EVALUATION SYSTEM OF POLICY MEASURE ALTERNATIVES FOR A METROPOLIS BASED ON TRANUS FROM THE VIEW POINT OF SUSTAINABILITY

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Abstract: A concept of sustainability has become a paradigm in urban development and there is also a belief that the sustainability could be achieved by compact development. Although there are many representation of compactness such as high density city, a mixed-used city, or transit oriented development, most of the discussions are only descriptive. This paper presents a quantitative analysis scheme that takes into accounts long range of time over generations of the residents. This approach of analysis has made the sustainability and compact city be discussed more clearly and effectively. The analysis is based on the empirical result of TRANUS Sapporo model. The simulation framework of decreased population in the later year is assumed based on the real population trend in Japan. It is found that the city will be sprawled if no appropriate policy measure is taken, but the city will become more compact and sustainable when combinations of appropriate policy measures are taken. The sustainability is evaluated from several aspects: as land-use, transportation, environmental, and, most importantly, financial viewpoints which consider the development cost.

Keywords: Sustainability, Compact City, Development Cost, TRANUS

1. INTRODUCTION

First of all, it is worth mentioning that the former version of this paper was included in the non-reviewed section of the proceeding of the 8th Conference in Computer in Urban Planning and Urban Management (Miyamoto, K., et.al., 2003). The idea of sustainable city is a new paradigm for urban development in the world. The principle of sustainability is known as the development that meets the needs of the present without compromising the ability of the future generation to meet their own needs'. Furthermore, there has been growing support in the recent years, mainly in the industrialized countries since the idea of a compact city is one of the popular alternatives for urban form facing the sustainability paradigm (Jenks, et al., 1996; De Roo and Miller, 2000). This concept has emerged primarily in response to the acknowledged need to find more sustainable models for towns and cities in the world. On the other hand, there are also various definitions for the compact city, although it is generally regarded as a high density and mixed-used city with an efficient public transportation system that encourages walking and cycling (Burton, 2002; Newman and Kenworthy, 1999; Breheny, 1997). However, both sustainable city and compact city have been mostly discussed qualitatively; but rarely discussed quantitatively. The present study has objectives to produce an analysis scheme for a city where the policy alternatives can be discussed quantitatively from the viewpoint of compactness and sustainability over generations of the residents as shown in Figure 1.

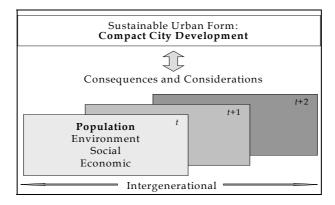


Figure 1 Compact City Development and Intergenerational Consideration

2. SUSTAINALE AND COMPACT CITY

In this section the state of the art of 'Compact City' literatures is briefly summarized. It is now widely accepted, particularly in urban development, that the most important in the urban planning is a sustainability concept. It plays an important role in shaping and raising the quality of urban living conditions. Despite important recent progress in measuring urban environment quality and performance, we know little about what makes a city sustainable. We only keep that plans should address the economic, environmental and social health of the city and this task can only be accomplished by approaching each of these issues at different scales (see for example Marcotullio, 2001). Alberti (1996) has stated that there is no consensus on how to define sustainability, nor is there consensus on city size, form, and spatial of activities best facilitate the rational allocation of natural resources and minimize environmental impacts.

The search to make realization of urban form and sustainability is currently one of the most interesting tasks on the planning fields. The way that cities should be developed in the future, and the effect of their form can have on resource depletion and social and economic sustainability are central of these tasks (Jenks, et.al., 1996). One common answer seems to be used planning systems to achieve environment improvement, and in turn, use the planning systems to achieve greater urban compaction (Breheny, 1996). The arguments that compact city can be as a representative urban form to describe a sustainable urban form, have been commonly accepted that a degree of compactness, in any several forms, reduces demand for car travel. However, the indications are that the success, desirability, and achievability of compact city are equivocal (Thomas and Cousins, 1996).

2.1 Compact City and Smart Growth

Recent issues in worldwide urban planning strategy approach, mainly the idea of concentration activities in central city, as proposed both by compact city strategy and smart growth strategy receive greater supports to real actions, mainly in Europe and the US. The philosophy of both strategy are quite the same, that is based on assumptions and also greater facts that low density residential development in general, and large lot home sites in particular, are frequently held up as the epitome of inefficient, costly and wasteful for urban land use. Low density, dispersed development is often portrayed as harming the environment. In particular, the argument is made that this pattern of growth spreads air pollution as a result of more commuters and increased automobile trips. The anti-sprawl growth as well as the supporter of concentration growth's arguments are often heard to the effect that land use policies should limit growth to areas served by mass transit, and to encourage higher density developments within the areas so as to make public transit more economically viable. With greater public transit use, air pollution generated by cars would be reduced. Table 3.1. provides the comparison in detail between these two strategies, compact city and smart growth strategy.

Table 1 Comparison of the Concepts of Compact City and Smart Growth

Aspects	Compact City Strategy	Smart Growth Strategy
Country	Europe	America
•	Australia	Canada
	Japan?	
Policy	Government regulation	Community based
-	Top-down approach	Bottom-up approach
	Local government initiative	Nation wide movement
Core	Compactness	Anti-Sprawl
Definition	An urban policy strategy in line with	A movement to stop any dispersed
	sustainable urban development efforts that a	development outside of compact urban and
	process to perform higher density	village centers along highways and in rural
	urbanization, mixed use development in	countryside that caused uneconomic of
	central area, towards benefits in all	services and doubtful social value
	dimensions of urban life	
Objectives	A concentrating positive growth and activities	A desired pattern urban development that
	in appropriate areas, all at once avoid	designate boundaries areas and create
	negative impacts on natural resources, and	economic incentives for development to
	getting more benefits on social/economic	take place within an appropriate area
	factors by a compactness development	together with a strong comprehensive plan,
	process.	with broad public input for the best way of a
		community or region
Principles/	Higher density	Accessibility and existence of community
Attributes	Mixed use	Sense of place
	Process (concentration etc.)	Housing and building opportunities
	Urban scale (economics, structure)	Mix land use
	Transport efficiency (environment dimension)	Transportation environmentally choice
	Social dimension	Effective development
Issues	Social equity	Loss of sense of space (genius loci)
	Traffic congestion and pollution	Land consumption and threat to farmland
	Quality of life and lower standard of living	Costs to local government
	Prospects of delivering compaction	The dependence on the automobile
	Worsening community position	Inner city: social impacts
	Reduction in privacy	Health impacts
	Reduction in present amenity space	Environmental impacts
	Perceived lack of greenery, open spaces	Design
	High price of housing	
	Appropriate land use	
Scope	Economic	Community quality of life
concern	Social	Economic
	Environment	Environment
	Policy	Health

		Housing
		Transportation
		Design
Causal factors	Land use planning	Zoning policies
	Regional planning/cooperation	Regional planning
	Highway building	Highway building
	Housing policies	Housing policies
	Competition for tax revenue	Competition for tax revenue
	Sub-urbanization	Lifestyle choice
Benefits	Support equity in some respects	Managing growth effectively (cooperation).
Denents	Reducing the need for travel by facilitating	Decreased public expenditures
	shorter journeys as well as car dependence	Open an isolation from the heart of the
	and inducing greater supply and use of public	community
	transport.	Decreased auto usage and commuting time
	Opportunities for emission-efficient modes of	Urban rural development synergy
	transport and pollution problems	Rational extension of urban service
	Accessibility to goods and services is more	Help to preserve rural lands outside the city
	equitably distributed by higher density	Generate center of city and its activities
	settlements	Eliminate competition for retail
	Deliver other environmental benefits, such as	development and the loss of associated tax
	reductions in loss of open land and valuable	revenues.
	habitats.	Provides both flexibility and certainty to the
	A milieu for enhanced business and trading	planning process.
	activities	Francisco Progression
Actual efforts	New policy implementation	Sense of place creation
	Process of intensification-concentration	Growth concentration
	Transportation strategy	Preservation of open space and farmland
	Higher densification	Transportation strategy
	Land use control/planning trends	Regional cooperation
		Demographic trends
Note	Tough debatable strategy and need for further	In general, smart growth invests time,
	more uncontentious evidences, compact city	attention, and resources in restoring
	claimed its advantages, include: conservation	community and vitality to center cities and
	of the countryside; less need to travel by car,	older suburbs. New smart growth is more
	thus reduced fuel emissions; support for	town-centered, is transit and pedestrian
	public transport and walking and cycling;	oriented, and has a greater mix of housing,
	better access to service s and facilities; more	commercial and retail uses. It also preserves
	efficient utility and infrastructure provision;	open space and many other environmental
	and revitalization in inner city.	amenities. But there is no "one-size-fits-all"
		solution.

Both the compact city and the smart growth strategy are designed to prevent the urban growth from the negative effects of growth which is believed to be happened if there exists a sprawl growth pattern throughout the city. This pattern is influenced by suburbanization which is characterized by such low density population in the suburb area and automatically increasing automobile dependencies (Newman and Kenworthy, 1999).

2.2 Scope of the Compact City Study

The compact city studies have been dominated by urban planning study, including urban/built environmental design, and urban geography respectively area. It is based on literature, journal, and manuscript on related major which has high frequency to take compact city concept into their consideration. This finding supports an argument in Jenks et.al (1996) that compact city becomes a great magnitude to architects, planners, and urban designers to discuss and debate this vision. However, the compact city study in the urban economics still has a little attention. Figure 2 summarizes the presentation situation of the compact city study.

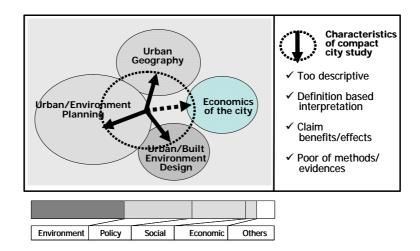


Figure 2 Scopes, Ranges, and Characters of Compact City Study

Although many studies have been conducted on compact city and its relevant aspects, including enshrinement in land use planning policy in many countries, the studies still remain contentious, mainly shortcoming in evidence to support both many claims and counterclaims in its favour (Burton, 2002, Jenks, et.al, 1996). Almost of its lack empirical evidence is exclusively on the environmental impacts, such as energy, transport emissions, loss of open land, natural habitats and resource depletion (Breheny, 1997). This shortcoming also influences range composition of compact city studies which has been dominated by environmental study followed by policy, social, economic, and other studies (history, psychology) respectively. Moreover, this concept appears to have a variety of attributes or characters (Burton, 2000; 2002), since many authors propose different characters of compactness. It is caused that compact city studies is too descriptive with lack evidence and only depend on the author assumptions and knowledge of what the compactness is.

2.3 Approach for the Evaluation of Compact City

Since the compact city could be defined in many ways and involves many influenced factors, indeed the evaluation analysis on compact city should also design to reflect objectives of compactness concept in broadly effects. It should include an assessment of effects of policy measures on urban factor and its entities. Van der Walls (2000) has also argued that the effect of compact (urbanization) depend strongly on social developments in one hand, and policies in other areas, like housing policy, traffic and infrastructure policy, energy policy environmental policy, and nature policy on the other.

To be a relevant evaluation as has been argued by Burton (1996), they do not have to be related directly to urban form, because the most important think is their concerns on assessment in general of actions designed to improve sustainability The following topics are covered: environmental impact assessment; policy evaluation techniques; monitoring technology; environmental threshold methods; forecasting; modeling; capacity evaluation methods; sustainable management; and perhaps, most important, sustainability indicators. However, assessments need constant updating, and measurement, as well evaluation techniques for local authorities with high access in database, thus the rise in interests of developing indicators.

Indicators allow assessment to be made using limited, representative information, with different capacity approaches. Burton, et.al. (1996) have stated that the advantage of the indicator approach is that it can accommodate the whole range of issues, including subjective

criteria (Burton, 2000, 2002). Indicator approach also allows better judgements to be made at the local level through comprehensive, structured framework. However, it has several drawbacks. One is that it dose not resolve the problem of the relative weight of each indicator and the interrelationships between them. Another one is limitation of indicator scope to be implemented in different levels (Jenks, et.al., 1996). It is likely urgent that the tools should be developed by a wide variety of different interested level and between the different approaches to be effective one. As described many times that there is no consensus on the definition of sustainable development on practice, including compactness. And interesting to cite the argument of Burton, et.al (1996): whatever the quality of monitoring and modeling, it is of little use unless linked to appropriate action, but how can this be determined without an explicit understanding of the goal?

Today's visionary solution in answering a sustainable urban form can initially be inspired by compact city concept. From academics, practitioners, and politicians have all been quick to adopt this as an all-embracing remedy for urban ills. Yet this contemporary vision displays the same lack of attention to the crucial question of feasibility. The case for the compact city remains largely unresolved as indicated in previous discussion that a range of issues which there is a degree of uncertainty. Competing and conflicting claims, which of necessity are argued from an incomplete knowledge base, exist theory, in the concept of sustainability, and in relation to environmental, economic, and social issues.

In spite of the concept of compact city as a model of sustainable development is only just beginning to be recognized, and associated complexities disclosed, there is an imperative to gain a deeper understanding of the compact city and its action to implement it. This particularly, important as policy is promoting new compact city forms, while at the same time results of implementation are largely unknown and hard to predict. Nevertheless, defining more concrete a compact city in line with searching a sustainable urban form, developing its policies, and overcoming implementation problems are all steps which need to be taken first to determine compactness rationally and reasonably.

Regards to introducing the implementation of compact city, firstly, it is necessary to cope with characteristics of the city before implementing such compactness policies is fundamental requirement, including better understanding of the criteria of urban agencies, range of methods, as well as scale and legitimating of the policies. Secondly, to introduce any degree of compactness in the future and to avoid the negative excess of compactness in such a city, city planning would require stronger regional guidance and planning, closer cooperation between regions and their individual local authorities, together with the development of suitable policies through government actions. The compact city approach will probably succeed, but with patient, balance, and by examples.

3. QUANTITATIVE ANALYSIS WITH AN URBAN MODEL: TRANUS

The basic functions that are required for the analysis system in this study are to be capable of space and time with adequate details. The interactions between measured indicators and the condition of urban change over time should be able to be represented in expected sequenced time series. In addition, indicators to measure the compactness are strongly related to land use, transportation, and environment. Therefore, this study has employed TRANUS as a core urban model for the analysis system, for it is one of the most general urban models that can deal with land use, transportation, and environment both temporally and spatially.

3.1 TRANUS Model of Sapporo

Developed by De la Barra (1989), TRANUS is one of the existing operational models that have been and being used in real applications (see, for example, US EPA, 2000; Wegener, 1994, etc). TRANUS is similar to MEPLAN (ME&P, 1995) in the way to represent the spatial interaction among urban activities by using input-output model framework. The main feature that distinguishes TRANUS from MEPLAN is the concept of 'scaled utilities' in TRANUS's logit model to allocate activities to different zones. Since TRANUS is a general model framework, a certain design must be specified for each application of the model for a study area. In the present study, we applied TRANUS to Sapporo Metropolitan area of Japan, which is located in its northern main island. It is markedly monocentric with about two millions population. Public transportations are well provided with several commuter railway lines (JR lines) and three subway lines. Zoning system in TRANUS Sapporo is the one used in the real transportation planning of Sapporo, which is consisted of 73 zones, as shown in Figure 3.

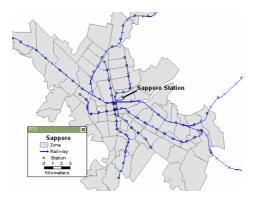


Figure 3 Study Area of TRANUS Sapporo

In one time period, there are three modules to model land-use and transportation interaction, i.e., activity (land-use) model, interface model, and transportation model. Firstly, the activity model (or so-called land-use model) operates with three groups of sectors namely resident, business (employment), and land sectors. In TRANUS Sapporo, residents are represented in terms of household. We have only one sector of household in our model due to the fact that social segregation is not evident in the Japanese society nowadays. It is, however, worth noting that most of the applications of TRANUS or MEPLAN models have several classes of household classified by income. Business is represented by three groups of worker namely primary, secondary, and tertiary employment sectors. This categorization was also used in the real analysis in Sapporo transportation planning. The primary and secondary employment sectors are exogenous (or given) while the tertiary sector is endogenous (or to be determined by the model). Land sector is represented by two types of land namely residential (Res land) and commercial land (Com Land). The growth of land development is constrained by total developable land (Dev Land). Relationships among these economic sectors are represented by 'Social Accounting Matrix' as shown in Table 2. The relationships among sectors are either fixed or elastic. The fixed relationship is represented by the fixed coefficient (f), which is the fixed consumption of producing sectors by consuming sectors. This is similar to technical coefficient in input-output model. Specifically, workers (of all three employment sectors) consumption of household is represented by the average number of worker per one household (f1). Similarly, household consumption of service of tertiary sector is represented by ratio of the number of tertiary sector by the number of household (f2). The elastic relationship is represented by the elastic coefficient, which is price-elastic (e). That is, e1 and e2 represent the price-elastic consumption of land by household and tertiary sectors.

	Produ	cing					
Consuming	Primary	Secondary	Tertiary	Household	Res Land	Com Land	Dev Land
Primary				f 1			
Secondary				f 1			
Tertiary				f 1		e1	
Household			f 2		e2		
Res Land							1
Com Land							1
Work				c1			
Private			c2				

Table 2 Social Accounting Matrix of TRANUS Sapporo

Secondly, the interface model makes linkage between the land-use (activity) model and the transportation model. In the SAM, the interface module is shown by the small matrix below the large matrix in Table 1. That is, c1 and c2 represent conversion of interzonal/sectoral flow from the activity model (in household or worker units) into travel flow for the transportation model, by trip categories: work and private trips. The work trip is derived by workers in the household going to work while the private trip is derived by tertiary workers providing service to residents (or household).

Thirdly, the transportation module determines the last two part of typical four-step transport model, i.e., mode split and assignment. Changes in transportation during 1980 to 1995 modeled in TRANUS Sapporo are the major projects such as new subway, highway, railway stations, etc. These three modules determine equilibrium in the land and transportation markets by repeating the model runs until convergence. Next, the model moves forward to the next time period by the incremental model, which specifies the growth of economic sectors. The growth is modeled by a fixed rate of growth in the exogenous sectors. The model base year is 1980 and run with five-year step to 1995, shown in Figure 4.

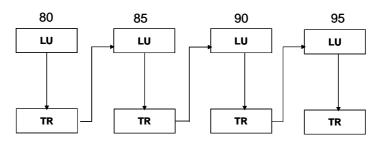


Figure 4 Quasi-Dynamic Structure

The model is calibrated for the base year (1980), and its base year forecast is accurate as it could be expected, i.e., the forecast of household in the base year versus the real number of household. Clearly, the model has been calibrated and adjusted well enough that the goodness of fit is perfect. Since TRANUS structure is quasi-dynamic, only the base year calibration is not relevant to represent the change of urban condition in time. So the interval calibration is conducted for the period of 1980 to 1985. And to validate the calibrated model, the model is

to forecast the household distribution in 1995. The model is evaluated by comparing the change in household from 1985 to 1995 with the change produced by the model. It is found that the model can represent the change satisfactorily with R² of 0.6116. The validated TRANUS Sapporo model will be used in the rest of the analysis.

3.2 Additional Indicators for Compact City Evaluation

Regarding the indicators for the evaluation, some of TRANUS outputs can be directly used for the compact city indicators. In addition, a large number of variables related to transportation and land use are produced either explicitly or implicitly in TRANUS. In the application of TRANUS for this study, several extensions are made to the original system. Table 3 summaries the indicators of the present system, which are originally produced by TRANUS and additionally produced outside TRANUS. The additional indicators are the congestion cost, air pollution emissions, and development cost, which is of the most interest to estimate the costs of infrastructure development and the maintenance/ operation by year and generation of the residents.

Type	Measure Indicators	Objectives
Type		
Indicators obtained	Number of trips	Calculate number of
directly from TRANUS		trips. Indicate level of
		attractiveness by zone
	Travel distance	Average and total
		distance to travel
	Travel time	Average time to travel.
		Indicate level of
		nearness among zones
	Travel costs	Average travel costs
		related to time, distance,
		and transfer
	Energy consumption	Average and total
		energy consumption by
		zone
Additional indicators	Congestion costs	Level of congestion
calculated in this study		costs by zone
_	Air pollution emission	Level of air emission
	1	(CO, NOx, HC) by zone
	Development Costs	Development costs
	_	related to growth pattern
		and households
		distribution

Table 3 Indicators for Compact City Evaluation with TRANUS Sapporo

4. COMPACT CITY POLICY MEASURES

In this study, the simulation and evaluation is made at interval of fifteen years, from 2000 to 2015 and from 2015 to 2030 where a number of policy measures are taken.

4.1 The Population Decrease Framework

The simulation framework is set to have the population increase in the near future and the population decrease in the later future, as shown in Figure 5. In words, it is foreseen that if no appropriate action is taken, the city core will be growing up, resulting in suburbanization. However, in the later year when population decrease, the urban will be sprawled. The traffic congestion will follow the trend of the city growth. The congestion will be severe when the

city is on the up-curve and the situation will be more or less relieved when the population is declining; less people travel long. Consequently, the traffic congestion will generate emission in the similar way. In this regard, the government needs to prepare for the increasing travel demand, which is normally to build road and other transport facilities. This results in the steady capital investment until the population start to decrease. The investment in transport infrastructure will be reduced when there is less travel demand after 2020. On the other hand, the operation and maintenance must continue with the existed infrastructure. The O&M cost will be larger when the structures are older. This is the general tendency of not only cities in Japan but also those in other industrialized countries. It is worth mentioning that the simulation system in the case, however, is also able capable of other different scenarios of population changes.

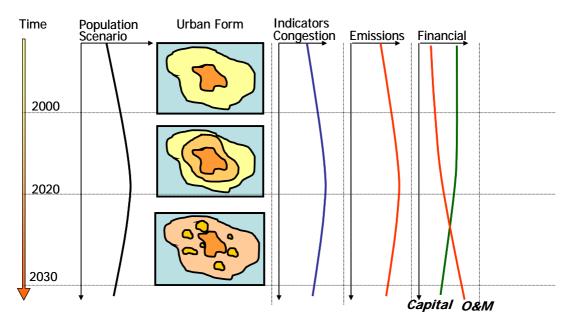


Figure 5 Population Decrease Framework of TRANUS Sapporo

4.2 Policy Alternatives

The policy alternatives for the analysis are summarized in Table 3.

Table 3 Policy alternatives for the analysis

Policy	Purpose/Implementation Measure	
Do Nothing (DN)	No action beyond existing (as forecast)	
Road Pricing (RP)	Reduce car dependencies in city as well reduce trips lengths	
	and improve traffic conditions in the city/Charge road usage	
	by kilometer drive.	
	(Transportation side)	
Transit Oriented	Increase residential and commercial areas located along	
Development	transit in center area to maximize access by transit and non	
(TOD)	motorized transportation/Promote development around	
	railway stations.	
	(Land use side)	
Public Transport Priority	Reduce car dependence by supporting residents to use public	
(PTP)	transportation in city/ Improve service of public transport.	
	(Transportation side)	
Urban Boundary (UB)	Introduce urban boundary to limit growth in the suburb and	
	promote more development in central city	
	(Land use side)	
Cordon Line Pricing (CL)	Reduce car dependencies certain areas in city as well reduce	

	trips lengths and improve traffic conditions/Charge cars when crossing cordon line.
	(Transportation side)
UB + RP	Combination of Urban Boundary and Road Pricing
UB + PTP	Combination of Urban Boundary and Public Transport
	Priority
RP + TOD	Combination of Road Pricing and Transit Oriented
	Development
RP + PTP	Combination of Road Pricing and Public Transport Priority
TOD + PTP	Combination of Transit Oriented and Development Public
	Transport Priority

4.3 Simulation Results

The results of the simulation are partly summarized in Figure 6 and 7. In general, compared to Do-Nothing (DN) case, all policy alternatives are certainly effective making better condition from the viewpoint of tested transportation indicators, such as reducing travel by car, promoting public transportation (subway) and non-motorized mode, reducing travel distance and travel costs, as well as reducing air emission and energy consumption to be lower. The policy alternatives related to transportation attempts seem to be more effective to realize quick results for transportation indicators in line with compactness objectives. Thus, from the modeling viewpoint, compactness is easier to be experimented with the transport related policies.

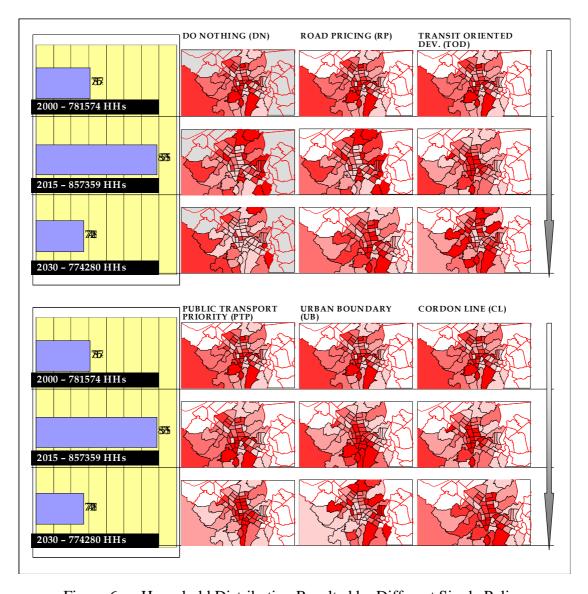


Figure 6 Household Distribution Resulted by Different Single Policy

Combinations among policy alternatives being complementary to each other (i.e. combination of push and pull policies) revealed significant evidences for more successful implementation of compact city development. However, these synergy effects are not always significant in every model results. For example, shown in Figure 8, one of the effective policies combinations is shown by CL and PTP combination, in which CL represents a push policy and PTP represents a pull policy. This policy shows a significant reduction in travel demand (total number of trip is reduced). The resulting city is considered more compact since the travel distances of the residents are averagely shorter. However it is interesting that the average travel time is longer. One reason it is simply due to a modal shift from car mode to non-motorized mode that takes longer travel time. Thus, it is found by the simulation evidence that a policy being specific to one mode also affect the use of its relating mode(s). Similarly the synergy effect is pronounced when combining policies with different directions, e.g., push and pull together.

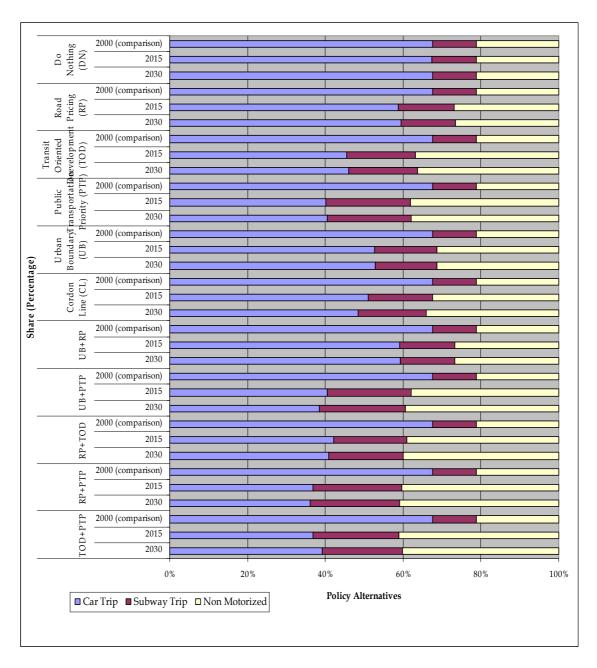
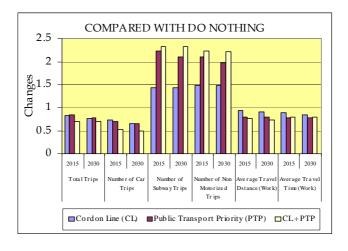


Figure 7 Transportation Indicators Resulted by Single and Combined Policies



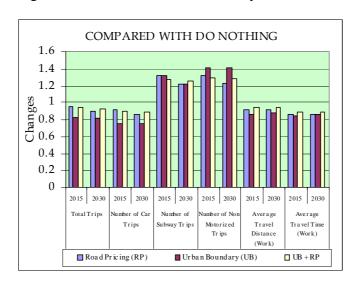


Figure 8 Positive Results from Policy Combination

Figure 9 Less Pronounced Results from Policy Combination

On the contrary, combination of policies by RP (road pricing) and UB (urban boundary) which are both push policies shows the other interesting findings as illustrated in Figure 9. It is obvious from the graph that RP and UB policies reduce travel demand when compared with the Do-Nothing case. It might be expected that devising a road pricing and setting urban boundary (RP+UB) would further reduce travel demand when compared with the UB case alone. But the result is not as expected; all model results of RP+UB policy are more or less similar to the single RP policy. Thus it is found again by the simulation evidence that a combination of push and push policies would not always yield the synergy effects. In this case, the single RP has much stronger impact than the single UB so that the role of UB is unseen when it is combined with RP in the RP+UB policy. Although the discussion here is based on the present version of TRANUS Sapporo, it could be improved and produce more meaningful results if it runs in a longer time-range with more comprehensive dataset. At least, TRANUS relies very much on land-use information, a careful consideration/expectation of future land-use condition as its model input will generate very much accurate and meaningful policy analysis.

Due to the population decrease framework, an assumption of developing costs for this study is shown in Figure 10.

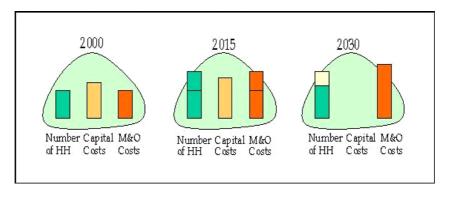


Figure 10 Assumption of the Development Cost

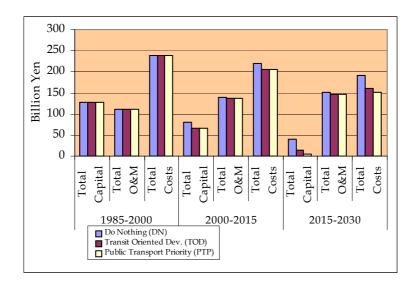


Figure 11 Development Costs Due to Different Policy Measures

Based on the estimated development costs, the costs for infrastructure development and the maintenance/operation are simulated for some policy alternatives, shown in Figure 11. The differences from the Do Nothing case are generally not as significant as were expected. The reason could be that the additional costs to keep the level of service for more densely development in the central area are almost equivalent to those required for suburban development. However, if the generation bears lower level of service for a while, the financial burden of the future generation will be relieved and recover the level of service again. The system can provide the degree of each indicator with alternative financing program of the city.

5. CONCLUDING REMARKS

The present study is going and has developed a pilot system with a quantitative analysis scheme of policy alternative analysis in terms of level of public service and financial expenditure in the future. Some representative policies, which were recognized formerly and descriptively, are quantitatively discussed with the numerical simulation results. The compactness is evaluated from several aspects: as land-use, transportation, environmental, and, most importantly, financial viewpoints which consider the development cost. This has brought various meaningful interpretations and discussion. With the population-decrease framework, it is found that the city will be sprawled if no appropriate policy measure is taken, i.e., not compact. But the city will become more compact if appropriate policy measures are taken. Moreover, the financial burden by the resident generation is clearly shown with alternative financial programs of the city. In conclusion, the quantitative analysis system has made possible to take the benefits and costs as well as the financial burden by generation into consideration for the evaluation of a compact city.

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