Development of Assessment Method for Future Urban Visions in the Depopulating Period



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Summary

This article explains the background, contents and results of a research project to develop a technological system to assess urban policy by developing forecast models and urban sustainability indices from the viewpoint of the quality of life, environmental load, administrative costs, etc., 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. Japanese is one of the most leading society experiencing decrease and aging of population, although urban sprawl is still taking place in local depopulating cities.

Keywords: sustainable urban structure, demographic change, assessment, land-use and transportation model, scenario planning

1. Introduction

1.1 Background and Purpose of Study

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 to 70 percent of the present and the ratio of 65-year-old and over is expected to grow from 20.2% in 2005 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 of efficient, cost-effective, and of high citizens' satisfactory 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 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 Research and Development Composition

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

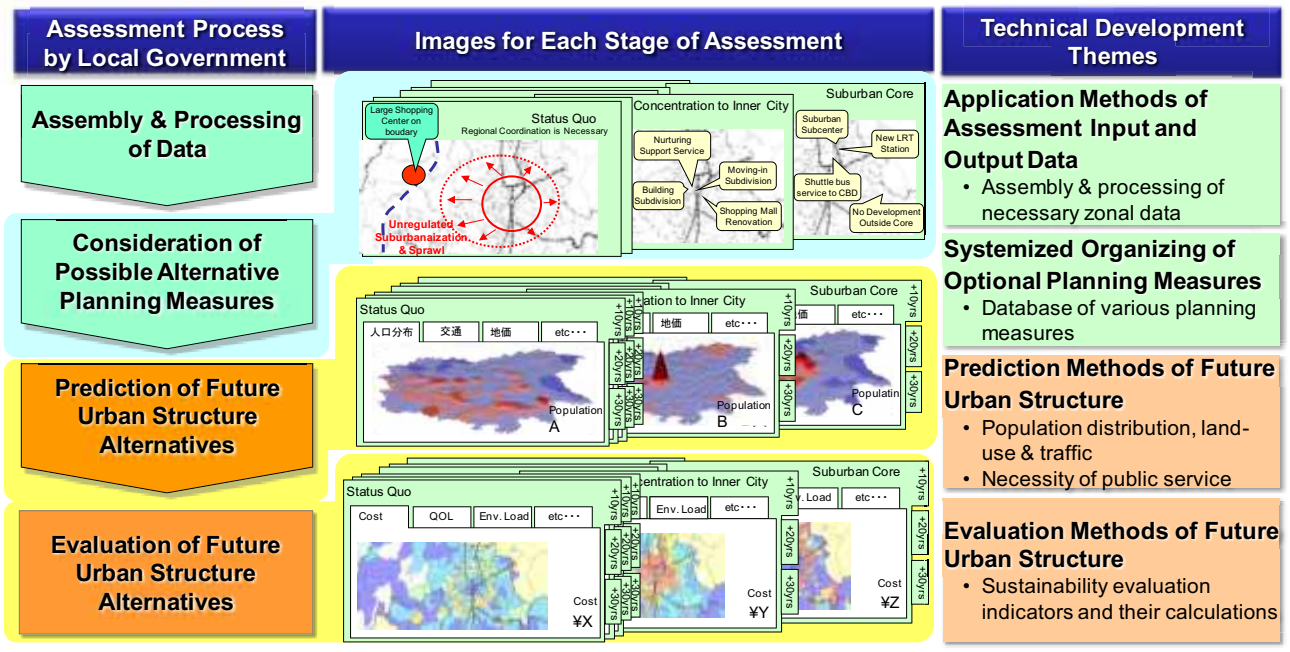


Fig. 1 Composition of Assessment Process and Technical Development Themes

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 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.

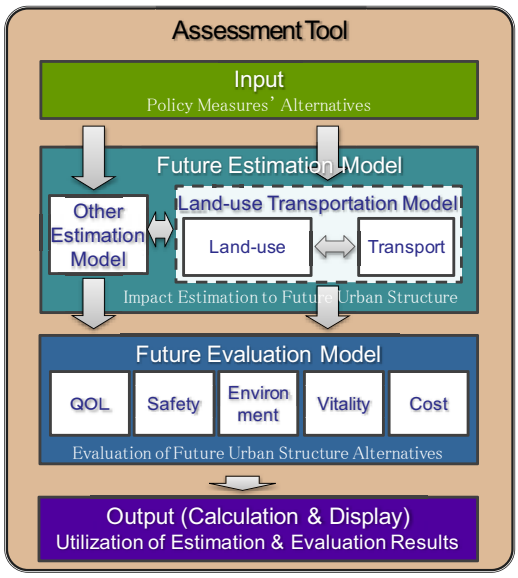


Fig. 2 Major Composition of the Assessment Tool

2. Development of Future Urban Structure Estimation Method

2.1 Basic Concept and Principle

This method is intended to guide the relationship between future urban structure and planning measure group. In the actual planning situations, the following 2 applying situations can be considered; when considering required measures to implement the given future urban structure (in advance as desired), and when considering future changes in urban structure by options for a set of planning measures.

We investigated the major applications of existing and domestic and overseas land use and transportation models, studied the reasons for introduction and application, overview of the applied models, strengths and limitations rooted due to the model construction, and their application cases. Further, such viewpoints as intimacy to applying to Japanese local cities were considered, and we have set the model requirements and the following basic concepts and principles.

Principles

The land use traffic model assumed to be a base, can be divided roughly into aggregation type and non-aggregation type (such as micro-simulation models). In this project, practicality such as easiness of input data purchase is considered and we decided to adopt the former.

The basic model structure was set as a comparatively simple and flexible one, where each sub-models to some extent can be replaced to another. Transportation model, particularly, is capable to be replaced by a model used in each city's "Comprehensive Transportation System Study" using "Person Trip Survey" data.

Under the depopulation context, analysis related to age hierarchy and family type is important. Therefore, household economy actors were defined as households by family type (not individuals) (Fig. 3).

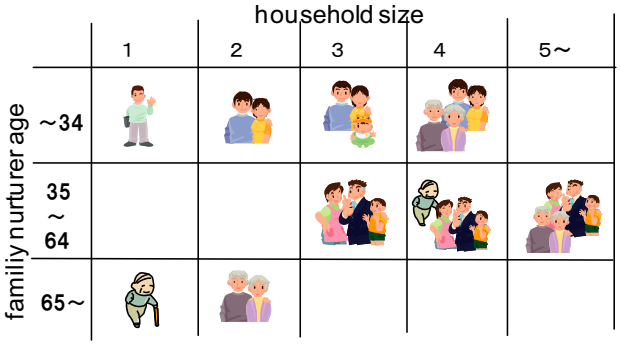


Fig. 3 Household Type Definition

Concepts

The total numbers of location actors (population by age and number of employees by industry) are exogenously-given ("closed city"), and the location demands for each zones are decided under the condition.

Land use and transportation markets are sequentially operated to configure each sub-model, and simulated by stages. The prices are considered, however, a steady-state situation at any stage of any market under the supply and demand coordination mechanism is not expressed.

Land-use market of a stage is influenced by the transportation market (such as by changes in

traffic convenience) of the previous stage. In other words, transportation infrastructure development (supply) will affect the demand for land use location demand for the next stage (Figure 4).
The model as a whole is the pseudo-dynamic model, which aims to express the difference in the speed of adjustment between land-use and transportation markets. The total number of location actors will change at every stage and never reach to a complete equilibrium.

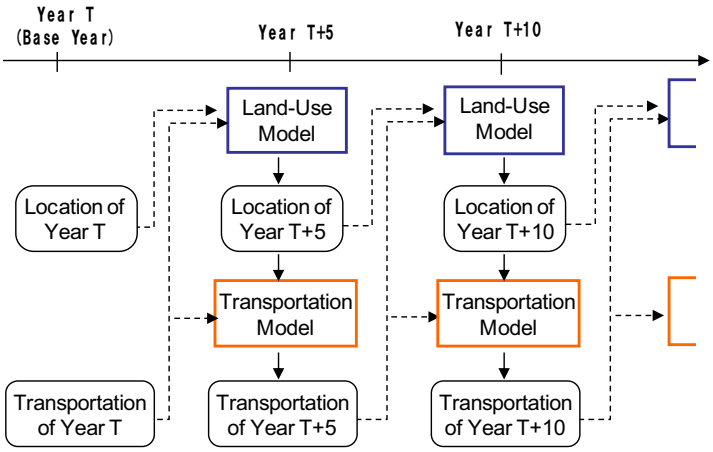


Fig. 4 Sequential of Coordination of the Models

2.2 Configuration of the Estimation Model

Under the above mentioned principles and concepts, the basic structure of the Future Urban Structure Estimation Model was designed as Fig.5. Each composing sub-models were edited, and the proto-type of the model was completed.

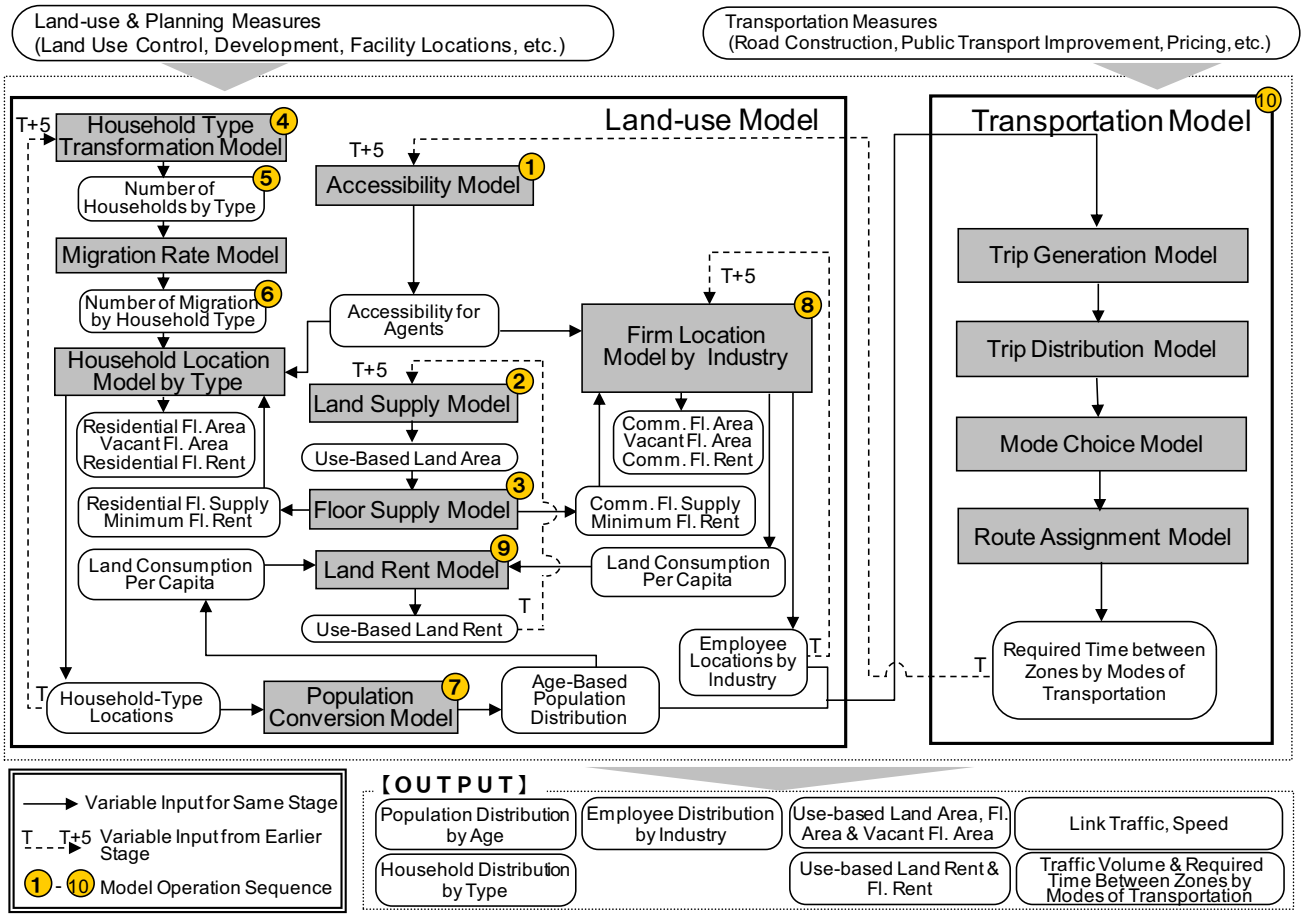


Fig. 5 Basic Structure of the Future Urban Structure Estimation Model Proto-type

2.3 Zone-size Transformation Tool

For the proto-type version model, it is required that various zone data for both the land use model and the transportation model, are of the same zone size. By this assumption, in many cases, small zones of the Person-Trip Survey are used, and it turned out from our case study that when

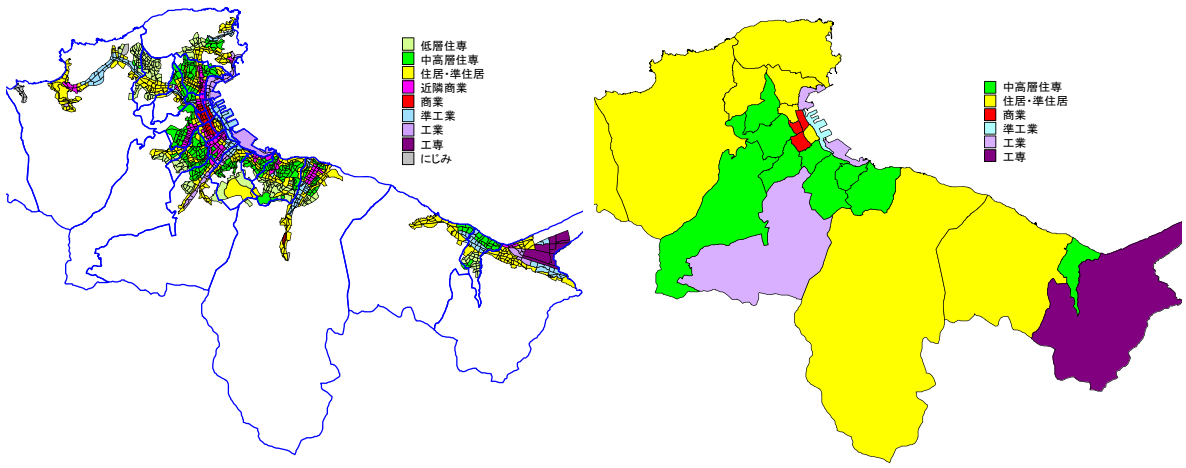


Fig. 6 Example of Land Use Zones and Transportation Zones

there is a large gap between land use and transportation zones as shown in Figure 6, and the sensitivity of the simulation result to the measure alternatives are not always sufficient.
The development of Zone-size Transformation Tools was started based on this finding, so that the model is applicable even if the sizes of the 2 zone systems are quite different. To cancel the differences between the zone sizes, the function to distribute and to integrate the values in the zones according to the setting of "Intermediate Zones" that took a spatial difference of each zone was developed.

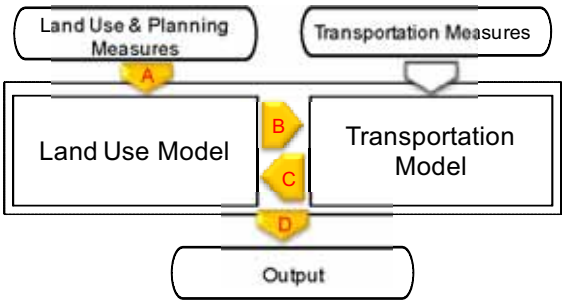


Fig. 7 Zone-size Transformation Steps

2.4 Sensibility Analysis and Operation Verification

Sensitivity analysis of the Estimation Model with Zone-size Transformation function has been implemented to check applicability. A few type of “Ideal City Model (Fig. 8)” were developed as a field to run this analysis. In this field, we verified that the model’s response to the planning measures were sensible and fit existing perception. Accompanying the sensibility analysis was the operation verification.

A “Future Urban Structure Estimation Model” was developed through such studies and examinations. The model is an application without so-called GUI, though all are constructed to operate on Windows Operation System. In actual use, each model can be controlled, by a batch file, configuring the execution/non-execution of necessary functions (models), the forecasting period and intervals, and the input-output files, handing data over to “Future Urban Structure Evaluation Model”, etc. by a text editor.

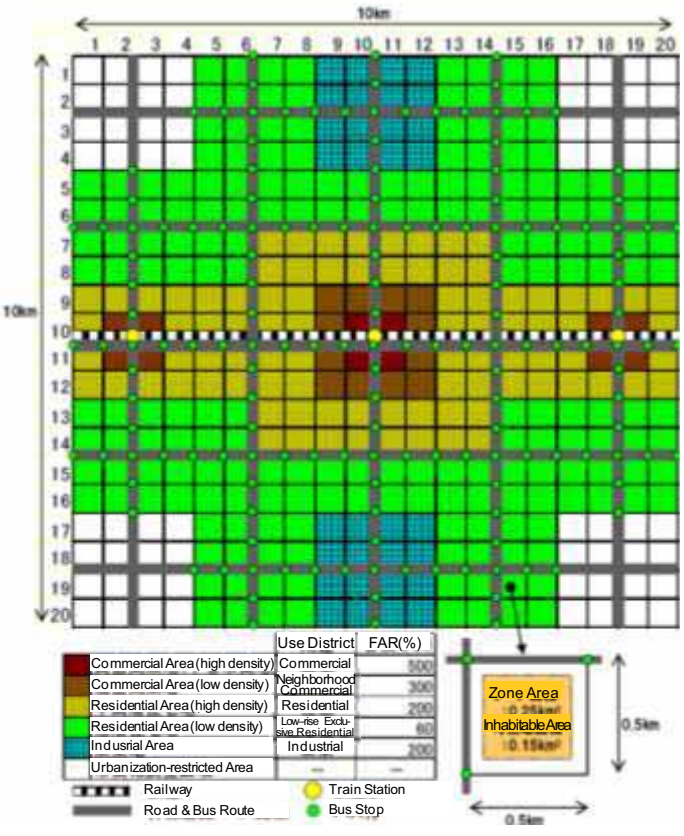


Fig. 8 An Example of “Ideal City” for Sensibility Test

3. Development of Future Urban Structure Evaluation Method

3.1 Basic Concept and Principle

Assessment metrics are the clues to compare the advantages and disadvantages of alternatives of future urban visions or planning measure groups. They are also indices to "achieve sustainability under future population decline and other constraints for each cities," an in addition, an indicator to know whether or not they are approaching, in the long term, towards "their achievable and aspiring future city vision." On the other hand, considering the use of the evaluation indicators, 2 types of "prediction-type assessment" and "declaration-type assessment" where indices are declared as policy goals can be supposed. It would be easy if an ideal city vision can be defined numerically, however, these figures are rarely seen in city master plans or other plans.

3.2 Deliberation of Evaluation Indices and Calculation Methods

Then, referring to the various plans and related research efforts in Table 1, candidate metrics were extracted, considered from both "prediction-type assessment" and "declaration-type assessment" applications. The "Prediction-type assessment" indices were examined by whether the change in "land use", "night time and daytime population distribution", and "transportation network conditions" will change their figures. The "declaration-type assessment" indices were examined by whether they are able to calculate by land use transportation model.

From these results, and considering whether they are mentioned in several different plans or research papers, and balance between the indices, we reached to some on 30 indicators (Table 2). The calculation method were studied through fore mentioned investigation process.

Table 1 Efforts and Plans of Sustainability Indicators and Indices

Evaluation Items and Indices in MLIT Relevant Plans		
"Priority Plan for Social Infrastructure Development" MLIT		
"Low Carbon City Development Guidance" MLIT		
Description in Local Cities' Plans		
Quantitative Indicators in City Master Plans		Kasugai, Kashiwa, Matsudo, Ise, etc.
Qualitative Targets in City Master Plans		Sapporo, Toyama, Akita, Aomori, Hitachi, etc.
Evaluation Items and Indices in Various Investigations and Studies		
Monitoring (Ex-post Evaluation) Indicator Instances	"Kei-han-shin Region Renovation Program" (MLIT)	
	"Tokyo Region Renovation Program" (MLIT)	
	"Community Renovation Grants Indicators" (MLIT)	
	"Indicators of Sustainable Development: Guidelines and Methodologies" United Nations	
	"Global City Indicators" World Bank	
	"Regional Quality of Life Counts" DETRA, UK	
Assessment (Advance Evaluation) Index Instances	Transportation Models	"Investigation Report on Role and Application of Person-Trip surveys" NILIM, MLIT, Japan
	Land Use Transportation Model-Applied Overseas Research Projects	"SPARTACUS (System for Planning and Research in Towns and Cities for Urban Sustainability)", Commission of the EC
		"PROPOLIS (Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability)", Finland
	Land Use Transportation Model-Applied Overseas Cases	"Cambridge Futures" Project, UK
		"LUMOS" Project, Netherlands, etc.
	Outputs from Domestic & Overseas Land Use & Transportation Models	"UrbanSim", "Delta", "IRPUD", "NYMTC-LUM", "Vmcue", "RURBAN2
Existing Research Papers	M. TAKAHASHI, A. DEGUCHI, "Method for Cost-Benefit Evaluation System of Impact by Forming Compact City", City Planning Review. Special issue, Papers on City Planning, Vol.42 No.3, 2007, pp.487-492, CPIJ Japan	
	T. KUROKAWA, M. TANIGUCHI, H. HASHIMOTO, and H. ISHIDA, "Cost of Infrastructure Improvement on Sprawl Area : Costsaving Effect by Early Action" City Planning Review. Special issue, Papers on City Planning, Vol.30 No.3, 1995, pp.121-126, CPIJ Japan	
	T. UJIHARA, M. TANIGUCHI, and R. MATUNAKA, "Ecological Footprint of Urban Retreat considering Development Methods : Case Study of Maintenance of Urban Infrastructure Network in Residential Zones" City Planning Review. Special issue, Papers on City Planning, Vol.42 No.3, 2007, pp.637-642, CPIJ Japan	

Table. 2 Evaluation Indices of Future Urban Structure

Categories			Indices	Declare	Fore-cast
Quality of Life	Housing	Habitation	No. of Inhabitants by Type (e.g. in 1km Radius City Centre)	●	○
		Quality	Floor Area per capita	—	●
		Cost	Cost of Housing	—	●
	Transport	Features	Required Time (by modes etc.)	—	●
			Mode Split	—	●
		Public Transport	No. of Public Transport Passengers	—	○
			Access to Transportation Facilities	●	○
		Clog	Congestion rate	—	◎
		Accidents	No. of Traffic Accident Victims	—	◎
		Accessibility	Accessibility to City Cores	—	●
	Infrastructure	Water & Sewerage	Sewage Serving Population Percentage	●	□
		Parks & Green	Parks & Green Area per Capita, Green Coverage	●	□
	Communication	Community	Population Composition Balance	—	●
Safety	Crime	Crime Prevention	No. of Crime, Crime Rate	—	—
	Disaster Mitigation	Disaster Mitigation	No. of People with Hardship in Home-returning in Case of Disaster	—	◎
			Difficult Areas of Fire-fighting	—	◎
			Wide Street Density	●	□
			No. in Houses in Hazardous Area	●	◎
			Quakeproof Building Rate	—	△
	Medical Care	Medical Care	Population of Accessible Area to Medical Facilities	—	◎
Environment	Global Env.	Global Warming	CO2 Emissions (by sector)	—	◎
			Amount of Fixed CO2 by Green	●	□
	Air Pollution	Emission	NOX Emissions	—	◎
	Nature	Green Coverage	Green & Agricultural Land Coverage	●	□
	Energy Resources	Fuel	Fuel Consumption	—	◎
	Waste	Waste Emission	Waste Emission Amount per Capita	—	△
Vitality	Activity Distribution	Industry	No. of Employee	—	●
	Industrial Activities	Distribution Costs	Time Reduction & Punctuality	—	◎
		Commerce	Commercial Sales Total	—	△
		Tourism	Accessibility between Tourist Spots	—	◎
	Economic Growth	GDP, GRP	GDP & GDP per Capita	—	△
	Economic Impact	Land Price	Land Price, Land Rent, Volatility	—	●

3.3 Deliberation of Cost Estimation for Public Services

The costs for public services are also important and indispensable to evaluate and judge efficiency and sustainability of future urban structure, and calculation methods are studied. A study by NILIM in 2009 March (Fig. 9) reveals that although it differs depending on the services, nearly half, in average, of the responded municipalities has recently executed some kind of future public service cost estimation. However, only half of them has considered change of either demography, soundness of construction, or urban structure, and other estimations are just trend forecasting.

In the examination of calculation technique, we have taken 4 study reports of public cost calculations; by a)MLIT, b)NILIM, c)Toyama City, and d)Ibaraki Prefecture. After comparison of public

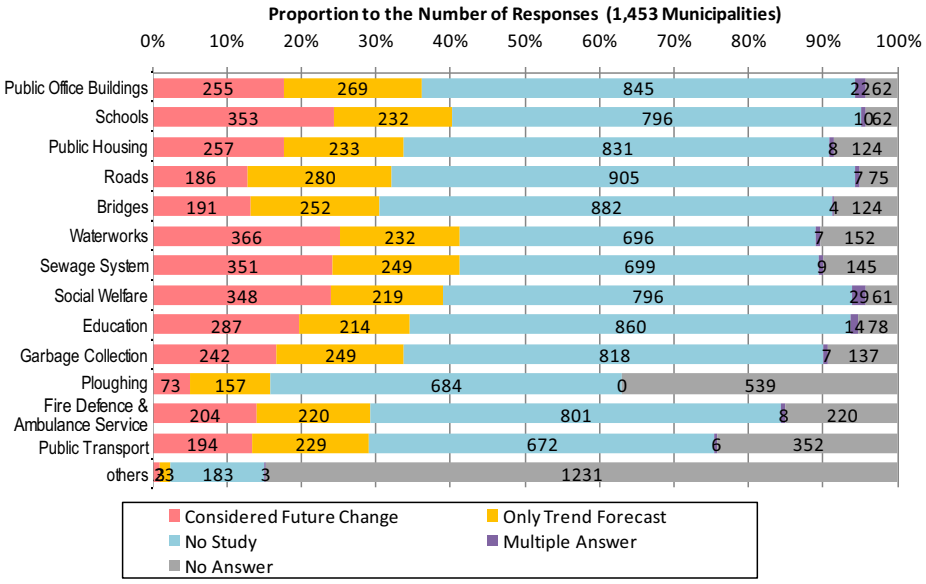


Fig. 9 Implementation Status of Future Public Service Cost Estimation by Municipalities

service items studied, the characters of the services were divided between "network type" and "hub type" by the offering form of service. We have categorized these items by above service forms, impact from future population age structure and distribution, and relation to policy valuables, and taken 4 public service cost items; “road maintenance”, “visiting nursing care for elderly”, “public transport”, and “public schools.”

From these studies calculation methods from the outputs of the Estimation Model, are defined.

3.4 Sensibility and Trade-off Analysis

Table 3 This is a Figure caption

Form of Service Provision	Public Service Category	MLIT (2009)	NILIM (2009)	Toyama (2004)	Ibaraki (2008)	Population Change Impact: Age Structure	Population Change Impact: Distri-bution	Policy Valuable	Adoption
Network Type	Road Maintenance	●	●	●	●		○	City Planning Area	◎
	Waterworks	●			●		○	Urban Area	
	Sewage System	●	●	●	●		○		
	Garbage Collection	●	●	●	●		○		
	Visiting Nursing Care for Elderly		●	●		○			◎
	Public Transport	●	●			○	○		◎
Hub Type	Parks	●	●		●		○	Location Density	
	Public Schools	●	●		●	○	○	Location Density	◎
	Feeding Centers	●				○	○	Location Density	
	Kindergartens	●				○	○	Location Density	
	Nursery Centers	●				○	○	Location Density	
	Community Centers	●						Location Density	
	Fire Defence, Ambulance Service	●	●			○		Location Density	

1. Ministry of Land Infrastructure, Transport, and Tourism, “Investigation on Financial Effect by Urban Structure”, 2009, Japan
2. National Institute for Land and Infrastructure Management, “Assignment of Administrative and Resident-Imposed Costs Estimation Caused by Changes Suburban Residential Areas”, 2009, Japan
3. Study Group on Compact City Formation of Toyama City, “Research and Investigation on Compact City Formation”, 2004, Japan
4. Ibaraki Prefecture, “Research and Investigation on Compact City Formation in Ibaraki Prefecture”, 2008, Japan

From above studies, we have constructed a “Future Urban Structure Evaluation Model” the input of which are the outputs from “Future Urban Structure Estimation Model” and other data used only for index calculation (such as school areas), and which consists of many sub module programs of calculation methods. The model is constructed to operate also on Windows Operation System, and the modules are also designated to accept replacement by more improved calculation technique in the possible future.

The verification of the trade-off relations between evaluation indices including the public service costs were executed, and sensitivity analyses was done also, using the “Ideal City Model” mentioned beforehand. As a whole, the total assessment tool was confirmed to respond correctly and logically to the planning measure group alternatives in the “Ideal City”.

4. Case Studies of Assessment Method

4.1 Overall Condition and Planning Agendas of the City

Joetsu City is a local city located in the southwest of Niigata Prefecture. The old city was approved in 1981 by an equal amalgamation of Takada city and Naoetsu City. In 2005, new city was born by a large amalgamation with vicinal 13 municipalities.

The total populations is 208,082 (by 2005 National Census), and with slight exception from 1975 to 1985, the City’s population continues to decrease almost consistently after the WWII (Fig. 10). By the forecast of National Institute of Population and Social Security Research, it is estimated to fall down to 158,425 by 2035. Population increases from 1980 to 2005 can only be seen in old Joetsu City and Kubiki Ward, and population decrease in other 12 wards are sharp. By age divisions, over 65 years shares 24.2%, and especially in Oshima, Maki, and Yasuzuka

Fig. 10 Population Change in Joetsu City

Ward, the share rapidly grew, and recently reached about 40%. The population decrease is also remarkable, and the progress of a further population decrease is expected in these districts. Densely inhabited district (DID) keeps expanding with the progress of infrastructure provision around Kasuga-yama where the City Hall locates (Figure 2). DID population density is consistently decreasing, and after 1995, fell below 40 people/ha.

The city planning district, occupies 32.9% of the administrative area, and is composed of three city planning districts, among which only the Joetsu City Planning District contains the urbanization control area. The population density in the urbanization promotion area is low below 30 people/ha. As for FAR regulations, 500% is designated in the centers of Takada, Naoetsu, Kasuga-yama, and also around the Joetsu General Hospital, however, sufficiency rate is very low and they are misfit. The Hokuriku Shinkansen station is under construction at the southern edge of the built up area and is planned to function in 2014.

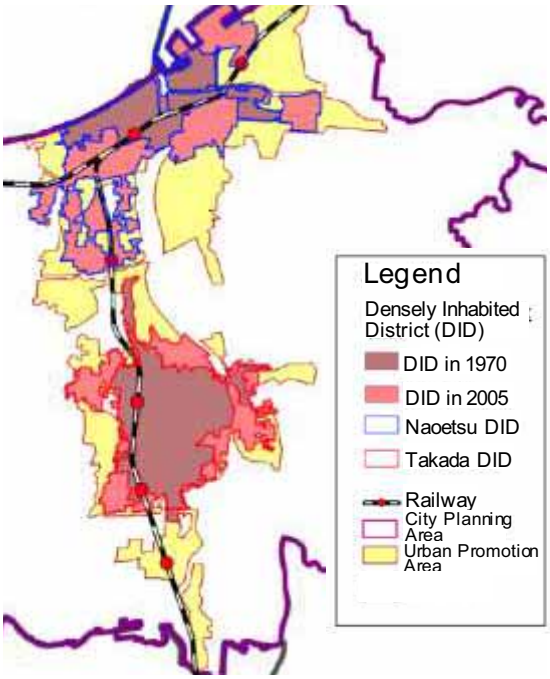


Fig. 11 Spread of DID

As mentioned, the urban structure of Joetsu City needs to be intensified, however, the geography and the story behind urban formation does not easily admit it, and there are little incentives working to intensify population and urban functions in the city core. Therefore, a strategy is needed to provide incentive to promote accumulation in the city core area together with control of accumulation in the suburbs. Moreover, conflicting effort to 1) accept population decline in total, but maintain population in the core and existing built-up area, 2) provide and maintain infrastructure of main roads and streets, but control related costs, 3) maintain train and bus service frequency, but control related costs will be necessary.

4.2 Preparation of Planning Alternatives

To work on the above-mentioned, the following alternatives were made, taking in account of the city's policy and plans(Fig. 12).

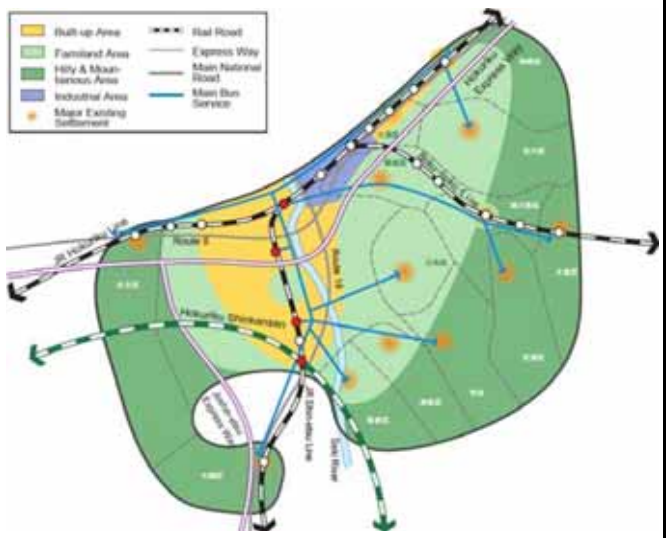
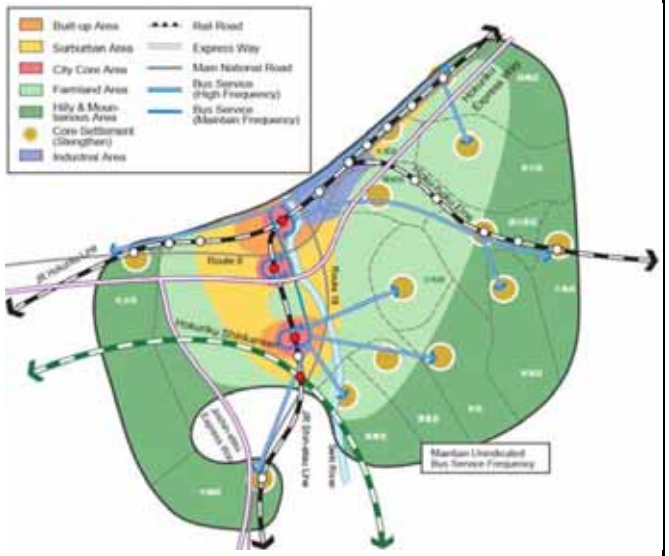
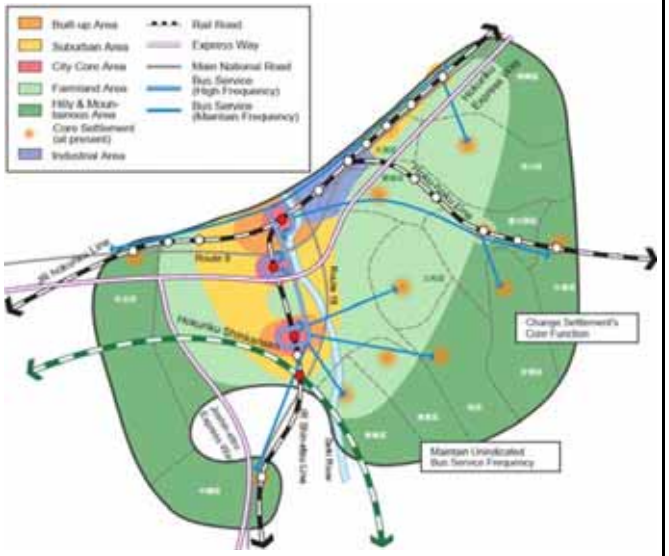
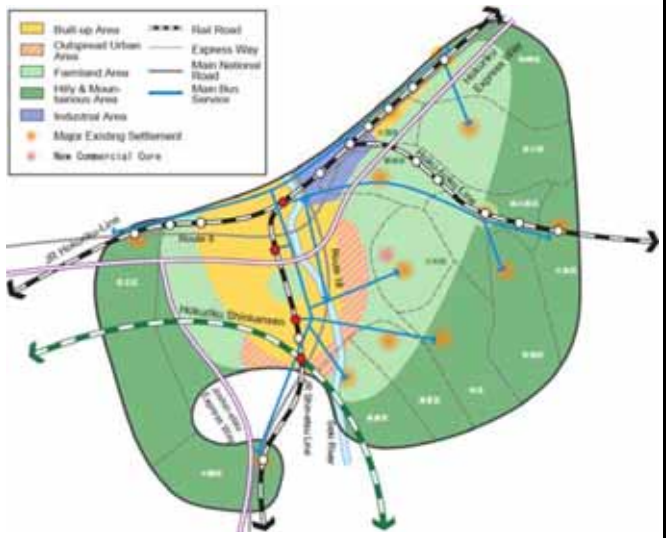
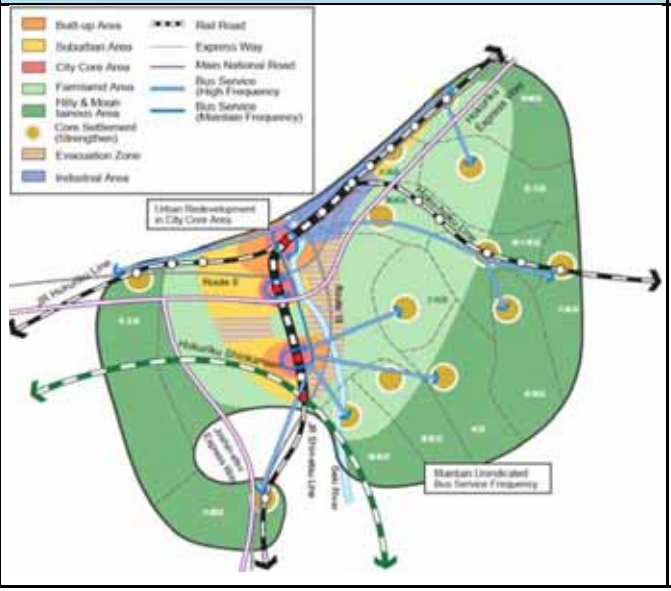
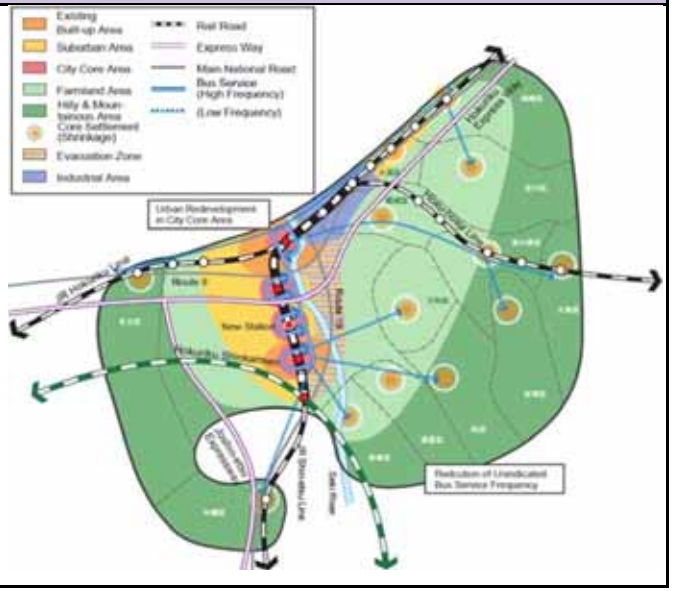
Plan A: Do Nothing Alternative
A plan that basically maintains urban scale and various measures at the same level as current state.

Plan B: Business as Usual Alternative (continue expansion)
A plan that expands the urban scale more further than the current state and the infrastructure etc. are newly constructed in the expansion urban area. Various measures are maintained basically at the same level as the current state.

Plan C: Multi-Core Concentration Alternative - without evacuation
A plan based on the current city plan, and accumulation is promoted to the core (in urban area in the core settlements) located in each districts. Measures in other areas are almost maintained like the current state.

Plan D: Multi-Core Concentration Alternative - with evacuation
A plan based on the current city plan, but aggressively evacuate from suburbs to promote accumulation around the JR Shin-etsu Line stations. Promote accumulation to district core, and strengthen development control and segmentalize large built up areas.

Table 4 Concept Plans of the 6 Planning Alternatives

Do Nothing Alternative (Plan A)	Multi-Core Concentration Alternative - without evacuation (Plan C)	3 Core Concentration Alternative - without evacuation (Plan E)
		
Business As Usual Alternative (Plan B)	**Multi-Core Concentration Alternative - with evacuation (Plan D)**	**3 Core Concentration Alternative - with evacuation (Plan F)**
		

Plan E: 3 Core Concentration Alternative - without evacuation
Promote accumulation only around Takada, Kasuga-yama, and Naoetsu where it is the highest in the city, and various measures are maintained almost maintained like the current state.

Plan F: 3 Core Concentration Alternative - with evacuation
Promote accumulation only around Takada, Kasuga-yama, Naoetsu, and a new Shin-etsu line station, and aggressively evacuate from suburbs. The scale of the core settlements is shrinked, the service level is decreased, and development control is strengthened.

According to the ideas of Alternative Plans A to F, definite area of expansion and evacuation, conditions for urban facilities and traffic service levels etc. were set, and input data to the assessment tool were created.

4.3 Estimation and Evaluation by the Assessment Model

Fig. 12 shows the rate of change from 2010 to 2035 of the population forecast value according to a 28 wards based on the municipality region before the amalgamation. The population decreases in all alternatives and all districts, and the decrease ratio is from 5% to 50%. In the suburbs, there are less decrease where developments are planned, and more decrease where evacuations are planned but not as much as intended. Difference between the alternatives can hardly be seen in Takada district. Moreover, the effect of the evacuation is greatly seen in the core settlements along the Hoku-hoku Line (Uragawara district and etc.).

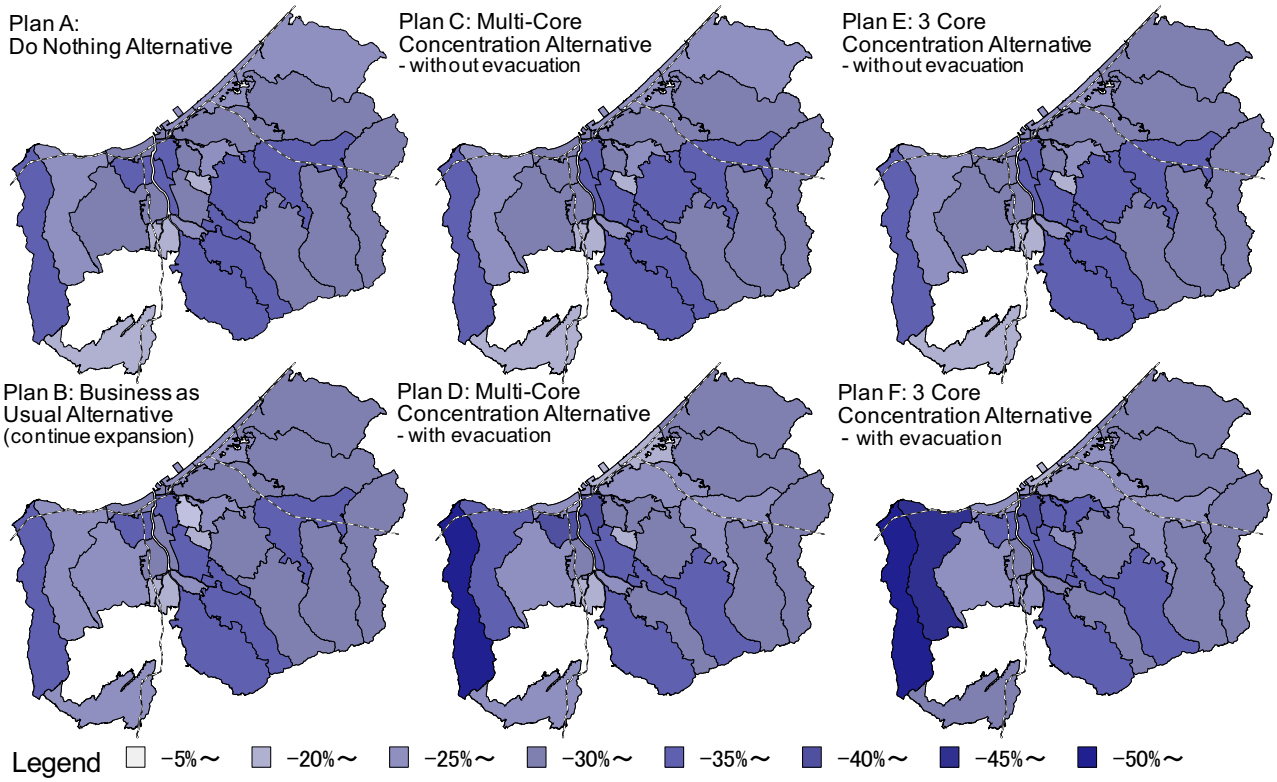


Fig. 12 Change of Population during 2010-2035

Fig. 13 to Fig. 17 shows the indices that had distinctive differences between the alternatives in 2035. As for effect of accumulation to core area and existing built up area (Fig.13), the relations of the alternatives are as intended (B<A<C<E<D<F) but the differences are at maximum below 10%.

As for the number of public transport users (Fig.14), Plan F (3 Core Concentration with evacuation) is the largest, and plan B (BAU) is the smallest, although the difference is only 3%.

As for CO2 emissions, there is little difference from transport (Fig. 15), but there is tendency such as; “DNA ≒ BAU”, “3 Core Concentration” < “Multi-core Concentration”, and “without evacuation” < “with evacuation” from household and industry (Fig. 16).

As for road maintenance costs (Fig. 17), Plan B (BAU) was highest, then Multi-Core concentration and 3 Core Concentration were the minimums. Multi-Core Concentration alternatives require new comparatively wide road provisions in the suburbs, whereas 3-Core Concentration alternatives require comparatively narrow road provisions in the built up area; thus as for total length, the latter exceeds the former, but as for maintenance cost, the former exceeds the latter.

5. Conclusion

In this paper, the development process of the “Future Urban Vision Assessment Tool” has been described. We believe that under a different social situation, some of the social sustainability indicators should be recognized differently, such as growing awareness in Japan for the cost of taking care of the elderly.

As for the case study, the appropriateness of the calculations are yet to be verified, as Person Trip Survey data and Tax lot data was not obtained and we had to rely on some estimation, but the following suggestions were obtained.

For population accumulation to core area, it is effective if there is less number of cores, and some evacuation measures were also taken. However the total decrease of the case study city was to rapid, the accumulation was only up to a level of less decrease, but no increase. If increase is to be intended, more drastic measures seems to be necessary. However, the study shows that as for CO2 emission reduction from household and industry, and road maintenance cost savings, the alternative still makes meaningful differences, and that we should give up from consuming too much land.

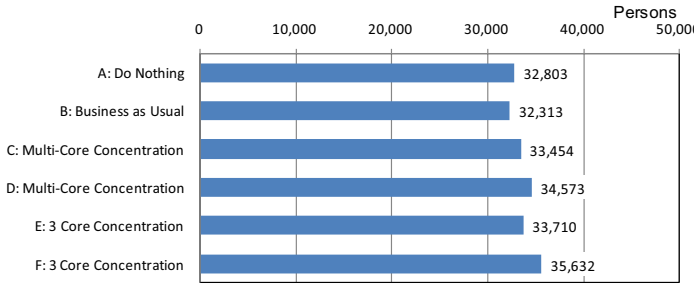


Fig. 13 Population in the Core Area -2035

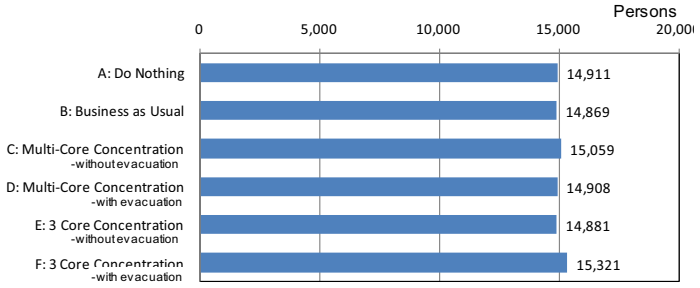


Fig. 14 Public Transport Users -2035

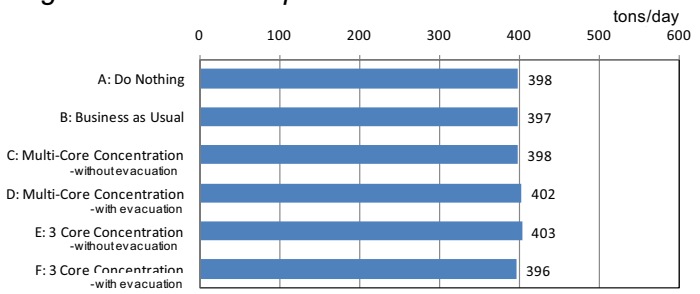


Fig. 15 CO2 Emissions (transport) -2035

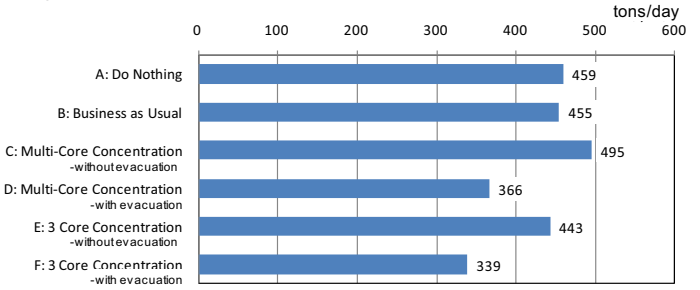


Fig. 16 CO2 Emissions (household and industry) -2035

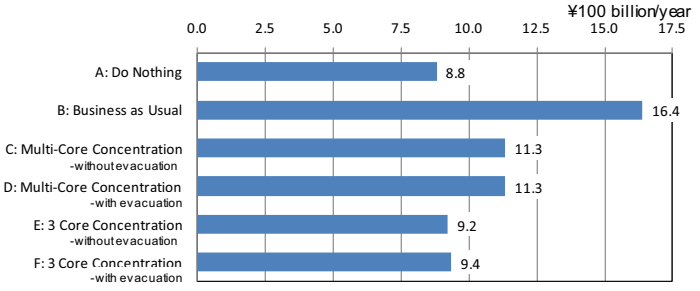


Fig. 17 Road Maintenance Costs -2035