city center by public transport

(14) Sewage served population rate

1) Total population by zone

Total population by age is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{99}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Population by age h in zone i

2) Sewage served population rate by zone

Sewage served population rate by zone is calculated by the following equation.

$$SWGJ_i = ZNJ_i \times SWG_i \tag{100}$$

SWG_i : Sewage served ratio in zone i

$SWGJ_i$: Sewage served population in zone i

3) Sewage served population rate

Sewage served population rate is calculated by the following equation.

$$RTSWGJ = \frac{\sum_i SWGJ_i}{\sum_i ZNJ_i} \tag{101}$$

$RTSWGJ$: Sewage served population rate

(15) Park and green area per capita

1) Total population by zone

Total population by age is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{102}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Population by age h in zone i

2) Park and green area per capita by zone

Park and green area per capita by zone is calculated by the following equation.

$$ZPSPJ_i = \frac{ZPS_i}{ZNJ_i} \tag{103}$$

ZPS_i : Park and green area in zone i

$ZPSPJ_i$: Park and green area per capita in zone i

3) Park and green area per capita

Park and green area per capita in whole area is calculated by the following equation.

$$TPSPJ = \frac{\sum_i ZPS_i}{\sum_i ZNJ_i} \tag{104}$$

$TPSPJ$: Park and green area per capita in whole area

(16) Balance of population attribute composition

1) Total population by zone

Total population is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{105}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Total population in zone i

2) Number of elderly by zone

Number of elderly by zone is calculated as a sum of population over 65.

$$ZONJ_i = \sum_{h'} NJ_{h'i} \tag{106}$$

$NJ_{h'i}$: Population of over 65 age category h' in zone i

$ZONJ_i$: Population of over 65 in zone i

3) Rate of aging

Rate of aging is calculated as a sum of population by age.

$$RZONJ_i = \frac{ZONJ_i}{ZNJ_i} \tag{107}$$

$RZONJ_i$: Rate of aging in zone i

4.4. Method of calculating Safety indicators

The Method of calculating the indicator for safety is as follows.

(17) People with difficulty returning home in case of disasters

1) People with difficulty returning home in case of disasters by zone

People with difficulty returning home in case of disasters by zone is calculated by the following equation.

$$ZRDN_i = \sum_s JOD_{sij} + \sum_s SOD_{sij} \tag{108}$$

subject to $T_{walk,ij} > TLMT$

JOD_{sij} : Commuting trips by mode s between zone i and j

SOD_{sij} : School commuting trips by mode s between zone i and j

$T_{walk,ij}$: Time distance by walk between zone i and j

$TLMT$: Upper limit of time distance of returning home possible

$ZRDN_i$: People with difficulty returning home in case of disasters by zone

2) People with difficulty returning home in case of disasters

People with difficulty returning home in case of disasters is calculated by the following equation.

$$TZRDN = \sum_i ZRDN_i \tag{109}$$

$TZRDN$: People with difficulty returning home in case of disasters

(18) Residents in difficult area of fire-fighting

1) Total numbers of household by zone

Total number of household by zone is calculated as a sum of household by type.

$$ZNH_i = \sum_l NH_{li} \tag{110}$$

NH_{li} : Number of household of type l in zone i

ZNH_i : Total number of household in zone i

2) Total population by zone

Total population by zone is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{111}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Total Population in zone i

3) Number of household in difficult area of fire-fighting by zone

Number of household in difficult area of fire-fighting is calculated by the following equation.

$$FFDNH_i = ZNH_i \times FLGFFD_i \tag{112}$$

$FLGFFD_i$: Flag for difficult area of fire-fighting (if zone i is target: 1, the other: 0)

$FFDNH_i$: Number of household in difficult area of fire-fighting in zone i

4) Population in difficult area of fire-fighting by zone

Population in difficult area of fire-fighting by zone is calculated by the following equation.

$$FFDNRJ_i = ZNJ_i \times FLGFFD_i \quad (113)$$

$FFDNJ_i$: Population in difficult area of fire-fighting in zone i

5) Number of household in difficult area of fire-fighting

Number of household in difficult area of fire-fighting is calculated by the following equation.

$$TFFDNH = \sum_i FFDNH_i \quad (114)$$

$TFFDNH$: Number of household in difficult area of fire-fighting

6) Population in difficult area of fire-fighting

Population in difficult area of fire-fighting is calculated by the following equation.

$$TFFDNJ = \sum_i FFDNJ_i \quad (115)$$

$TFFDNJ$: Population in difficult area of fire-fighting

(19) Initial response time of fire-fighting

1) Total population by zone

Total population by zone is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \quad (116)$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Total population in zone i

2) Time distance to nearest fire house by zone

Time distance to nearest fire house by zone is calculated by the following equation.

$$MINTFS_i = \min_{nf}\{T_{car,i,nf}\} \quad (117)$$

$T_{car,i,nf}$: Time distance by car to fire house nf in zone i

$MINTFS_i$: Time distance to nearest fire house in zone i

3) Population in covered area by fire station

Population in covered area by fire station is calculated as a sum of population multiplied by the target flag for all zone.

$$TCOVJFS = \sum_i (ZNJ_i \times FLG_i) \quad (118)$$

FLG_i : Flag for covered area by fire station (if $MINTFS_i \le TLMTFS$: 1, the other: 0)

$TLMTFS$: Upper limit of fire station covering time distance

$TCOVJFS$: Population in covered area by fire station

4) Ratio of population in covered area by fire station

Ratio of population in covered area by fire station is calculated as the proportion of target population to total population of entire urban area.

$$RCOVJFS = \frac{TCOVJFS}{\sum_i ZNJ_i} \quad (119)$$

$RCOVJFS$: Ratio of population in covered area by fire station

(20) Length of wide road

1) Flag for wide road by link

Flag for wide road by link is defined by the following equation.

$$FRGWR_l = \begin{cases} 1: \text{more than 4 lean and in urban area} \\ 0: \text{the other} \end{cases}$$

$FRGWR_l$: Flag for wide road in link l

2) Length of wide road

Length of wide road is calculated by the following equation

$$TWL = \sum_l (LL_l \times FRGWR_l) \quad (120)$$

LL_l : Length of link l

TWL : Length of wide road in urban area

(21) Residents in disaster hazard area

1) Total numbers of household by zone

Total number of household by zone is calculated as a sum of household by type.

$$ZNH_i = \sum_l NH_{li} \quad (121)$$

NH_{li} : Number of household of type l in zone i

ZNH_i : Total number of household in zone i

2) Number of elderly by zone

Number of elderly by zone is calculated as a sum of population over 65.

$$ZONJ_i = \sum_{h'} NJ_{h'i} \quad (122)$$

$NJ_{h'i}$: Population of over 65 age category h' in zone i

$ZONJ_i$: Population of over 65 in zone i

3) Number of household in disaster hazard area by zone

Number of household in disaster hazard area by zone is calculated by the following equation.

$$HZRNH_i = ZNH_i \times FLGHZR_i \quad (123)$$

$FLGHZR_i$: Flag for disaster hazard area (if zone i is target: 1, the other: 0)

$FFDNH_i$: Number of household in disaster hazard area in zone i

4) Number of elder in disaster hazard area by zone

Number of elder in disaster hazard area by zone is calculated by the following equation.

$$HZRONJ_i = ZONJ_i \times FLGHZR_i \quad (124)$$

$HZRONJ_i$: Number of elder in disaster hazard area in zone i

5) Number of household in disaster hazard area

Number of household in disaster hazard area is calculated by the following equation.

$$THZRNH = \sum_i HZRNH_i \quad (125)$$

$THZRNH$: Number of household in disaster hazard area

6) Number of elder in disaster hazard area

Number of elder in disaster hazard area is calculated by the following equation.

$$THZRONJ = \sum_i HZRONJ_i \tag{126}$$

$THZRONJ$: Number of elder in disaster hazard area

(22) Population accessible area to medical facilities

1) Total population by zone

Total population by zone is calculated as a sum of population by age.

$$ZNJ_i = \sum_h NJ_{hi} \tag{127}$$

NJ_{hi} : Population by age h in zone i

ZNJ_i : Total population in zone i

2) Time distance to nearest medical facilities by zone

Time distance to nearest medical facilities by zone is calculated by the following equation.

$$MINTIRYOU_i = \min_n \{T_{car,i,n}\} \tag{128}$$

$T_{car,i,n}$: Time distance by car to medical facilities n in zone i

$MINTIRYOU_i$: Time distance to nearest medical facilities in zone i

3) Population accessible area to medical facilities by zone

Population accessible area to medical facilities by zone is calculated by the following equation.

$$ACCJIRYOU_i = ZNJ_i \times FLGIRYOU_i \tag{129}$$

$FLGIRYOU_i$: Flag for accessible area to medical facilities

(if $MINTIRYOU_i \leq TLMTIR$: 1, the other: 0)

$TLMTIR$: Upper limit of medical facility access time distance

$ACCJIRYOU_i$: Population accessible area to medical facilities by zone

4) Ratio of population in accessible area to medical facilities by zone

Ratio of population in accessible area to medical facilities by zone is calculated by the following equation.

$$RACCJIRYOU = \frac{\sum_i ACCJIRYOU_i}{\sum_i ZNJ_i} \tag{130}$$

$RACCJIRYOU$: Ratio of population in accessible area to medical facilities by zone

(23) Accessibility of elderly to medical facilities by public transport

1) Number of elderly by zone

Number of elderly by zone is calculated as a sum of population over 65.

$$ZONJ_i = \sum_{h'} NJ_{h'i} \tag{131}$$

$NJ_{h'i}$: Population of over 65 age category h' in zone i

$ZONJ_i$: Population of over 65 in zone i

2) Time distance accessing to medical facilities by public transport by zone

Time distance accessing to medical facilities by public transport by zone is calculated by the following equation.

$$MINPTIRYOU_i = \min_n \{T_{bus,i,n}, T_{train,i,n}\} \quad (132)$$

$T_{bus,i,n}$: Time distance accessing to medical facility n by bus in zone i

$T_{train,i,n}$: Time distance accessing to medical facility n by railway in zone i

$MINPTIRYOU_i$: Time distance accessing to medical facilities by public transport in zone i

3) Number of elderly in accessible area to medical facilities by public transport by zone

Number of elderly in accessible area to medical facilities by public transport by zone is calculated by the following equation.

$$ACCONJPTIRYOU_i = ZONJ_i \times FLGPTIRYOU_i \quad (133)$$

$ACCONJPTIRYOU_i$: Number of elderly in accessible area to medical facilities by public transport in zone i

$TLMTPTIR$: Upper limit of medical facility access time distance by public transport

$FLGPTIRYOU_i$: Flag for accessible area to medical facilities by public transport (if $MINPTIRYOU_i \leq TLMTPTIR$: 1, the other: 0)

4) Number of elderly in accessible area to medical facilities by public transport

Number of elderly in accessible area to medical facilities by public transport is calculated by the following equation.

$$TACCONJPTIRYOU = \sum_i ACCONJPTIRYOU_i \quad (134)$$

$TACCONJPTIRYOU$: Number of elderly in accessible area to medical facilities by public transport

5) Ratio of elderly in accessible area to medical facilities by public transport

Ratio of elderly in accessible area to medical facilities by public transport is calculated by the following equation.

$$RACCONJPTIRYOU = \frac{TACCONJPTIRYOU}{\sum_i ZONJ_i} \quad (135)$$

$RACCONJPTIRYOU$: Ratio of elderly in accessible area to medical facilities by public transport

4.5. Method of calculating Environment indicators

The Method of calculating the indicator for environment is as follows.

(24) CO2 emissions by transportation sector

1) CO2 emissions by transportation sector

CO2 emissions by transportation sector is calculated by the following equation.

$$TUCO2 = \sum_{l} (CO2AU_l + CO2TU_l + CO2AD_l + CO2TD_l) \quad (136)$$

$$CO2AU_l = KU_l \times LL_l \times RAUTO \times RAU_l / 1000 \quad (137)$$

$$CO2TU_l = KU_l \times LL_l \times (1 - RAUTO) \times RTU_l / 1000 \quad (138)$$

$$CO2AD_l = KD_l \times LL_l \times RAUTO \times RAD_l / 1000 \quad (139)$$

$$CO2TD_l = KD_l \times LL_l \times (1 - RAUTO) \times RTD_l / 1000 \quad (140)$$

$$RAU_l = PCO2A1 / VU_l + PCO2A2 \times VU_l + PCO2A3 \times VU_l^2 + PCO2A4 \quad (141)$$

$$RTU_l = PCO2T1 / VU_l + PCO2T2 \times VU_l + PCO2T3 \times VU_l^2 + PCO2T4 \quad (142)$$

$$RAD_l = PCO2A1 / VD_l + PCO2A2 \times VD_l + PCO2A3 \times VD_l^2 + PCO2A4 \quad (143)$$

$$RTD_l = PCO2T1 / VD_l + PCO2T2 \times VD_l + PCO2T3 \times VD_l^2 + PCO2T4 \quad (144)$$

where, if $VU_l < 20, VD_l < 20$ then $VU_l = 20, VD_l = 20$.

$CO2AU_l, CO2AD_l$: Inbound and outbound CO2 emissions from medium-sized cars in link l

$CO2TU_l, CO2TD_l$: Inbound and outbound CO2 emissions from large vehicles in link l

$TUCO2$: CO2 emissions by transportation sector

KU_l, KD_l : Inbound and outbound traffic volume in link l

VU_l, VD_l : Inbound and outbound speed in link l

LL_i : Length of link l

$RAUTO$: Medium-sized car ratio

RAU_l, RAD_l : Inbound and outbound CO2 emission unit from medium-sized cars in link l

RTU_l, RTD_l : Inbound and outbound CO2 emission unit from large vehicles in link l

$PCO2A1, PCO2A2, PCO2A3, PCO2A4$: Parameter of CO2 emission unit from medium-sized cars

$PCO2T1, PCO2T2, PCO2T3, PCO2T4$: Parameter of CO2 emission unit from large vehicles

(25) CO2 emissions by private and industrial sector

1) CO2 emissions by private and industrial sector by zone

CO2 emissions by private and industrial sector by zone is calculated by the following equation.

$$MCO2_i = RCO2_i + CCO2_i + BCO2_i \tag{145}$$

$$RCO2_i = HPCO2_{FLGHCO2_i} \times RFA_i \tag{146}$$

$$CCO2_i = CPCO2_{FLGCCO2_i} \times CFA_i \times \frac{CNB_i}{CBNB_i} \tag{147}$$

$$BCO2_i = BPCO2_{FLGBCO2_i} \times CFA_i \times \frac{1 - CNB_i}{CBNB_i} \tag{148}$$

$RCO2_i$: CO2 emissions from residential sector in zone i

$CCO2_i$: CO2 emissions from commercial sector in zone i

$BCO2_i$: CO2 emissions of business sector in zone i

$MCO2_i$: CO2 emissions by private and industrial sector in zone i

RFA_i : Residential floor area in zone i

CFA_i : Commercial floor area in zone i

CNB_i : Number of service and retail employees in zone i

$CBNB_i$: Number of employees in tertiary industry in zone i

$HPCO2_n$: CO2 emissions per residential floor area for residential CO2 emissions type flag n (t-CO2/m2)

$CPCO2_n$: CO2 emissions per commercial floor area for commercial CO2 emissions type flag n (t-CO2/m2)

$BPCO2_n$: CO2 emissions per business floor area for business CO2 emissions type flag n (t-CO2/m2)

$FLGHCO2_i$: Residential CO2 emissions type flag in zone i

$FLGCCO2_i$: Commercial CO2 emissions type flag in zone i

$FLGBCO2_i$: Business CO2 emissions type flag in zone i

2) CO2 emissions by private and industrial sector

CO2 emissions by private and industrial sector is calculated by the following equation.

$$TMCO2 = TRCO2 + TCCO2 + TBCO2 \tag{149}$$

$$TRCO2 = \sum_i RCO2_i \tag{150}$$

$$TCCO2 = \sum_i CCO2_i \tag{151}$$

$$TBCO2 = \sum_i BCO2_i \tag{152}$$

$TRCO2$: CO2 emissions from residential sector

$TCCO2$: CO2 emissions from commercial sector

$TBCO2$: CO2 emissions from business sector

$TMCO2$: CO2 emissions by private and industrial sector

(26) Amount of fixed CO2 by green

1) Amount of fixed CO2 by green

Amount of fixed CO2 by green is calculated by the following equation.

$$TGSCO2 = GSCO2PRM \times \sum_i ZFR_i \tag{153}$$

ZFR_i : Forest area in zone i

$GSCO2PRM$: Unit amount of fixed CO2 per forest area (tCO2/ha/year)

$TGSCO2$: Amount of fixed CO2 by green

(27) NOx emissions

1) NOx emissions by link

NOx emissions by link is calculated by the following equation.

$$LNOX_l = NOXAU_l + NOXTU_l + NOXAD_l + NOXTD_l \tag{154}$$

$$NOXAU_l = KU_l \times LL_l \times RAUTO \times PAU_l / 1000 \tag{155}$$

$$NOXTU_l = KU_l \times LL_l \times (1 - RAUTO) \times PTU_l / 1000 \tag{156}$$

$$NOXAD_l = KD_l \times LL_l \times RAUTO \times PAD_l / 1000 \tag{157}$$

$$NOXTD_l = KD_l \times LL_l \times (1 - RAUTO) \times PTD_l / 1000 \tag{158}$$

$$PAU_l = PNOXA(VU_l) \tag{159}$$

$$PTU_l = PNOXT(VU_l) \tag{160}$$

$$PAD_l = PNOXA(VD_l) \tag{161}$$

$$PTD_l = PNOXT(VD_l) \tag{162}$$

$NOXAU_l, NOXAD_l$: Inbound and outbound NOx emissions from medium-sized cars in link l

$NOXTU_l, NOXTD_l$: Inbound and outbound NOx emissions from large vehicles in link l

$LNOX_l$: NOx emissions in link l

KU_l, KD_l : Inbound and outbound traffic volume in link l

VU_l, VD_l : Inbound and outbound speed in link l

LL_i : Length of link l

$RAUTO$: Medium-sized car ratio

PAU_l, PAD_l : Inbound and outbound NOx emission unit from medium-sized cars in link l

PTU_l, PTD_l : Inbound and outbound NOx emission unit from large vehicles in link l

$PNOXA(vn)$: NOx emission unit of medium-sized cars for speed vn

$PNOXT(vn)$: NOx emission unit of large vehicles for speed vn

Link speed is rounded to every 10km/h, and emission unit which corresponds to is used. Where, if $VU_l < 20, VD_l < 20$ then $VU_l = 20, VD_l = 20$, and if $VU_l > 110, VD_l > 110$ then $VU_l = 110, VD_l = 110$.

2) NOx emissions

NOx emissions is calculated by the following equation.

$$TNOX = \sum_l LNOX_l \tag{163}$$

$TNOX$: NOx emissions

3) NOx emissions by zone

NOx emissions by zone is calculated by the following equation, by aggregating links l included in zone i.

$$ZNOX_i = \sum_{l \in i} LNOX_l \tag{164}$$

$ZNOX_i$: NOx emissions in zone i

(28) Green and agricultural land coverage rate

1) Green and agricultural land coverage

Green and agricultural land coverage is calculated by the following equation.

$$TGA = \sum_i (ZAG_i + ZFR_i) \tag{165}$$

ZAG_i : Agricultural land area in zone i

ZFR_i : Forest area in zone i

TGA : Total of green and agricultural land area

2) Green and agricultural land coverage rate

Green and agricultural land coverage rate is calculated by the following equation.

$$TRGA = \frac{TGA}{\sum_i ZA_i} \tag{166}$$

ZA_i : Area of zone i

$TRGA$: Green and agricultural land coverage rate

(29) Fuel consumption by transportation sector

1) CO2 emissions from medium-sized cars and large vehicles

CO2 emissions from medium-sized cars and large vehicles is calculated by the following equation,

$$CO2AU_l = KU_l \times LL_l \times RAUTO \times RAU_l / 1000 \tag{167}$$

$$CO2TU_l = KU_l \times LL_l \times (1 - RAUTO) \times RTU_l / 1000 \tag{168}$$

$$CO2AD_l = KD_l \times LL_l \times RAUTO \times RAD_l / 1000 \tag{169}$$

$$CO2TD_l = KD_l \times LL_l \times (1 - RAUTO) \times RTD_l / 1000 \tag{170}$$

$$RAU_l = PCO2A1 / VU_l + PCO2A2 \times VU_l + PCO2A3 \times VU_l^2 + PCO2A4 \tag{171}$$

$$RTU_l = PCO2T1 / VU_l + PCO2T2 \times VU_l + PCO2T3 \times VU_l^2 + PCO2T4 \tag{172}$$

$$RAD_l = PCO2A1 / VD_l + PCO2A2 \times VD_l + PCO2A3 \times VD_l^2 + PCO2A4 \tag{173}$$

$$RTD_l = PCO2T1 / VD_l + PCO2T2 \times VD_l + PCO2T3 \times VD_l^2 + PCO2T4 \tag{174}$$

where, if $VU_l < 20, VD_l < 20$ then $VU_l = 20, VD_l = 20$.

$CO2AU_l, CO2AD_l$: Inbound and outbound CO2 emissions from medium-sized cars in link l

$CO2TU_l, CO2TD_l$: Inbound and outbound CO2 emissions from large vehicles in link l

$TUCO2$: CO2 emissions by transportation sector
KU_l, KD_l : Inbound and outbound traffic volume in link l
VU_l, VD_l : Inbound and outbound speed in link l
LL_i : Length of link l
$RAUTO$: Medium-sized car ratio
RAU_l, RAD_l : Inbound and outbound CO2 emission unit from medium-sized cars in link l
RTU_l, RTD_l : Inbound and outbound CO2 emission unit from large vehicles in link l
$PCO2A1, PCO2A2, PCO2A3, PCO2A4$: Parameter of CO2 emission unit from medium-sized cars
$PCO2T1, PCO2T2, PCO2T3, PCO2T4$: Parameter of CO2 emission unit from large vehicles

2) Gasoline consumption

Gasoline consumption is calculated by the following equation.

$$GSL = \sum_l (CO2AU_l + CO2AD_l) / PGSLCO2 \quad (175)$$

$PGSLCO2$: CO2 emissions per Gasoline (km)
GSL : Gasoline consumption (l/day)

3) Diesel fuel consumption

Diesel fuel consumption is calculated by the following equation.

$$LGH = \sum_l (CO2TU_l + CO2TD_l) / PLGHCO2 \quad (176)$$

$PLGHCO2$: CO2 emissions per one Diesel Fuel (km/l)
LGH : Diesel fuel consumption (l/day)

(30) Fuel consumption by private and industrial sector

1) Fuel consumption by private and industrial sector by zone

Fuel consumption by private and industrial sector by zone is calculated by the following equation.

$$MFL_i = RLF_i + CFL_i + BFL_i \quad (177)$$

$$RFL_i = HPFL_{FLGHFL_i} \times RFA_i \quad (178)$$

$$CFL_i = CPFL_{FLGCFL_i} \times CFA_i \times \frac{CNB_i}{CBNB_i} \quad (179)$$

$$BFL_i = BPFL_{FLGBFL_i} \times CFA_i \times \frac{1 - CNB_i}{CBNB_i} \quad (180)$$

RFL_i : Fuel consumption of residential sector in zone i
CFL_i : Fuel consumption of commercial sector in zone i
BFL_i : Fuel consumption of business sector in zone i
MFL_i : Fuel consumption by private and industrial sector in zone i
RFA_i : Residential floor area in zone i
CFA_i : Commercial floor area in zone i
CNB_i : Number of service and retail employees in zone i
$CBNB_i$: Number of employees in tertiary industry in zone i

$HPFL_n$: Fuel consumption to convert by kerosene per residential floor area for residential fuel consumption type flag n (L/m2)

$CPFL_n$: Fuel consumption to convert by kerosene per commercial floor area for commercial fuel consumption type flag n (L/m2)

$BPFL_n$: Fuel consumption to convert by kerosene per commercial floor area for commercial fuel consumption type flag n (l/m2)

$FLGHFL_i$: Residential fuel consumption type flag in zone i

$FLGCFL_i$: Commercial fuel consumption type flag in zone i

$FLGBFL_i$: Business fuel consumption type flag in zone i

2) Fuel consumption by private and industrial sector

Fuel consumption by private and industrial sector is calculated by the following equation.

$$TMFL = TRFL + TCFL + TBFL \qquad (181)$$

$$TRFL = \sum_i RFL_i \qquad (182)$$

$$TCFL = \sum_i CFL_i \qquad (183)$$

$$TBFL = \sum_i BFL_i \qquad (184)$$

$TMFL$: Fuel consumption by residential sector

$TRFL$: Fuel consumption by commercial sector

$TCFL$: Fuel consumption by industrial sector

$TBFL$:Fuel consumption by private and industrial sector

4.6. Method of calculating Vitality indicators

The Method of calculating the indicator for vitality is as follows.

(31) Employee

1) Number of employee by zone

Number of employee by zone is calculated by the following equation.

$$ZNB_i = \sum_h NB_{hi} \qquad (185)$$

NB_{hi} : Number of employee of industrial type h in zone i

ZNB_i : Number of employee in zone i

(32) Average time distance of trips

1) Average time distance of trips by all mode

Average time distance of trips by all purpose is calculated by the following equation .

$$TSATRPT = \frac{\sum_m \sum_s \sum_i \sum_j \left(OD_{msij} \times T_{sij} \right)}{\sum_m \sum_s \sum_i \sum_j OD_{msij}} \qquad (186)$$

OD_{msij} : Trips of purpose m by mode s between zone i and j

T_{sij} : Time distance by mode s between zone i and j

$TSATRPT$: Averaged time distance of purpose m in zone i

(33) Visitors to central commercial area

1) Number of visitors to central commercial area of all purpose

Number of visitors to central commercial area of all purpose is calculated by the following equation , subject to $FLGSGC_j = 1$.

$$TSCGOD = \sum_m \sum_s \sum_i \sum_j OD_{msij} \qquad (187)$$

OD_{msij} : Trips of purpose m by mode s between zone i and j

$FLGSGC_j$: Flag for central commercial area

(if zone j is central commercial area:1, the other: 0)

$TSCGOD$: Number of visitors to central commercial area of all purpose

2) Number of visitors to central commercial area of private purpose

Number of visitors to central commercial area of private purpose is calculated by the following equation, subject to $FLGSGC_j = 1$.

$$FSCGOD = \sum_{m=FM} \sum_s \sum_i \sum_j OD_{msij} \qquad (188)$$

FM : Category number of private purpose

$FSCGOD$: Number of visitors to central commercial area of private purpose

(34) Accessibility between sightseeing spots

1) Time distance between major sightseeing spots

Time distance by car of target OD pair is extracted by defining zone of major sightseeing spots.

$$STCAR_{n1,n2} = T_{car,n1,n2} \tag{189}$$

$T_{car,n1,n2}$: Time distance by car between sightseeing spot $n1$ and $n2$

$STCAR_{n1,n2}$: Time distance between sightseeing spot $n1$ and $n2$

(35) Total value of land price

1) Total value of residential land price by zone

Total value of residential land price by zone is calculated by the following equation.

$$ZTRLP_i = RLP_i \times RLA_i \tag{190}$$

$ZTRLP_i$: Total value of residential land price in zone i

RLP_i : Residential land price in zone i

RLA_i : Residential land area in zone i

2) Total value of commercial land price by zone

Total value of commercial land price by zone is calculated by the following equation.

$$ZTCLP_i = CLP_i \times CLA_i \tag{191}$$

CLP_i : Value of Commercial land price in zone i

CLA_i : Commercial land area in zone i

$ZTCLP_i$: Total value of commercial land price in zone i

3) Total value of land price by zone

Total value of land price in zone is calculated by the following equation.

$$ZTLP_i = ZTRLP_i + ZTRLP_i \tag{192}$$

$ZTLP_i$: Total value of land price in zone i

4) Total value of residential land price

Total value of residential land price is calculated by the following equation.

$$TTRLP = \sum_i ZTRLP_i \tag{193}$$

$TTRLP$: Total value of residential land price

5) Total value of commercial land price

Total value of commercial land price is calculated by the following equation.

$$TTCLP = \sum_i ZTCLP_i \tag{194}$$

$TTCLP$: Total value of commercial land price

6) Total value of land price

Total value of land price is calculated by the following equation.

$$TTLP = TTRLP + TTCLP \tag{195}$$

$TTLP$: Total value of land price

4.7. Method of calculating Administrative service cost indicator

The Method of calculating the indicator for administrative service cost is as follows.

(36) Road maintenance cost

The road maintenance cost is subject to calculate for cost of road. To describe the relationship between evaluation indicator and the cost when the service level of road is changed, the unit cost of road maintenance by road type is defined that higher type and class of road needs higher maintenance cost.

1) Road maintenance cost

Road maintenance cost is calculated by the following equation.

$$TCRM = \sum_{LTY}\sum_{l}(CRM_{LTY} \times LL_{LTY,l}) \quad (196)$$

$LL_{LTY,l}$: Length of link l of link type LTY (km)

CRM_{LTY} : Unit cost of road maintenance for link type LTY (thousand yen/km- year)

$TCRM$: Road maintenance cost (thousand yen/year)

(37) Elder care service cost

Concerning elder care service cost, the moving cost is subject to calculate to analyze the relationship between the cost and facility arrangement or urban structure in addition to care payment. And the maintenance cost of service facility is also considered because that is involved the number of facilities directly.

1) Number of elder care service user

The number of elder care service user is calculated by the following equation.

$$KNJ_i = \sum_{h}(NJ_{hi} \times PCJ_h \times PCH) \quad (197)$$

NJ_{hi} : Population by age h in zone i

PCJ_h : Utilization rate of elder care service by age h

PCH : Adjustment term for number of elder care service user for a year

KNJ_i : Number of elder care service user in zone i

2) Payment of elder care service by zone

Payment of elder care service by zone is calculated by the following equation.

$$ZCC_i = KNJ_i \times PCC \times (1 - PCR) \quad (198)$$

PCC : Payment of elder care service per capita (thousand yen/person)

PCR : Contribution percentage of Long-term Care Insurance

ZCC_i : Payment of elder care service in zone i

3) Moving cost by zone

Moving cost by zone is calculated by the following equation.

$$ZTC_i = KNJ_i \times 12 \times \frac{PTU}{PTC} \times 2 \times MINTKAIGO_i \times \frac{PCT}{1000} \quad (199)$$

PTU : Times of utilization per capita for a month (times/month)

PTH : Number of correspondence per a day by a helper (number/day)

PTC : Time value

$MINTKAIGO_i$: Time distance to the nearest elder care service facility in zone i

$T_{car,i,ZKAIGO_n}$: Time distance by car to the service site n in zone i

$ZKAIGO_n$: Zone number of the elder care service facility site n

ZTC_i : Moving cost in zone i

PMC : Maintenance cost per one elder care service facility site (thousand yen)

ZMC_i : Maintenance cost of elder care service facility sites in zone i (thousand yen)

4) Maintenance cost of elder care service facility sites by zone

Maintenance cost of elder care service facility sites is calculated by the following equation, subject to $i = ZKAIGO_n$.

$$ZMC_i = PMC \tag{200}$$

5) Elder care service cost by zone

Elder care service cost by zone is calculated by the following equation as the sum of payment of elder care service, moving cost, and maintenance cost of elder care service facility sites.

$$ZKC_i = ZCC_i + ZTC_i + ZMC_i \tag{201}$$

ZKC_i : Elder care service cost in zone i (thousand yen)

6) Elder care service payment, Moving cost, Maintenance cost of facility sites, and Elder care service cost

Payment of elder care service, moving cost, maintenance cost of elder care service facility sites, and elder care service cost is calculated by the following equation.

$$TZCC = \sum_i ZCC_i \tag{202}$$

$$TZTC = \sum_i ZTC_i \tag{203}$$

$$TZMC = \sum_i ZMC_i \tag{204}$$

$$TZKC = \sum_i ZKC_i \tag{205}$$

$TZCC$: Payment of elder care service

$TZTC$: Moving cost

$TZMC$: Maintenance cost of elder care service facility sites

$TZKC$: Elder care service cost

(38) Public transport cost

Concerning the public transport, the government assistance cost for bus operation is calculated. The government assistance cost is calculated as the difference of income and expenditure of bus service which is based on the number of transported passengers by link that is obtained from Urban Structure Estimation model.

1) Bus traffic volume by link

Bus traffic volume by link is calculated by the following equation.

$$NBSL_l = BBKU_l + BBKD_l + BRKU_l + BRKD_l \tag{206}$$

$BBKU_l, BBKD_l$: Bus traffic volume of inbound and outbound in bus link l

$BRKU_l, BRKD_l$: Bus traffic volume of inbound and outbound in railway link l

2) Vehicle-km of Bus

Vehicle-km of Bus is calculated by the following equation.

$$NBSL = \sum_{l} (NBS_l \times LLB_l) \tag{207}$$

NBS_l is set as follows,

if $BK_l < PBJ^0$,

$$NBS_l = 0, \tag{208}$$

else if $PBJ^0 < BK_l < PBJ^1$,

$$NBS_l = PBHS \tag{209}$$

else if $PBJ^1 < BK_l < PBJ^2$,

$$NBS_l = INT(BK_l / PBPJ) \tag{210}$$

else if $PBJ^2 < BK_l$

$$NBS_l = INT(PBJ^2 / PBPJ + (BK_l - PBJ^2) / PBSJ) \tag{211}$$

NBS_l : Number of bus service in link l (service/day)

PBJ^0 : Standard passengers for bus route disuse (person/day)

PBJ^1 : Standard passengers for bus route sustain by assistance (person/day)

$PBHS$: Number of bus service setting for bus route sustain by assistance (service/day)

PBJ^2 : Profitable line of passengers (person/day)

$PBPJ$: Passengers per a bus service in profitable state (person/service)

$PBSJ$: Passengers for increasing one bus service in high profit (transportable passengers)(person/service)

3) Expenditure

Expenditure is calculated by the following equation.

$$TBCOST = PBPC \times NBSL \tag{212}$$

$PBPC$: Unit cost (yen/vehicle-km)

$TBCOST$: Expenditure (yen)

4) Total transport person-km

Total transport person-km is calculated by the following equation, subject to $NBSR_i > 0$.

$$TNBSL = \sum_{i} (BK_l \times LLB_l) \tag{213}$$

$TNBSL$: Total transport person-km (person-km)

5) Income

Income is calculated by the following equation.

$$TBINC = TNBSL \times PBFR \tag{214}$$

$TBINC$: Income (yen)

$PBFR$: Base fare rate (yen/person-km)

NBS_l : Number of bus service in link l (service/day)

LLB_l : Length of bus link l (km)

$NBSL$: Vehicle-km of Bus (vehicle-km)

6) Government assistance cost

Government assistance cost is calculated by the following equation, by assuming that government assists for deficit of bus operation with a fixed rate, subject to $TBINC < TBCOST$.

$$BLBS = PBHR \times (TBCOST - TBINC) \tag{215}$$

$BLBS$: Government assistance cost (yen)

$PBHR$: Government assistance rate

(39) Elementary and junior high school cost

Elementary and junior high school cost is calculated as a sum of costs for students, schools, classes, school bus operation.

1) Numbers of students of elementary school and junior high school by school district

Numbers of students of elementary school and junior high school by school district are calculated by the following equations.

$$ENJ_{en} = \sum_{i \in en} (NJ_{LANK1,i} \times 0.6) \tag{216}$$

$$JNJ_{jn} = \sum_{i \in jn} (NJ_{LANK1,i} \times 0.2 + NJ_{LANK2,i} \times 0.2) \tag{217}$$

$NJ_{LANK1,i}$: Population age 5-14 in zone i

$NJ_{LANK2,i}$: Population age 15-19 in zone i

ENJ_{en} : Number of students in elementary school district en

JNJ_{jn} : Number of students in junior high school district jn

2) Fixed costs for number of schools by elementary and junior high school district

Fixed costs for number of schools by elementary and junior high school district are calculated by the following equations, subject to $ENJ_{en} \geq PEMJ$ and $JNJ_{jn} \geq PJMJ$, otherwise equal to zero.

$$EFC_{en} = PEFC \tag{218}$$

$$JFC_{jn} = PJFC \tag{219}$$

$PEFC$: Fixed cost of elementary school (thousand yen)

$PJFC$: Fixed cost of elementary school (thousand yen)

$PEMJ$: Minimum students of elementary school

$PJMJ$: Minimum students of junior high school

EFC_{en} : Fixed cost for number of schools in elementary school district en (thousand yen)

JFC_{jn} : Fixed cost for number of schools in junior high school district jn (thousand yen)

3) Variable costs for number of classes by elementary and junior high school district

Variable costs for number of classes by elementary and junior high school district are calculated by the following equations

$$ECC_{en} = ROUND(ENJ_{en} / PEAJ, 0) \times PECC \tag{220}$$

$$JCC_{jn} = ROUND(JNJ_{jn} / PJAJ, 0) \times PJCC \tag{221}$$

$PEAJ$: Average students per a class of elementary school

$PJAJ$: Average students per a class of junior high school

$PECC$: Variable costs per a class of elementary school (thousand yen)

$PJCC$: Variable costs per a class of junior high school (thousand yen)

ECC_{en} : Variable cost for number of classes in elementary school district en (thousand yen)

JCC_{jn} : Variable cost for number of classes in junior high school district jn (thousand yen)

4) Variable costs for number of students by elementary and junior high school district

Variable costs for number of students by elementary and junior high school district are calculated by the following equations.

$$EJC_{en} = ENJ_{en} \times PEJC \quad (222)$$

$$JJC_{jn} = ENJ_{jn} \times PJJC \quad (223)$$

$PEJC$: Variable costs per a student of elementary school (thousand yen)

$PJJC$: Variable costs per a student of junior high school (thousand yen)

EJC_{en} : Variable cost for number of students in elementary school district en (thousand yen)

JJC_{jn} : Variable cost for number of students in junior high school district jn (thousand yen)

5) School bus costs by elementary and junior high school district

School bus costs by elementary and junior high school district are calculated by the following equations, subject to $ENJ_{en} < PEMJ$ and $JNJ_{jn} < PJMJ$, otherwise equal to zero.

$$EBC_{en} = ROUNDUP(ENJ_{en} / PEBJ, 0) \times PEBC \quad (224)$$

$$JBC_{jn} = ROUNDUP(JNJ_{jn} / PJBJ, 0) \times PJBC \quad (225)$$

$PEBJ$: Transportable number of students per a school bus of elementary school

$PJBJ$: Transportable number of students per a school bus of junior high school

$PEBC$: Cost for school bus of elementary school (thousand yen)

$PJBC$: Cost for school bus of junior high school (thousand yen)

EBC_{en} : School bus costs in elementary school district en (thousand yen)

JBC_{jn} : School bus costs in junior high school district jn (thousand yen)

6) Total of elementary school and junior high school cost by school districts

Total of elementary school and junior high school cost by school districts are calculated by the following equation.

$$ETC_{en} = EFC_{en} + ECC_{en} + EJC_{en} + EBC_{en} \quad (226)$$

$$JTC_{jn} = JFC_{jn} + JCC_{jn} + JJC_{jn} + JBC_{jn} \quad (227)$$

ETC_{en} : Total of elementary school cost in elementary school district en (thousand yen)

JTC_{jn} : Total of junior high school cost in junior high school district jn (thousand yen)

7) Total of elementary school cost

Total of elementary school cost is calculated by the following equation as a sum of fixed cost for number of schools, variable cost for number of classes variable cost for number of students and school bus costs of elementary school.

$$TEFC = \sum_{en} EFC_{en} \tag{228}$$

$$TECC = \sum_{en} ECC_{en} \tag{229}$$

$$TEJC = \sum_{en} EJC_{en} \tag{230}$$

$$TEBC = \sum_{en} EBC_{en} \tag{231}$$

$$TETC = \sum_{en} ETC_{en} \tag{232}$$

$TEFC$: Fixed cost for number of elementary schools
$TECC$: Variable cost for number of classes in elementary school
$TEJC$: Variable cost for number of students in elementary school
$TEBC$: School bus costs of elementary school
$TETC$: Total of elementary school cost

8) Total of junior high school cost

Total of junior high school cost is calculated by the following equation as a sum of fixed cost for number of schools, variable cost for number of classes variable cost for number of students and school bus costs of junior high school.

$$TJFC = \sum_{jn} JFC_{jn} \tag{233}$$

$$TJCC = \sum_{jn} JCC_{jn} \tag{234}$$

$$TJJC = \sum_{jn} JJC_{jn} \tag{235}$$

$$TJBC = \sum_{jn} JBC_{jn} \tag{236}$$

$$TJTC = \sum_{jn} JTC_{jn} \tag{237}$$

$TJFC$: Fixed cost for number of junior high schools
$TJCC$: Variable cost for number of classes in junior high school
$TJJC$: Variable cost for number of students in junior high school
$TJBC$: School bus costs of junior high school
$TJTC$: Total of junior high school cost

5. Model application system

5.1. Basic concept for system development

(1) Used language

Programming is described by the C + + and the compiler has adopted the Microsoft VisualC + + 2008. The program is designed and implemented to be flexible with the class modules that can take into account the maintenance.

(2) System requirements

The system is designed to run on Microsoft Windows XP. It is a console application without GUI of program, and the main control is described in a batch file. System requirements are shown in Table 14.

Table 14. System requirements

OS	Microsoft WindowsXP/Vista/ 7
CPU	x86 compatible CPU（After Intel Core2 Duo）
Memory	More than 1GB

(3) Execution means

The operating of the subprogram is controlled flexibly by the execution right or wrong switch which described in batch file in order to support the situation that the practice right or wrong of the submodel cannot but be chosen according to the setting of the representative value or the assumption of input data. A method to call each submodel from one execute file is adopted because the management of the program became complicated when one execute file for each submodel is prepared.

The reason why converting execution switch by batch file is adopted is that the operation check of each submodels and the easy change of working submodels are possible, though I do not develop the user interface at present. Therefore, even if all zone sizes are the same, execution of the simulation is possible if execution switches in batch file of the Zone-size Transformation Tool are turned off.

(4) Calculation Time

The calculation time using this system was approximately 270 minutes in the case of virtual city with land use measure zone approximately 1,600, land use analysis zone approximately 400, traffic analysis zone approximately 100 by the computer specifications of the Intel Core2 Duo 3.16GHz, CPU 3.25GB RAM, and in the case of practical city with land use measure and analysis zone approximately 2,000, traffic analysis zone approximately 300 was approximately 100 minutes. Thus, it has been confirmed that this system can calculate with in the range of practical time.

However it was confirmed that the calculation time became enormous in a calculation about the conversion of the OD data from traffic analysis zone to land use measure zone in the case of land use measure zone approximately 16,000, and a calculation within the range of practical time was difficult. This is that the number of the OD pairs is zonal numerical square and becomes enormous with approximately 200 million ways, and a notice is necessary for the point where a calculation is difficult with the 32bit machine to carry out such a large-scale calculation.

5.2. System structure

System structure is illustrated in Figure 10. The processing details, that is input and output zone shape, file name, process type and distribution indicator for each target data, are described in "Zoneconvert.ini", and it is stored in the system. Zone-size Transformation Tool is a gathering of transformation process for zone division and integration. It is implemented as executing numerical process according to correspondence file with intermediate zone file and processing details file and outputting the result files.

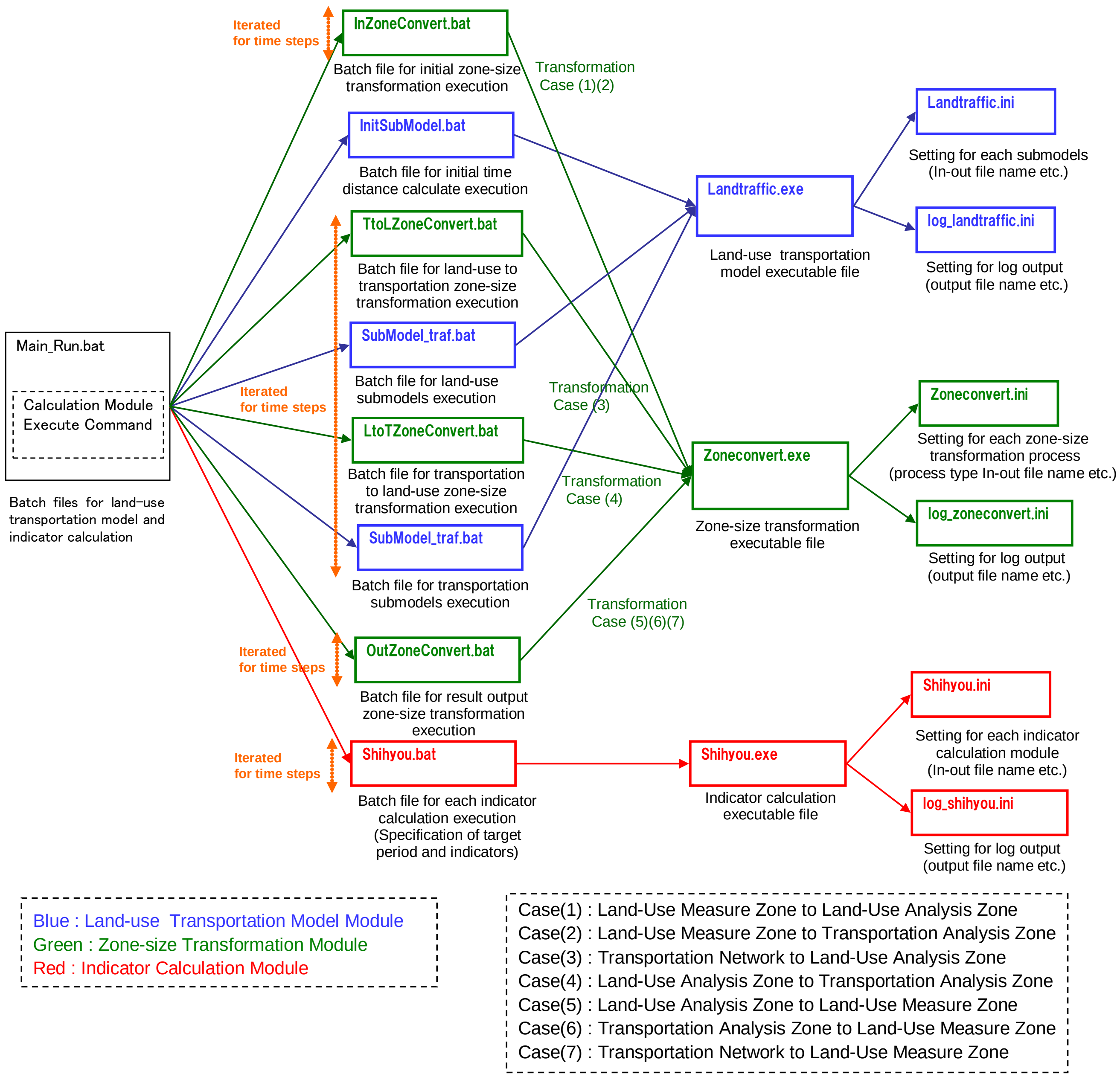

Figure 10. System structure

5.3. Processing flow

Processing flow of Future Urban Structure Estimation Model and Zone-size Transformation Tool is shown in Figure 11, and it of Future Urban Structure Evaluation Model is shown in Figure 12. Future Urban Structure Estimation Model is consist of 17 submodels, 4 data conversion models and Zone-size Transformation Tool which connect them. Zone-size transformations before and after simulation calculation are processed the multiple period together. Land-use transportation model and zone-size transformation between land-use analysis zone and transportation analysis zone are executed by repetitive multiple process for each period. Future Urban Structure Evaluation Model is consist of 36 submodels, and these models are executed for each period.

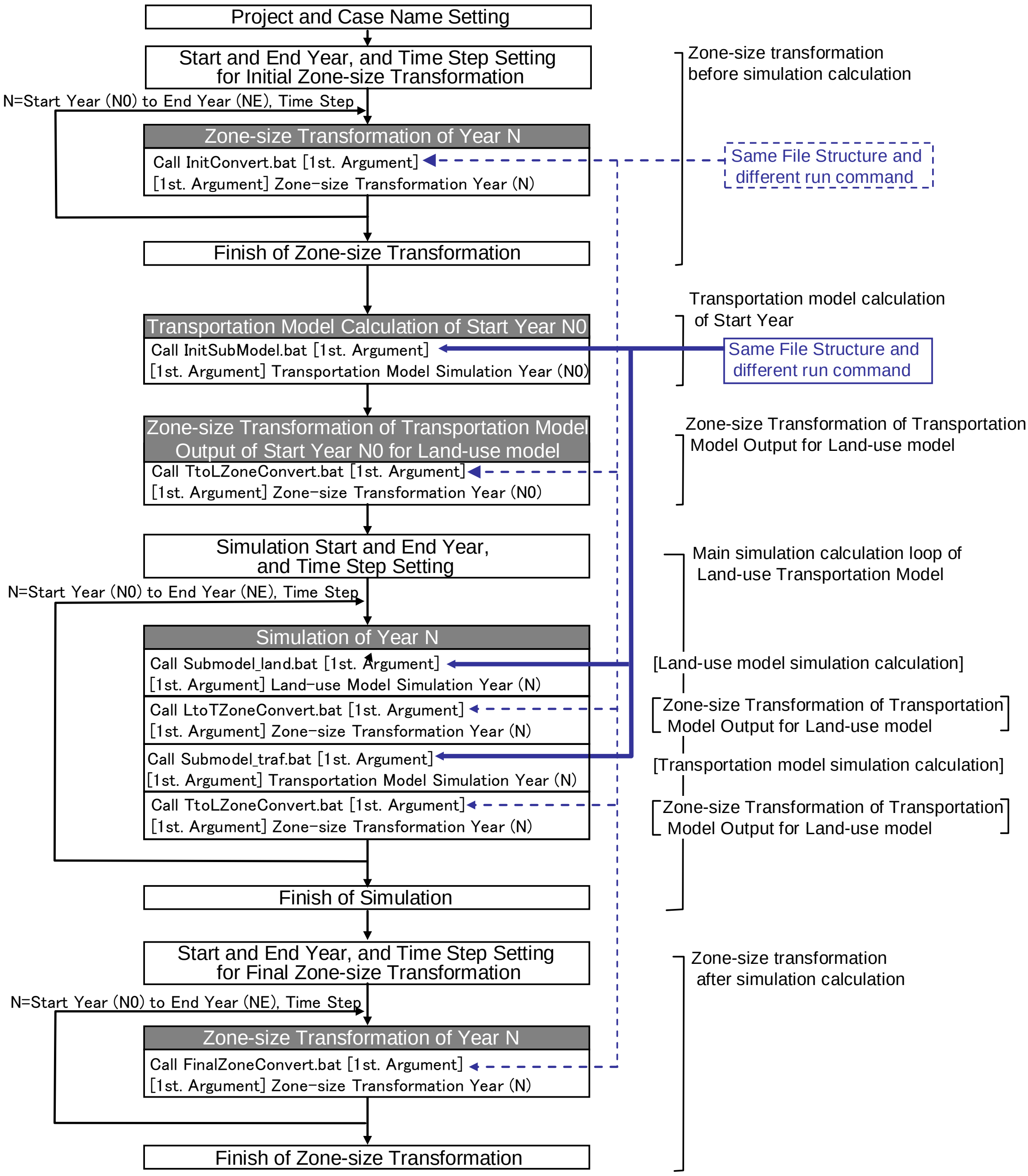

Figure 11. Processing flow of Future Urban Structure Estimation Model and Zone-size Transformation Tool

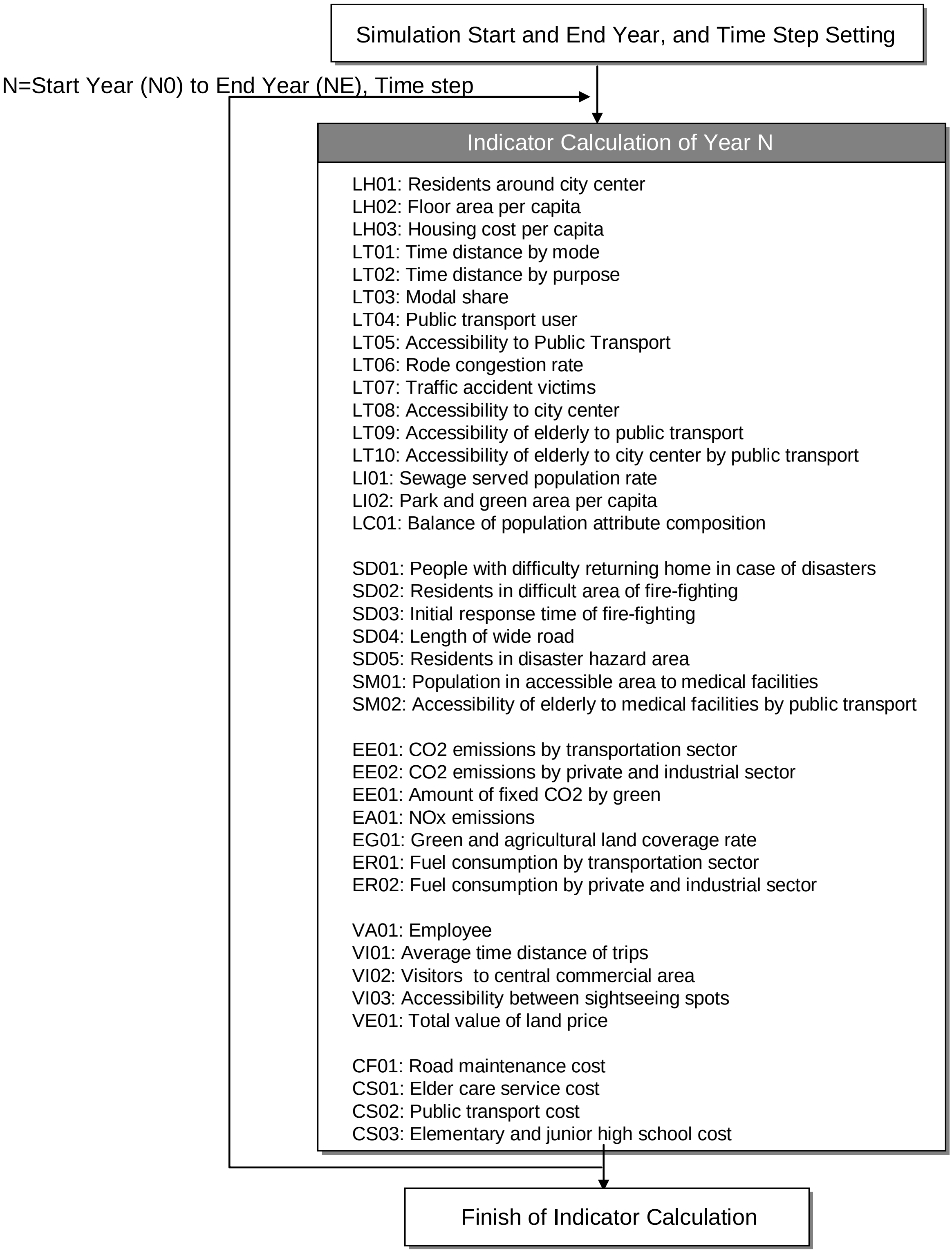

Figure 12. Processing flow of Future Urban Structure Evaluation Model

5.4. Input and output structure of files

Input and output structures of files on land-use model and transportation model which compose Future Urban Structure Estimation Model are shown in Table 15 and 16, respectively. And the process and flow of input and output files in a period are illustrated in Figure 13, 14 and 15, because it has quite complex structure. Moreover Input and output structure of files on Zone-size Transformation Tool is shown in Table 17, and it on Future Urban Structure Evaluation Model is shown in Table 18 and 19.

Table 15. Input and output structure of files
(Future Urban Structure Estimation Model: Land-use Model)

	Submodel No.	Submodel	Input files			Output files
			Previous period	File type	Contents	Contents
Land-Use Model	1	Accessibility Model	*	E/M	Population distribution by age	Accessibility
			*	E/M	Household distribution by type	Zonal traffic condition
			*	E/M	Employee distribution by industry	
			*	ZC/M	Time distance by car	
			*	ZC/M	Time distance by public transport	
	2	Land Supply Model		E	Land supply model parameter	Land area by use type
				ZC/E	Zonal land condition	
				ZC/E	Zonal condition	
				E	Land supply adjustment term	
			*	E/M	Land price by use type	
	3	Floor Supply Model		E	Floor supply model parameter	Floor area by use type
				ZC/E	Zonal condition	Lower limit of floor rent
				E	Floor supply adjustment term	
			*	E/M	Land price by use type	
				M	Land area by use type	
	4	Household Type Transition Model		E	Household type transition probability	Transformed household distribution by type
						Number of generated household
			*	E/M	Household distribution by type	Number of disappear household
	5	Migration Rate Model		E	Reservation rate by household type	Number of migration household
				M	Transformed Household distribution by type	Non-migration household distribution
	6	Location Choice Target Household Adjustment		E	Total population by age	Number of location choice target households
				E	Population conversion coefficient	
				M	Number of generated household	
				M	Number of migration household	
				M	Non-migration household distribution	
	7	Household Location Choice Model		ZC/E	Zonal condition	Household distribution by type
				E	Household location choice model parameter	Residential floor rent
				E	Household location choice adjustment term	Residential floor area
			*	E/M	Household distribution by type	
				M	Accessibility	
				M	Zonal traffic condition	
				M	Land area by use type	
				M	Floor area by use type	
				M	Lower limit of floor rent	
				M	Non-migration household distribution	
				M	Number of location choice target households	
	8	Population Conversion		E	Population conversion coefficient	Population distribution by age
				M	Household distribution by type	
	9	Firm Location Choice Model		ZC/E	Zonal condition	Employee distribution by industry
				E	Employee Condition	Commercial floor rent
				E	Firm location choice model parameter	Commercial floor area
				E	Firm location choice adjustment term	
			*	E/M	Employee distribution by industry	
				M	Accessibility	
				M	Zonal traffic condition	
				M	Land area by use type	
				M	Floor area by use type	
				M	Lower limit of floor rent	
	10	Land Price Model		E	Land price model parameter	Land price by use type
				E	Land price adjustment term	
				M	Land area by use type	
				M	Household distribution by type	
				M	Employee distribution by industry	

E: Exogenous file
M: Endogenous file by Future Urban Structure Estimation Model
ZC: Input file by Zone-Size Tranformation Tool

Table 16. Input and output structure of files
(Future Urban Structure Estimation Model: Transportation Model)

	Submodel No.	Submodel	Input files: Previous period	Input files: File type	Input files: Contents	Output files: Contents
Transportation model	C01	Data Conversion for Transportation Model		E	School attendance and employment rate by age	Population by age, industry and license
				E	Population index conversion coefficient	Population index
				ZC/E	Student distribution	Population by zone, age and license
				E	Licensed rate by industry	
				ZC/M	Population distribution by age	
				ZC/M	Employee distribution by industry	
	11	Trip Generation Model		E	Trip production rate by purpose, industry, age and	Generation and attraction trip
				E	Licensed rate adjustment term by purpose and	
				E	Generation trip adjustment term	
				E	Attraction trip adjustment term	
				E	Trip generation and attraction model parameter	
				M	Population by age, industry and license	
				M	Population index	
	12	Trip Distribution Model		E	Present trip by mode and purpose	Distribution trip of commuting
				ZC/E	Zonal condition	Distribution trip of school commuting under 15
				E	Distribution trip adjustment term	Distribution trip of school commuting over 15
				E	Trip distribution model parameter	Distribution trip of home returning
				E	Distribution trip of student under 15	Distribution trip of business
				E	Distribution trip of student over 15	Distribution trip of private
			*	M	Time distance by car	
			*	M	Time distance by public transport	
				M	Generation and attraction trip	
	13	Mode Choice Model		M	Population by zone, age and license	Walk trip
				E	Present trip population rate	Bus and tram trip
				E	Zone matching data	Railway trip
				E	Present modal share	Car trip
				E	Walk mode choice model parameter	Trip by mode and purpose
				E	Transit mode choice model parameter	Total distribution trip of school commuting
				E	Walk mode choice adjustment term	
				E	Transit mode choice adjustment term	
			*	M	Time distance by car (except for zone inside)	
			*	M	Time distance by mass transport	
				M	Distribution trip of commuting	
				M	Distribution trip of school commuting under 15	
				M	Distribution trip of school commuting over 15	
				M	Distribution trip of home returning	
				M	Distribution trip of business	
				M	Distribution trip of private	
	14	Route Assignment Model (Walk)		E	Walk network	Walk traffic volume
				E	Walk route assignment model parameter	Distance by walk
				E/M	Walk trip	Time distance by walk
						Time distance including fee by walk
	15	Route Assignment Model (Bus and Tram)		E	Bus and tram network	Bus and tram traffic volume
				E	Bus and tram route assignment model parameter	Distance by bus and tram
				E/M	Bus and tram trip	Time distance by bus and tram
						Time distance including fee by bus and tram
	16	Route Assignment Model (Railway)		E	Railway network	Railway traffic volume
				E	Railway route assignment model parameter	Distance by railway
				E/M	Railway trip	Time distance by railway
						Time distance including fee by railway
	C02	Data Conversion of Outside Zone Expansion		E	Outside zone car trip	Car trip for outside zone extension
				E/M	Car trip	
	17	Route assignment model (Car)		E	Car network	Car traffic volume
				E	Car route assignment model parameter	Distance by car for outside zone extension
				M	Car trip for outside zone extension	Time distance by car for outside zone extension
						Time distance including fee by car for outside
						User equilibrium assignment index of car
	C03	Data conversion of Time Distance by Car		M	Car traffic Volume	Time distance by car
	C04	Data Conversion of Time Distance by Public Transport		E	Mass transport time distance base data	Time distance by car (except for zone inside)
				M	Time distance by bus and tram	Time distance by public transport
				M	Time distance by railway	Time distance by mass transport
				M	Time distance by car	

E: Exogenous file
M: Endogenous file by Future Urban Structure Estimation Model
ZC: Input file by Zone-Size Tranformation Tool

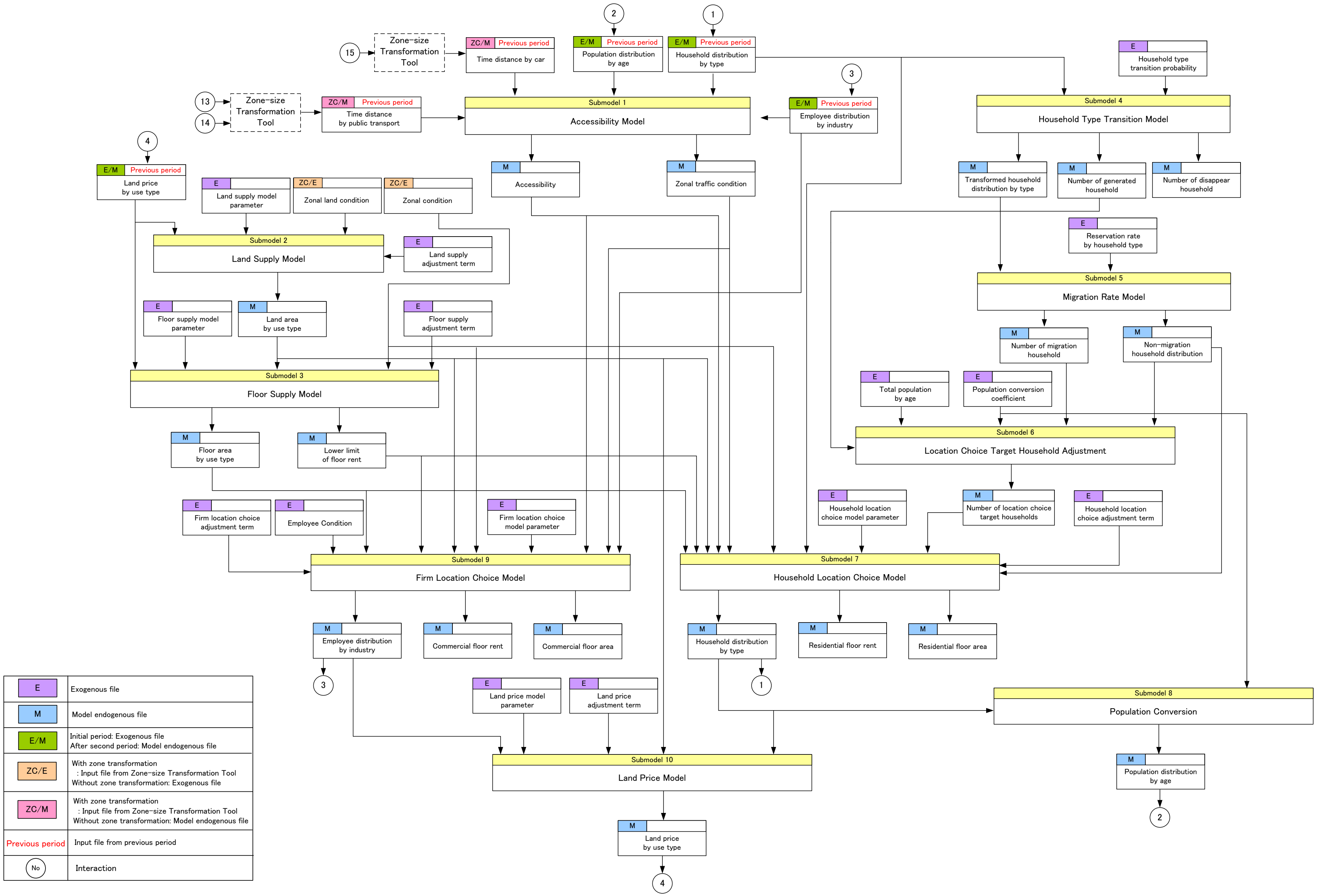

Figure 13. Input and output structure of files (Future Urban Structure Estimation Model: Land-use Model)

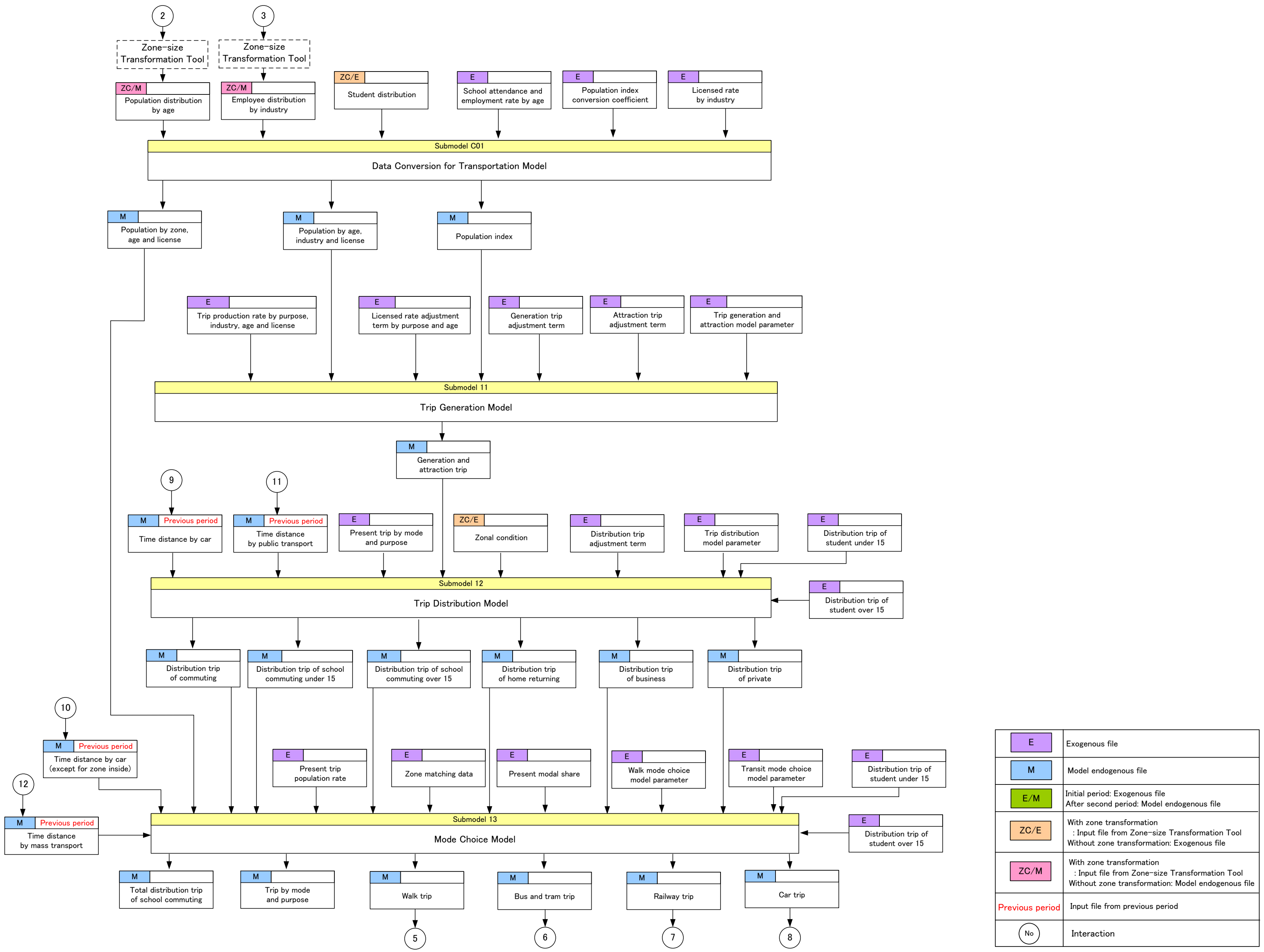

Figure 14. Input and output structure of files (Future Urban Structure Estimation Model: Transportation Model 1 of 2)

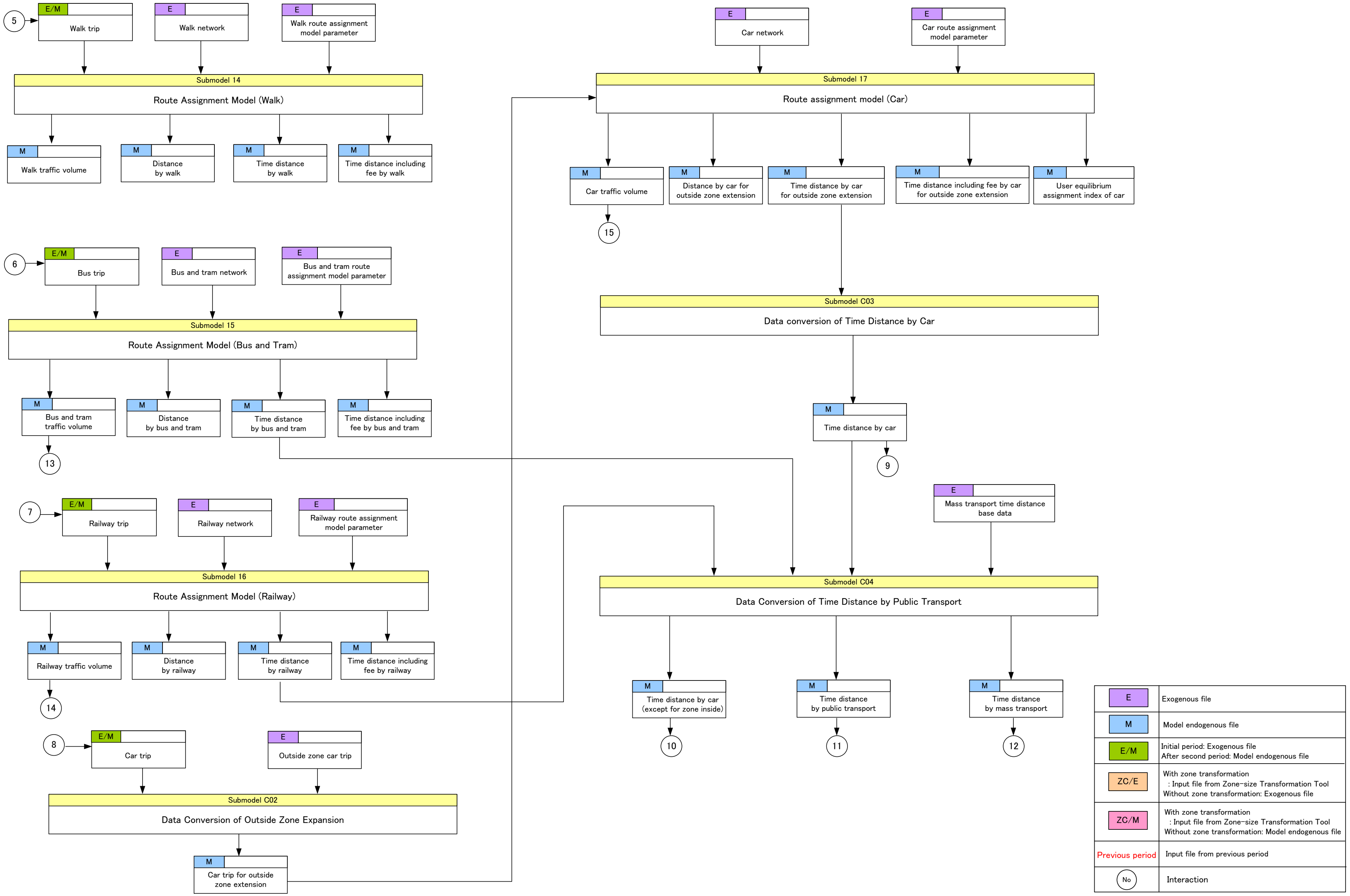

Figure 15. Input and output structure of files (Future Urban Structure Estimation Model: Transportation Model: 2 of 2)

Table 17. Input and output structure of files (Zone-size Transformation Tool)

Zone-size transformation process No.	Zone-size transpormation process	Transformed file No.	Input file		Output file
			File type	Contents	Contents
1	Land-Use Measure Zone to Land-Use Analysis Zone	C01	E	Zonal Land condition	Zonal Land condition
			E	Zone matching (Land-Use Measure to Land-Use Analysis)	
			E	Zone number for output data (Land-Use Analysis)	
		C02	E	Zonal condition	Zonal condition
			E	Zone matching (Land-Use Measure to Land-Use Analysis)	
			E	Zone number for output data (Land-Use Analysis)	
2	Land-Use Measure Zone to Transportation Analysis Zone	C03	E	Zonal Land condition	Zonal Land condition
			E	Zone matching (Land-Use Measure to Transportation Analysis)	
			E	Zone number for output data (Transportation Analysis)	
		C04	E	Student distribution	Student distribution
			E	Zone matching (Land-Use Measure to Transportation Analysis)	
			E	Zone number for output data (Transportation Analysis)	
3	Transportation Network to Land-Use Analysis Zone	C05	M	Car traffic Volume	Time distance by car
			E	Zonal representing node (Land-Use Analysis)	
			E	Car route assignment model parameter	
			E	Zone number for output data (Land-Use Analysis)	
		C06	M	Bus and tram traffic Volume	Time distance by public transport
			M	Railway traffic Volume	
			E	Zonal representing node (Land-Use Analysis)	
			E	Bus and tram route assignment model parameter	
			E	Railway route assignment model parameter	
			E	Zone number for output data (Land-Use Analysis)	
4	Land-Use Analysis Zone to Transportation Analysis Zone	C07	M	Population distribution by age	Population distribution by age
			E	Zone matching (Land-Use Analysis to Transportation Analysis)	
			E	Zone number for output data (Transportation Analysis)	
		C08	M	Employee distribution by industry	Employee distribution by industry
			E	Zone matching (Land-Use Analysis to Transportation Analysis)	
			E	Zone number for output data (Transportation Analysis)	
5	Land-Use Analysis Zone to Land-Use Measure Zone	C09	M	Land area by use type	Land area by use type
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C10	M	Floor area by use type	Floor area by use type
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C11	M	Household distribution by type	Household distribution by type
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C12	M	Residential floor rent	Residential floor rent
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C13	M	Residential floor area	Residential floor area
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C14	M	Population distribution by age	Population distribution by age
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C15	M	Employee distribution by industry	Employee distribution by industry
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C16	M	Commercial floor rent	Commercial floor rent
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C17	M	Commercial floor area	Commercial floor area
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
		C18	M	Land price by use type	Land price by use type
			E	Zone matching (Land-Use Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
6	Transportation Analysis Zone to Land-Use Measure Zone	C19	M	Trip by mode and purpose	Trip by mode and purpose
			E	Zone matching (Transportation Analysis to Land-Use Measure)	
			E	Zone number for output data (Land-Use Measure)	
7	Transportation Network to Land-Use Measure Zone	C20	M	Walk traffic Volume	Time distance by walk
			E	Zonal representing node (Land-Use Measure)	
			E	Walk route assignment model parameter	
			E	Zone number for output data (Land-Use Measure)	
		C21	M	Bus and tram traffic Volume	Time distance by bus and tram
			E	Zonal representing node (Land-Use Measure)	
			E	Bus and tram route assignment model parameter	
			E	Zone number for output data (Land-Use Measure)	
		C22	M	Railway traffic Volume	Time distance by Railway
			E	Zonal representing node (Land-Use Measure)	
			E	Railway route assignment model parameter	
			E	Zone number for output data (Land-Use Measure)	
		C23	M	Car traffic Volume	Time distance by car
			E	Zonal representing node (Land-Use Measure)	
			E	Car route assignment model parameter	
			E	Zone number for output data (Land-Use Measure)	

E: Exogenous file
M: Endogenous file by Future Urban Structure Estimation Model

Table 18. Input and output structure of files
(Future Urban Structure Evaluation Model: 1 of 2)

Indicator No.	Category		Indicator	Input files		Output files
				File type	Contents	Contents
1	Life: L	Housing: H	Residents around city center	ZC/M	Population distribution by age	Total and ratio of population in around city center zone
				E	Around city center flag	
2			Floor area per capita	ZC/M	Population distribution by age	Floor area per capita (average of whole area/ by zone)
				ZC/M	Residential floor area	
3			Housing cost per capita	ZC/M	Population distribution by age	Housing cost (total of whole area/ by zone), housing cost per capita (average of whole area/ by zone)
				ZC/M	Residential floor area	
				ZC/M	Residential floor rent	
4		Transportation: T	Time distance by mode	ZC/M	Trip by mode and purpose	Averaged time distance by mode (whole area/ by zone)
				ZC/M	Time distance by walk	
				ZC/M	Time distance by car	
				ZC/M	Time distance by bus and tram	
				ZC/M	Time distance by Railway	
5			Time distance by purpose	ZC/M	Trip by mode and purpose	Averaged time distance by purpose (whole area/ by zone)
				ZC/M	Time distance by walk	
				ZC/M	Time distance by car	
				ZC/M	Time distance by bus and tram	
				ZC/M	Time distance by Railway	
6			Modal share	ZC/M	Trip by mode and purpose	Modal share (whole area/ by origin zone/ by destination zone)
7			Public transport user	ZC/M	Trip by mode and purpose	Number of public transport user (whole area/ by
8			Accessibility to Public Transport	ZC/M	Population distribution by age	Time distance accessing to station by walk (total of whole area/ by zone, average of whole area/ by zone)
				ZC/M	Zonal condition	
9			Rode congestion rate	ZC/M	Car traffic Volume	Road congestion rate (average of whole area/ by inbound and outbound link/ by zone), traveler kilometer with road congestion rate over 1 (whole area)
				E	Link and zone matching	
10			Traffic accident victims	ZC/M	Car traffic Volume	Number of injury accident (total of whole area/ by zone, average of by inbound and outbound link)
				E	Traffic accident rate parameter	
				E	Road type	
				E	Link and zone matching	
11			Accessibility to city center	ZC/M	Population distribution by age	Time distance accessing to city center (total of whole area/ by zone, average of whole area/ by zone)
				ZC/M	Time distance by walk	
				ZC/M	Time distance by car	
				ZC/M	Time distance by bus and tram	
				ZC/M	Time distance by Railway	
				E	City center sites	
12			Accessibility of elderly to public transport	ZC/M	Population distribution by age	Total and ratio of elderly in accessible area to public transport (whole area), number of elderly (by zone), minimum access time and accessible flag to public transport (by zone)
				ZC/M	Time distance by walk	
				E	Bus stop and station sites	
				E	Public transport accessibility parameter	
13			Accessibility of elderly to city center by public transport	ZC/M	Population distribution by age	Time distance of elderly accessing to city center (total of whole area/ by zone, average of whole area/ by zone)
				ZC/M	Time distance by bus and tram	
				ZC/M	Time distance by Railway	
				E	City center sites	
14		Infrastructure: I	Sewage served population rate	ZC/M	Population distribution by age	Sewage served population rate (whole area), sewage served population (by zone)
				E	Sewage served rate	
15			Park and green area per capita	E	Parks & green, farms and forest area	Park and green area per capita (average of whole area/ by zone)
				ZC/M	Population distribution by age	
16		Communication: C	Balance of population attribute composition	ZC/M	Population distribution by age	Rate of aging (by zone)
17	Safety: S	Disaster mitigation: D	People with difficulty returning home in case of disasters	ZC/M	Trip by mode and purpose	Population with difficulty returning home in case of disasters (whole area/ by zone)
				ZC/M	Time distance by walk	
				E	People with difficulty returning home in case of disasters parameter	
18			Residents in difficult area of fire-fighting	ZC/M	Household distribution by type	Number of household and population in difficult area of fire-fighting (whole area/ by zone)
				ZC/M	Population distribution by age	
				E	Difficult area of fire-fighting flag	
19			Initial response time of fire-fighting	ZC/M	Population distribution by age	Total and ratio of population in covered area by fire station (whole area), time distance from the nearest fire station (by zone)
				ZC/M	Time distance by car	
				E	Fire station sites	
				E	Fire station cover area parameter	
20			Length of wide road	ZC/M	Car network	Total length of wide road (whole area), wide road flag (by link)
				E	Road type	
21			Residents in disaster hazard area	ZC/M	Household distribution by type	Number of household and elderly in disaster hazard area (whole area/ by zone)
				ZC/M	Population distribution by age	
				E	Disaster hazard area flag	

E: Exogenous file
M: Endogenous file by Future Urban Structure Estimation Model or Zone-Size Transformation Tool
ZC: Input file by Zone-Size Tranformation Tool

Table 19. Input and output structure of files
(Future Urban Structure Evaluation Model: 2 of 2)

Indicator No.	Category		Indicator	Input files		Output files
				File type	Contents	Contents
22	Safety: S	Medical services: M	Population in accessible area to medical facilities	ZC/M	Population distribution by age	Ratio of population in accessible area to medical facilities (whole area), population in accessible area to medical facilities (by zone)
				ZC/M	Time distance by car	
				E	Medical facilities sites	
				E	Accessible area to medical facilities parameter	
23			Accessibility of elderly to medical facilities by public transport	ZC/M	Population distribution by age	Total and ratio of elderly in accessible area to medical facilities by public transport (whole area), number of elderly (by zone), total of elderly in accessible area, minimum access time and accessible flag to medical facilities by public transport (by zone)
				ZC/M	Time distance by bus and tram	
				ZC/M	Time distance by Railway	
				E	Medical facilities sites	
				E	Accessible area to medical facilities by public transport parameter	
24	Environment: E	Global environment: E	CO2 emissions by transportation sector	ZC/M	Car traffic Volume	Total of CO2 emissions by transportation sector (whole area)
				E	CO2 emissions by transportation sector parameter	
25			CO2 emissions by private and industrial sector	ZC/M	Residential floor area	Total of CO2 emissions by private and industrial sector (whole area/ whole area by sector/ by zone/ by zone and by sector)
				ZC/M	Commercial floor area	
				ZC/M	Employee distribution by industry	
				E	CO2 emissions type flag	
				E	CO2 emissions by private and industrial sector parameter	
26			Amount of fixed CO2 by green	E	Parks & green, farms and forest area	Total amount of fixed CO2 by green (whole area)
				E	CO2 fixed by green parameter	
27		Air pollution: A	NOx emissions	ZC/M	Car traffic Volume	Total NOx emissions (whole area)
				E	NOx emissions parameter	
				E	Link and zone matching	
28		Nature: G	Green and agricultural land coverage rate	E	Parks & green, farms and forest area	Total and ratio of green and agricultural land coverage area (whole area)
29		Resources and energy: R	Fuel consumption by transportation sector	ZC/M	Car traffic Volume	Total of fuel consumption by transportation sector (whole area)
				E	CO2 emissions by transportation sector parameter	
				E	Fuel consumption by transportation sector parameter	
30			Fuel consumption by private and industrial sector	ZC/M	Residential floor area	Total of fuel consumption by private and industrial sector (whole area/ whole area by sector/ by zone/ by zone and by sector)
				ZC/M	Commercial floor area	
				ZC/M	Employee distribution by industry	
				E	Fuel consumption type flag	
				E	Fuel consumption by private and industrial sector parameter	
31	Vitality: V	Activity distribution:	Employee	ZC/M	Employee distribution by industry	Total of employee (by zone)
32		Industrial activities: I	Average time distance of trips	ZC/M	Trip by mode and purpose	Averaged time distance of trips by all mode (whole area)
				ZC/M	Time distance by walk	
				ZC/M	Time distance by car	
				ZC/M	Time distance by bus and tram	
				ZC/M	Time distance by Railway	
33			Visitors to central commercial area	ZC/M	Trip by mode and purpose	Number of visitors to central commercial area by all purpose and by private (whole area)
				E	Central commercial area flag	
34			Accessibility between sightseeing spots	ZC/M	Time distance by car	Time distance by car (by OD pair between sightseeing spots)
				E	Sightseeing spots	
35		Economic impact: E	Total value of land price	ZC/M	Land area by land-use type	Total value of land price (whole area/ whole area by residential and commercial/ by zone/ by zone and by residential and commercial)
				ZC/M	Land price by land-use type	
36	Administrative service cost: C	Facilities: F	Road maintenance cost	ZC/M	Car network	Total of road maintenance cost (whole area)
				E	Road maintenance cost parameter	
37		Services: S	Elder care service cost	ZC/M	Population distribution by age	Total of elder care service cost (whole area/ whole area by expense item/ by zone/ by zone and by expense item)
				ZC/M	Time distance by car	
				E	Elder care service facility sites	
				E	Elder care service cost parameter	
38			Public transport cost	ZC/M	Bus and tram traffic Volume	Income and expenditure of bus service (whole area/ whole area by expense item)
				ZC/M	Railway traffic Volume	
				E	Bus cost parameter	
39			Elementary and junior high school cost	ZC/M	Population distribution by age	Total of elementary and junior high school cost (whole area/ whole area by residential and commercial/ by zone/ by zone and by residential and commercial)
				E	School district setting	
				E	Elementary and junior high school cost parameter	

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