UP School of Urban and Regional Planning
Journal in Urban and Regional Planning
journal homepage: http://journals.upd.edu.ph/ | 2014 ISSUE

Effects of Public Transport Improvement in the Formation of Compact Cities*

*Daniel L. Mabazza***
*Tohru Tamura ****

**This research was published in Japanese last September 2010 at the Journal of the Japan Society of Traffic Engineers* (JSTE) (交通工学研究会) Vol. 30, pp. 293-296 with title:
公共交通サービスの向上がコンパクトシティ形成に与える影響

ABSTRACT

Many cities recently have initiated efforts in the formation and development of sustainable cities through transport policies in realizing a low carbon city. But changes in the urban structure and transport as a result of the urban growth are not sufficiently analyzed and established including its evaluation methods as a result of such changes. The study aims to evaluate the changes in urban structure and transportation in a target city-wide two million people in Japan, in an era of depopulation in the country. An empirical analysis was performed to clarify the changes in the urban structure and journey-to-work travel characteristics. In order to realize the formation of a low carbon sustainable city, an optimum commuting allocation solution was formulated by estimating reduction in the form of commuter trip length. As a result, by evaluating the changes of urban structures and transportation, estimation of the journey-to-work trip length reduction was possible.

Keywords: *subway, compact city, preference curve*

*** Associate Professor at the Department of Geography, University of the Philippines in Diliman. He may be reached through daniel.mabazza@up.edu.ph*
**** Professor at the Division of Engineering and Policy for Cold Regional Environment, Graduate School of Engineering, Hokkaido University in Sapporo, Hokkaido, Japan. He may be contacted via email through tamura-t@eng.hokudai.ac.jp*

We express our deep gratitude to Mr. Toshiyuki Naito of Docon Co. Ltd. of Japan for his great assistance during the conduct of this research.

INTRODUCTION

Automobiles have become indispensable in people's lives today and the proportion of users relying on automobiles as mode of transportation has become increasingly overwhelming in Japan. However, this phenomenon has caused growing number of problems related to traffic congestion, obstacles and the like, as well as global environmental problems related to air pollution and energy consumption. As part of the solution to address these problems, policy debates over the implementation of compact cities have started in a number of European countries throughout the 1990s.

Compact cities have been extensively discussed in urban planning theory and micro-analytical studies such as residential location choice behavior. However, macro-analytical studies dealing with the effects of public transport improvement particularly in employment-residence spatial distribution are limited. In this regard, Mayama *et al.* (2009) have shown using a macro-analytical perspective the possibility of reducing actual journey-to-work trip length based on optimal commuting assignment problem.

This research paper investigates the improvement in mass transport services with a focus on the expansion of the subway network system; its effects in journey-to-work trip length, changes in urban structure, as well as its impact in the formation of compact cities.

DATA AND ANALYSIS OF TARGET CITIES

We analyzed the origin and destination traffic focusing on the subway system among other transportation modes available for commuting to work in Sapporo City. The analysis is performed using the person-trip surveys that were conducted in 1972, 1983 and 1994 in seven metropolitan areas led by Sapporo City and three municipalities in central Hokkaido. These target areas are namely: the cities of Sapporo, Kitahiroshima, Ishikari, Chitose, Eniwa, Otaru, Ebetsu, and the municipalities of Nanporo, Naganuma, and Tobetsu.

As part of the infrastructure development in preparation for the Winter Olympics staged in Sapporo City in 1972, the Namboku Subway Line (from Kita 24 Jyo to Makomanai) was launched in 1971. This drastically transformed the city’s prior reliance on trams and buses as means of public transport. Following this was the consecutive completion of construction projects for the extension of subway lines: The Tozai Subway Line in 1976 (Kotoni to Shiroshi), Namboku Subway Line (Kita 24 Jyo to Aso) in 1978, and Tozai Subway Line (Shiroishi to Shin-Sapporo) in 1982. The Toho Subway Line (Sakae-machi to Toyomizususuki) commenced operations in 1988 and was also extended (Toyomizususuki to Fukuju) in 1994. Further extension of the Tozai Subway Line (Kotoni to Miyanosawa) was made in 1999, and presently a transportation network linking buses and subways are being established.

Table 1 shows the total number of journey-to work trips by utilizing subways as well as the total number of journey-to work trips utilizing all transportation modes. The number of zones that were covered in all person-trip surveys that were conducted in three different years is also reflected in the table. Furthermore, the zone and administrative divisions of Sapporo City are shown in Figure 1. In this research, we align all data using the zones (53 zones) covered in the 1972 survey and then re-tabulate the origin-destination data for analytical purposes.

Table 1 *City data analyzed in the study*

Survey Year	Number of Zones Surveyed	Total Number of Trips		
		Subway (A)	All transportation Modes (B)	A/B
1972	53	33064	335218	0.098634
1983	70	125496	498438	0.251779
1994	75	156471	606021	0.258194

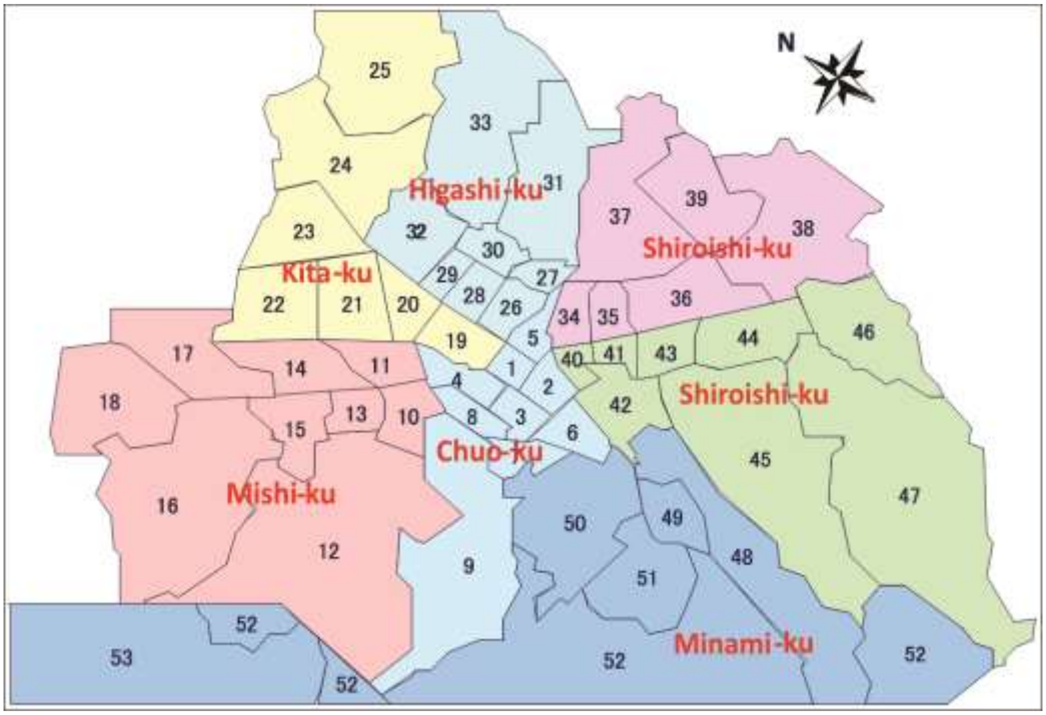

Figure 1 *Zones and Administrative divisions (53 zones)*

EMPLOYMENT-RESIDENCE SPATIAL DISTRIBUTION INDICES

Cumulative frequency distribution curve

Figure 2 shows the cumulative frequency distribution curve which is used to analyze transport movement expressed as journey-to-work origin and destination (OD) traffic, as well as transport resistance which is expressed as distance. The x-axis of the curve expresses inter-zonal distance while the y-axis expresses the cumulative ratio of OD traffic volume bound within a set of distances included in the target OD traffic. The total actual journey-to-work trip length in each city can be estimated based on the cumulative frequency distribution curve.

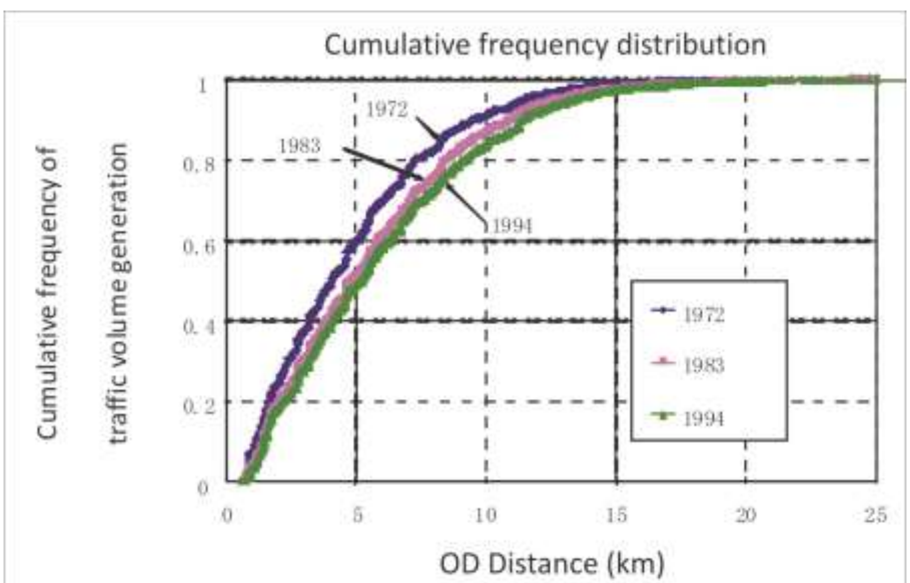

Figure 2 *Journey-to-work trip length and cumulative frequency distribution curve*

Looking at Figure 2, the OD distance corresponding to a cumulative ratio of traffic volume generation of 0.8 was 7.3 km, 8.5 km, 9.2 km in 1972, 1983 and 1994 respectively. In effect, this implies that journey-to-work trip length in Sapporo City has been increasing.

Preference curve

We apply the use of preference curve as prescribed by Masuya *et al.* (2001) to visually and quantitatively examine urban structures according to the distribution and scale of residential and employment locations.

Preference curves show the relationship between the cumulative trip generation ratio from the trips made by workers originating from their respective residential locations, and the cumulative trip attraction ratio which expresses the distribution of employment locations. As the curve shifts towards the upper left corner of the two-dimensional space where the curve is plotted, the trip ratio generated in short distances becomes higher. Conversely, a shift towards the lower right corner would mean higher trip ratio generated over longer distances.

A cumulative trip ratio that is higher in shorter distances, or in other words, proximity of residential to employment locations would mean reduction in excess or wasteful commuting. This would likewise have socially favorable effects like reduction of environmental damage, easing of traffic congestion etc. These effects are also foreseen towards the implementation of compact city policies.

We examine Zone 29 (around the vicinity of Motomachi Station on the subway line) as an example to illustrate the characteristics of preference curves. A shown in Figure 3, Zone 29 is along the transit route of the Toho subway line, which was constructed between 1983 and 1994.

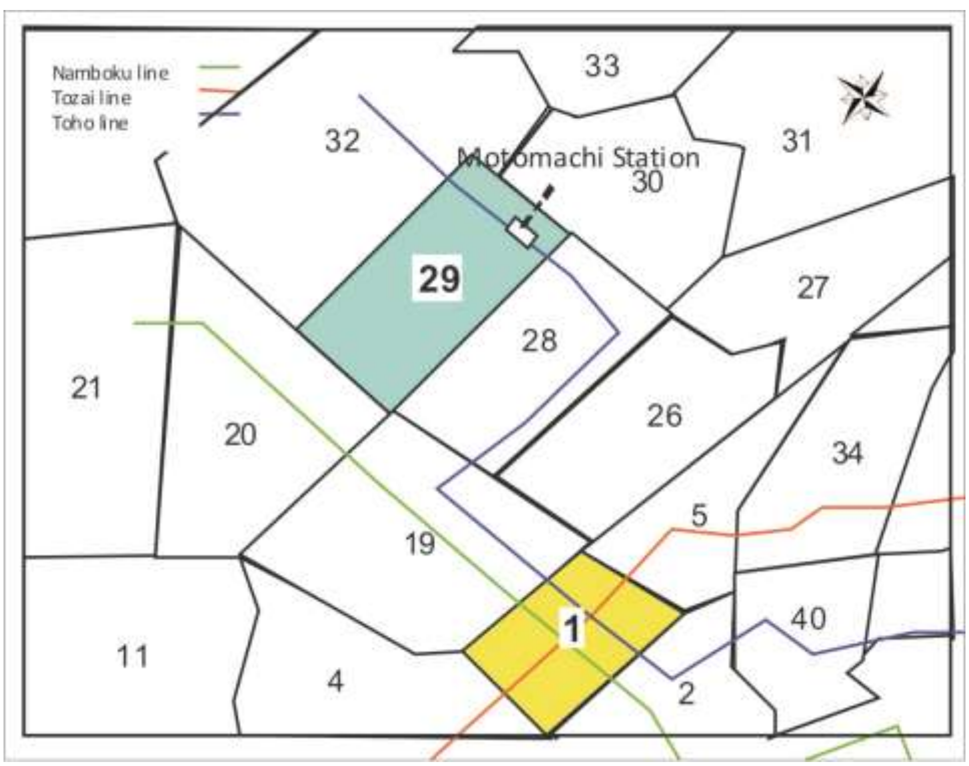

***Figure 3** Zones in Sapporo City*

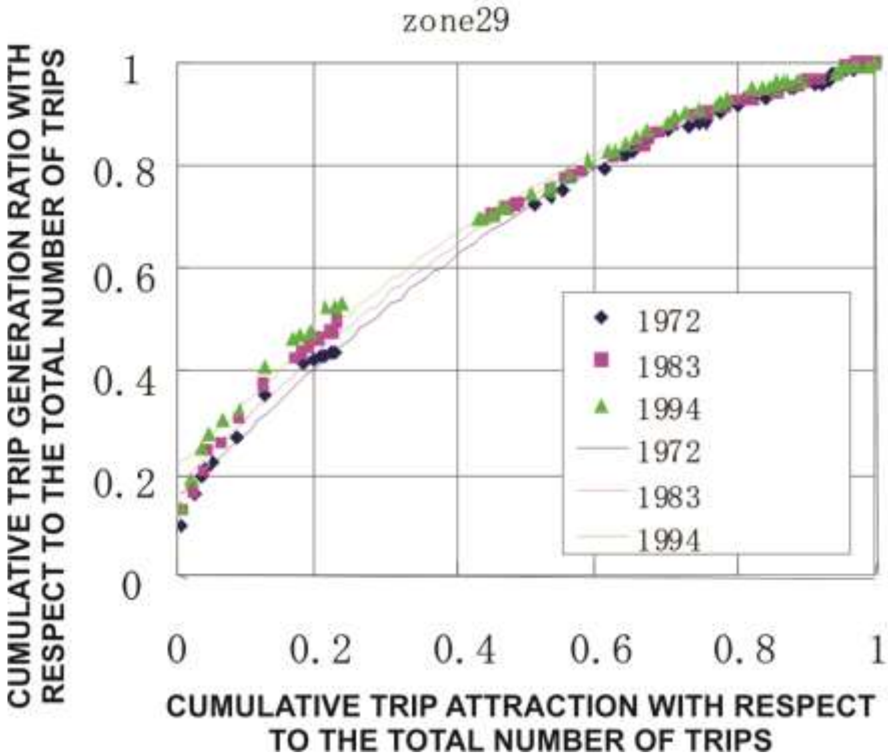

Figure 4 *Changes in preference curves (Zone 29)*

Looking at the preference curves of Zone 29 in Figure 4, a 0.2 value in the cumulative trip attraction ratio with respect to the total number of trips would have corresponding values on the y-axis of 0.42, 0.45, and 0.5 along the preference curves for the years 1972, 1983 and 1994, respectively. This means that the cumulative trip ratio generated between zones with shorter distances has been increasing. It can be concluded that the spatial structure of residence and employment in Sapporo City's Zone 29 is becoming more compact. Moreover, combining this with the findings drawn from Figure 2, the mean trip length was found to be increasing yearly in Sapporo City in general. However, the increase in the trip ratio towards locations of shorter distances in Zone 29 which is along the extended subway route, the mean journey-to-work trip length in the said zone may be reduced.

In this research, we examine and focus on the changes in the employment-residence spatial structure between 1983 and 1994, which also correspond to the period when the Toho Subway Line was launched and extended. Figure 5 shows the changes in the preference curves by mapping out the patterns of proximity and remoteness exhibited in each zone before and after the sample period. Figure 6 shows the changes in population in each zone with the same sample period. The lines drawn in the center of the zone map represent the different subway lines (as of 1994). The Toho Subway Line is represented by the solid line.

In Figure 5, we can see that most of the zones where subway services are accessible have exhibited proximity with regard to employment-residence spatial structure. Meanwhile, the zones where subway services are inaccessible have shown general patterns of remoteness. It can be inferred that workers who prefer to live in zones where subway is accessible would have employment located in nearby areas while people who prefer to live in zones where subway is inaccessible (sub-urban areas) would have employment that is usually located further away from their residential zone, i.e. off-center areas.

Meanwhile, it has also been observed that a significant number of zones that are accessible by subways have already been exhibiting shared patterns of remoteness with regard to employment-residence spatial structure. This observation has become evident in rapidly developing urban zones such as the increasingly progressive areas in and around Shin-Sapporo, regarded as the sub-center of Sapporo City. This phenomenon can also be observed in Higashi-Sapporo, Kotoni, Teine and other city centers that possess highly developed urban functions. Drawing from these observations, it can be inferred that not only changes in subway operations but also urban policies in general could directly influence patterns in employment-residence spatial structure.

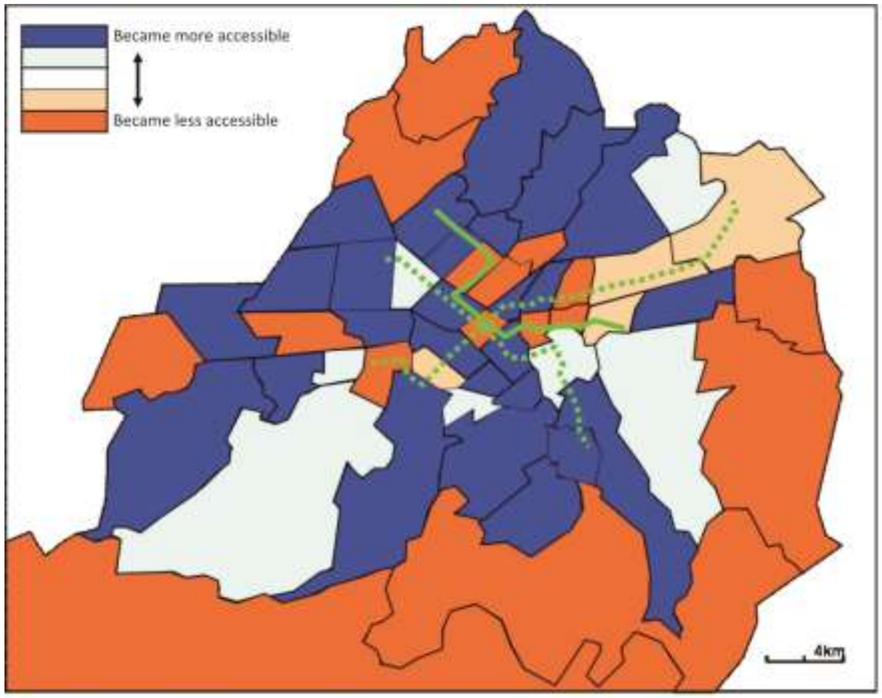

Figure 5 *Changes in preference curves (53 zones)*

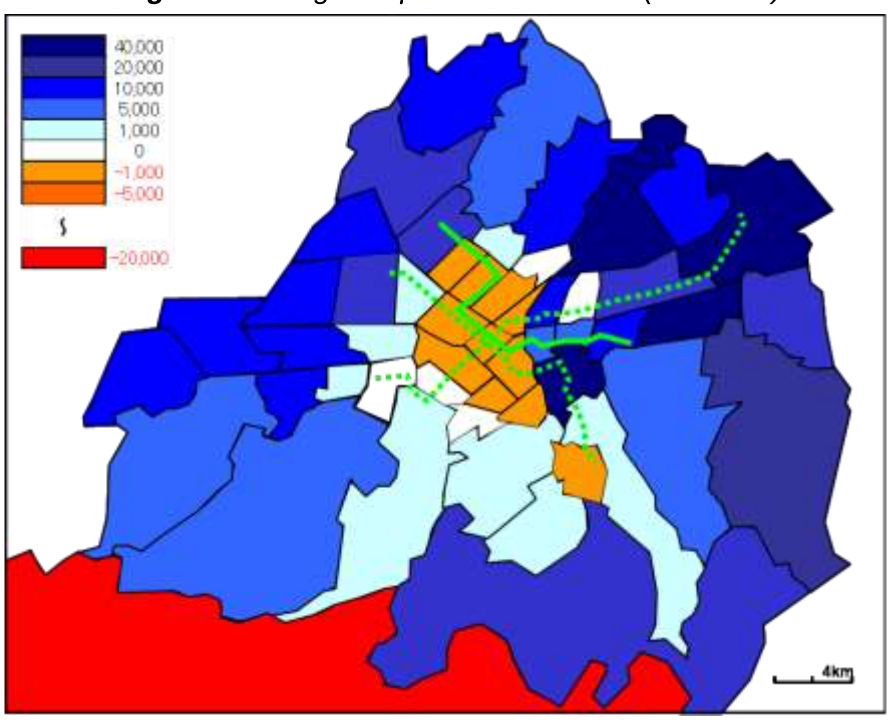

Figure 6 *Changes in population (53 zones)*

Looking at Figure 6, a significant number of the population has been increasingly migrating towards zones with mass transit options, or subways in particular, as far as this study is concerned. The population in zones surrounding Zone 1 which has been designated as the central business district has decreased from 1,000 to 5,000 people. Areas available for residential purposes (or for the population) in business centers are diminishing due to the scarcity of land and the constraints in residential development.

Meanwhile in Zone 53 which is located around Jouzankei has seen an unprecedented decrease in population, numbering to more than 20,000 people as compared to other zones. Because of the continuously increasing influx of population into Sapporo City, however, instead of migrating to other cities the population is migrating towards the peripheral areas, which are arguably more strategic and where there are more chances for employment.

Urban composite index

The urban composite index can be computed using the following equation. The equation is composed of T_{min} and T_{max} which correspond to the minimum and maximum values of total journey-to-work trip length, respectively. These values are estimated using developed optimal employment-residence spatial distribution structure problem derived from certain urban structures.

$$\text{Urban composite index} = \frac{T_{\min}}{T_{\max}} \qquad (1)$$

This index expresses the spatial structure of urban employment locations. An index with a value 0 would mean that employment locations are perfectly distributed in each zone. On the other hand, an index will have a value that is close to 1 when employment locations are converging into one zone.

The mean trip length and the urban composite indices computed for the years studied are shown in Table 2. From the table, it can be seen that the mean length of trips made in Sapporo City has been increasing year after year. This observation has also been evident in the cumulative frequency distribution curve. On the other hand, the urban composite index has dropped from 0.3204 in 1972 to 0.2641 in 1994, which means that employment locations are becoming more dispersed. Thus, it can be said that work locations are being decentralized and total number of trips are expanding (due to population increase) in Sapporo City, or precisely, along with the expansion of the city's scale, work locations are increasingly moving away from the central business district (Zone 1) towards the peripheral zones or even suburban areas.

Table 2 *Average trip length and urban composite index*

Item	Year	1972	1983	1994
Total Number of Trips		335,218	498,438	606,021
Total Commuting Distance (Person-km)	Maximum	2,966,792	5,252,418	7,035,577
	Actual	1,625,681	2,802,461	3,615,255
	Minimum	950,543	1,467,213	1,857,899
Mean Trip Length (km/person)		4.850	5.622	5.966
Urban Composite Index		0.3204	0.2793	0.2641

EXCESS COMMUTING RATE AND TRAFFIC FLOW RATE

The excess (wasteful) commuting rate is computed by dividing the difference between the actual value and minimum value of total journey-to-work trip length to the actual value of the total journey-to-work trip length. The index is equal to 0 if the actual and minimum values of the total journey-to-work trip length are equivalent. It will draw close to 1 if the actual value becomes larger relative to the minimum value. Hence, it is possible to determine trip length difference (waste in commutation due to distance) from the actual and minimum (optimized) values of the total journey-to-work trip length.

On the other hand, efficient commuting rate is calculated using the actual, minimum and maximum values of total journey-to-work trip length. If the actual trip length is equivalent to the minimum value, this index will have a value of 0; and if it is equivalent to the maximum value, the index will be equal to 1. Thus, an efficient commuting rate value that is close to 0 would mean minimizing travel behavior. Conversely, a value that is close to 1 would mean that travel behavior is inclined towards the maximum. In this regard, the actual journey-to-work trip length in a city relative to the minimum and maximum points may be determined from this index. Thus, it may also be possible to determine how journey-to-work distance has been influenced by changes in urban structure such as developments in public transportation.

In finding for the excess commuting and efficient commuting rate, the actual value of the total journey-to-work trip length T_{act} is used. Its minimum T_{min} and maximum T_{max} values derived from developed optimal employment-residence spatial distribution structure problem should also be obtained. These values are then substituted into equations 2 and 3, as formulated below.

$$\text{Excess commuting rate} = \frac{T_{act} - T_{\min}}{T_{act}} \tag{2}$$

$$\text{Efficient commuting trip rate} = \frac{T_{act} - T_{\min}}{T_{\max} - T_{\min}} \tag{3}$$

The computed values of the excess commuting and traffic flow rates using the actual, minimum and maximum values of the total journey-to-work trip length for the years in study are shown in Table 3.

***Table 3** Excess commuting and traffic flow rates*

Survey Year		1972	1983	1994
Total Number of Trips		335,218	498,438	606,021
Mean Trip Length (km/person)	Maximum	8.850	10.538	11.609
	Actual	4.850	5.622	5.966
	Minimum	2.836	2.944	3.066
Increase/Decrease in the Total Number of Trips			163,220	107,583
Increase/Decrease in the Average Trip Length			0.772	0.343
Excess Commuting Rate		0.4153	0.4765	0.4861
Traffic Flow Rate		0.3348	0.3528	0.3394

The excess (wasteful) commuting rate has changed significantly between 1972 and 1983, but has remained almost on the same level between 1983 and 1994. Here, it can be said that wasteful commuting has increased in Sapporo City, however, the rate of increase in the average trip length between 1983 and 1994 is low relative to the rate of increase of the total number of trips.

Meanwhile, the growth in efficient commuting trip rate was seen until 1983, and has then reversed to a decreasing trend to the rate computed for 1994. Taking this result together with the urban composite index, it can be seen that the actual values of the actual trip length in 1994 is approaching the minimum relative to the increased traffic efficiency following the decentralization of work locations. It can be concluded thereupon that in Sapporo City in general, between 1983 and 1994, the employment-residence spatial distribution structure of workers per zonal unit is exhibiting characteristics of a compact city.

CONCLUSIONS

We analyzed in this research the employment-residence spatial distribution structure in Sapporo City by constructing preference curves based on the person trip survey conducted in the major metropolitan areas in Hokkaido Prefecture. The following are the findings of this study:

1) Following the population increase in Sapporo City, work locations has dispersed into different zonal units rather than converging into a central location. It was found out that the average trip length of commuters is increasing.
2) Most of the zones where subway is accessible have exhibited patterns of proximity, which has resulted to the reduction of average journey-to-work trip length.
3) Journey-to-work traffic flow in zones covered by the subway system is approaching minimization relative to the population expansion in Sapporo City and decentralization of work locations as observed in 1 and 2.

Examining the effects of the expansion of the subway system in the formation of compact cities based on the abovementioned results, we may infer some observations as summarized below: 1) Although there has been cases of suburbanization of population, for 22 years between 1972 and 1994, work locations have likewise been decentralized into suburban units; it can also be seen that the proximity of work-residence spatial distribution (reduction of journey-to-work trip length) is steadily increasing in zones where subways are accessible. 2) It has been suggested that a replication of Nagoya City's "Eki Soba Plan" (Surrounding Station Plan) in Sapporo City, which is a policy encouraging residential development along transit routes in suburban areas can possibly promote compactness in subway transport accessible areas along certain routes.

For future research, we recommend the inclusion of 1) the 4th person-trip survey data in the metropolitan areas of Hokkaido prefecture collected in 2006 and 2) the use of private other than public transportation in commuting to work in the analysis.

REFERENCES

Hashimoto, Shinsuke *et. al.* (2009) Relation of public transportation service level and city diffusion by area based population density, Journal of the City Planning Institute of Japan Vol. 44, No. 1, 117-123.

Masuya, Yuzo *et al.* (2001) Regression analysis of journey-to-work preference curves. Japan Society of Civil Engineers: Research and lecture series in civil engineering planning and research., Vol. 18, 445-453.

Mayama, Daisuke et al. (2009) Reducing journey-to-work trip length by examining travel behavior. Japan Society of Civil Engineers: Research and lecture series in civil engineering planning and research, Vol. 39, 30, CD-ROM.

Mimura, Yasuhiro (2009) Examination of mass transport evaluation in Toyota City through a Citizen's Awareness Survey: A Case Study, Journal of the City Planning Institute of Japan No. 44-3, 493-498.

Tamura, Masafumi and Tohru Tamura (2009) A proposal on basic modeling specifications for the spatial structure of compact cities, Japan Society of Transportation Economics: