

The Possibility of Building Compact City through Transit Investment -Lessons from Japanese City

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Abstract: *Building compact city is recognized as a main agenda to cope with the urban problems in many countries. Additionally in Japan, building compact city is also considered as a strategy to adapt cities to coming depopulation and ageing society. This study aimed at analyzing the impact of transit investment in a dispersed city. A 20 years span empirical study was conducted in Sendai city, Japan, a relatively low density and car dependent city. Significant findings are that investment in transit enables high density residential developments around stations. However, the impact is much reduced in places where stations were constructed after residential development, therefore the development order of transit and housing is important. Although the population density in station areas grew in the last two decades, the share of transit use does not increase too much and car use remains to be dominant.*

Keywords: *compact city, transit investment impact, Sendai Metropolitan Area, Japan*

1. Introduction

A conceptual framework about urban structure and sustainability was developed in urban planning and political approaches [1]. As Japanese cities have been suffering long term low birth rate and ageing since 1980s, how to adapt the situation of depopulation and rapid ageing might be a main task in the 21st century. Municipal governments are trying to find a sustainable way to cope with the unprecedented social-demographic change. From 1990s, some cities attempted to change the direction of urban development, i.e. from a dispersed urban structure to a more compact one (e.g. Aomori city, Toyama city, Sendai city, etc.), corresponding to the concepts such as new urbanism and growth management. A main common strategy is the renaissance of transit system, making the transit network works as axis for re-concentration of urban functions. Now, nearly 20 years later, it is needed to give a comprehensive analysis of the effect of this direction change. There were some intensive transportation impact studies in North American and European cities (e.g. [2-5]). The previous studies mainly considered the impact on land value and land use change, but rarely study examined the impact on the whole urban structure and transport mode. This study aimed to find the impact of transit investment in a dispersed urban area, to recognize its effectiveness and limitations in moving towards a more compact city.

2. Study Area

Sendai Metropolitan Area is chosen as a case study. Sendai city is located in the Tohoku Region, North Eastern Region of mainland Japan (Fig. 1). There was over 1 million population living in Sendai City according to the 2000 Census, and is the 12th largest city in Japan. The city is recognized as an administration hub of Tohoku Region, having concentration of regional branch offices of nationwide enterprises and tertiary sector is dominant. The city rapidly expanded during the rapid economic growth period in 1960s and 1970s as with other large cities. The **Densely Inhabited Districts** (DIDs: census districts with over 4000 people per square km), as

defined in the Census from 1960, expanded more than 4 times whereas their population density dropped to 2/3 in the past 50 years. Unlike the three largest metropolises of Japan, Sendai Metropolitan Area is a car dominant city with relatively low density suburbs, and over 55% of total trips were by individual vehicles according to the 4th Person Trip Survey in 2002 [6]; whereas, the share of transit use (rail and bus) was only 11%, and had been continual declining since the 1st Person Trip Survey in 1972. The city government tried to change the unsustainable situation and began to reconsider the master plan in the early 1990s. As a result, the city adopted a compact development strategy in the 1998 city master plan. The city delayed and cancelled nearly 70km proposed automobile route in the suburban areas, instead, the city reorganized the bus routes and began constructing the second subway line (i.e. the Tozai (East-West) Line planned in 1998 and due to open in the late 2015). A main direction in the 1998 master plan was to restructure the then low-density car-oriented urban structure. The city considered four sub-centres in the inner suburban areas, and all around the existing rail stations. The existing Namboku (North-south) Subway Line (partially opened in 1987 and fully opened in 1992) and the coming Tozai Subway Line were considered as two axis for the re-concentration of urban factions. Floor to area ratios were increased in station areas to attract more developments of high-rise apartments, while those in areas not served by transits were kept low.

Our analysis are mainly based on the Census and application of Geographical Information System. This study adopted the most basic indicators in the assessment of transit investment [7]. Due to the availability of high quality data since 1990, this study analyses the population and household change from 1990 to 2010. Analysing this period allows examination of the urban changes after opening of Namboku subway Line and some new **Japan Rail (JR)** stations opened after 1985. This study analysed 79 stations in the Sendai Metropolitan area, 30 stations are subway stations (including Tozai Subway Line stations), the rest are **JR** stations; 46 stations were constructed after 1985, and the rest were constructed in early years.

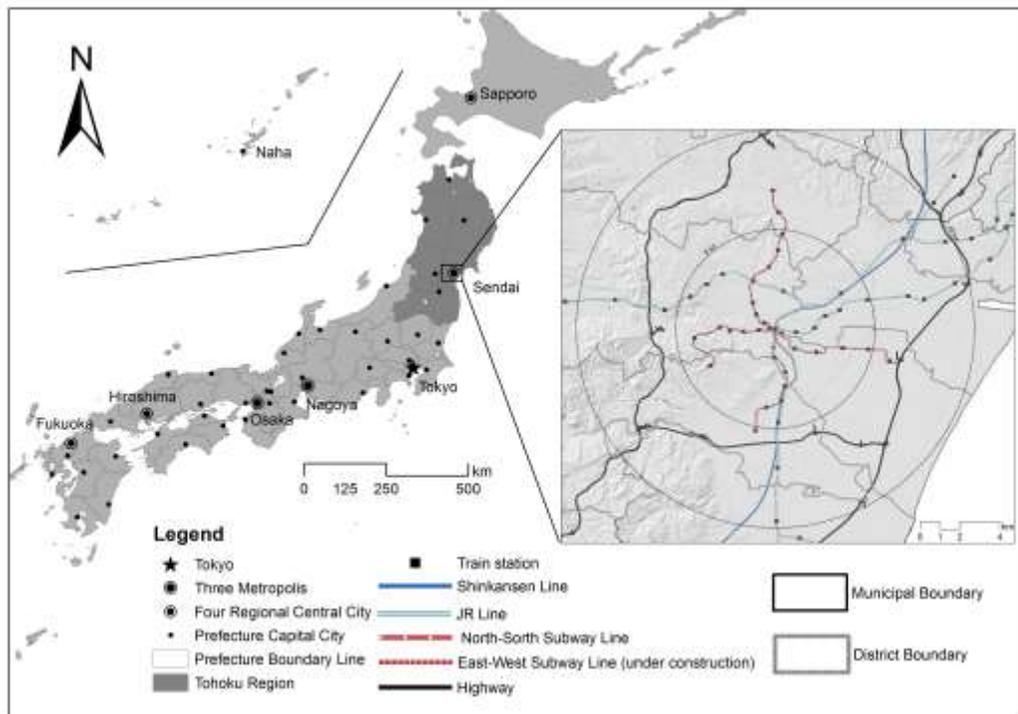


Fig. 1: Location of study area and main transport networks.

3. Impact Assessment of Transit Investment

3.1. Impact on population and household distribution

The Namboku Subway Line is the first rapid transit system in Sendai city, and recognized as one of the most important infrastructure development project in the city's history. It is 14.8 km long has 17 stations and links the

two sub-centres in the north (Izumi Chuo) and south (Nagamachi). Its construction started in 1981 and partially opened in 1987, and then extended to the northern sub-centre in 1992.

Fig. 2 presents the population and household change 1990-2010 in the study area based on the standard mesh (around 1km x 1km grid) data. More dynamic changes were observed during 1990 to 2000. Population and households increased substantially in the northern suburban areas, between 5 and 10 km away from city centre. However, in 2000-2010, the increases were more concentrated near the urban centre except some estate development sites in the suburban area.

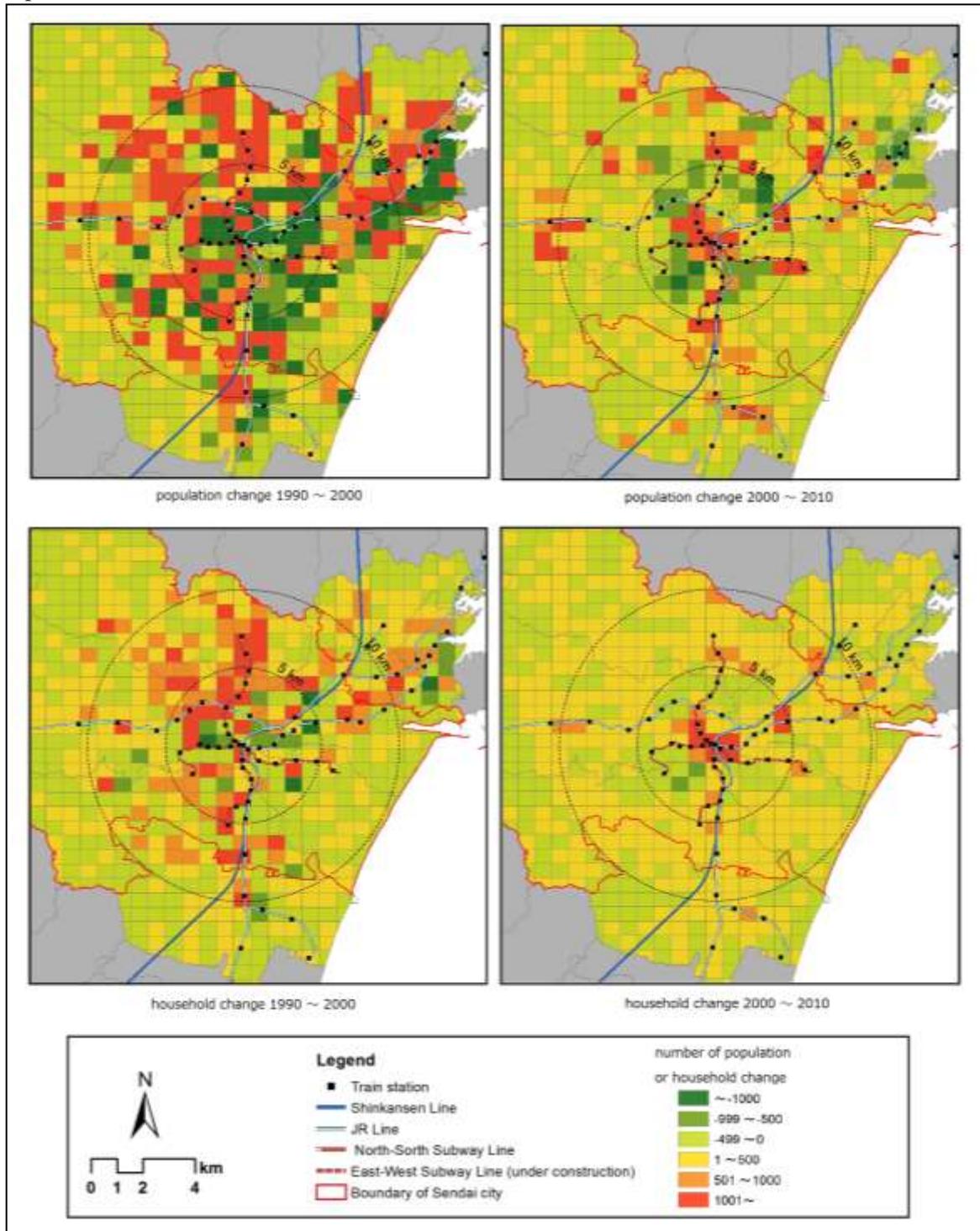


Fig. 2: Population and household change in Sendai metropolitan area.
Data source: standard mesh data of Census, 1990, 2000, 2010.

Population and household changes differ considerably near and away from the stations. Fig. 3 shows the ratio of population and household changes comparing the mesh within 1km from stations (station areas) and those over (non-station areas). Before 2000, the growth rates of population and household in non-station areas exceeded those of station areas. After 2000, as the new urban planning strategy were announced in 1998, the population and household growth in non-station areas slowed down, and in the contrary, the growth in station areas accelerated.

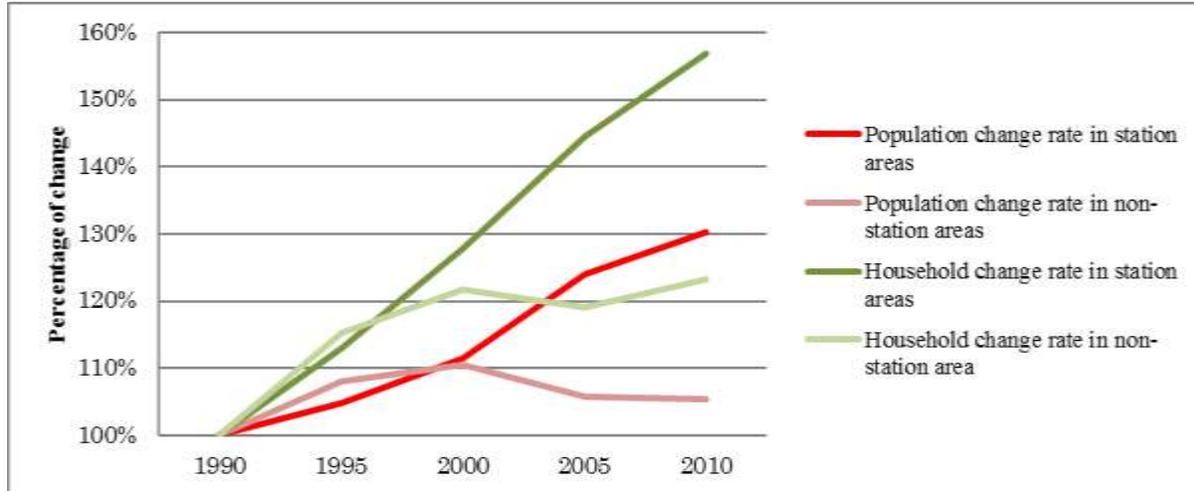


Fig. 3: Population and household change in station areas and in non-station areas.

3.2. Impact on the urban landscape

The population and household growth in station areas was closely related with the development of high-rise apartments, especially owner-occupied condominium. We plotted the location of almost all the condominiums (about 1,379 buildings) in Sendai Metropolitan Area developed after 1970, and we find nearly 70% of the developments were located within 1km buffer area from the new stations opened after 1987 (Fig. 4). Before the opening of the subway line, the developments of condominiums were located mostly in the inner city areas, especially in the west side of Sendai Station (the fringes of the CBD). After the opening of subway line and some new stations on the existing **JR** line, the developments of condominiums were more often located within 1km from the stations.

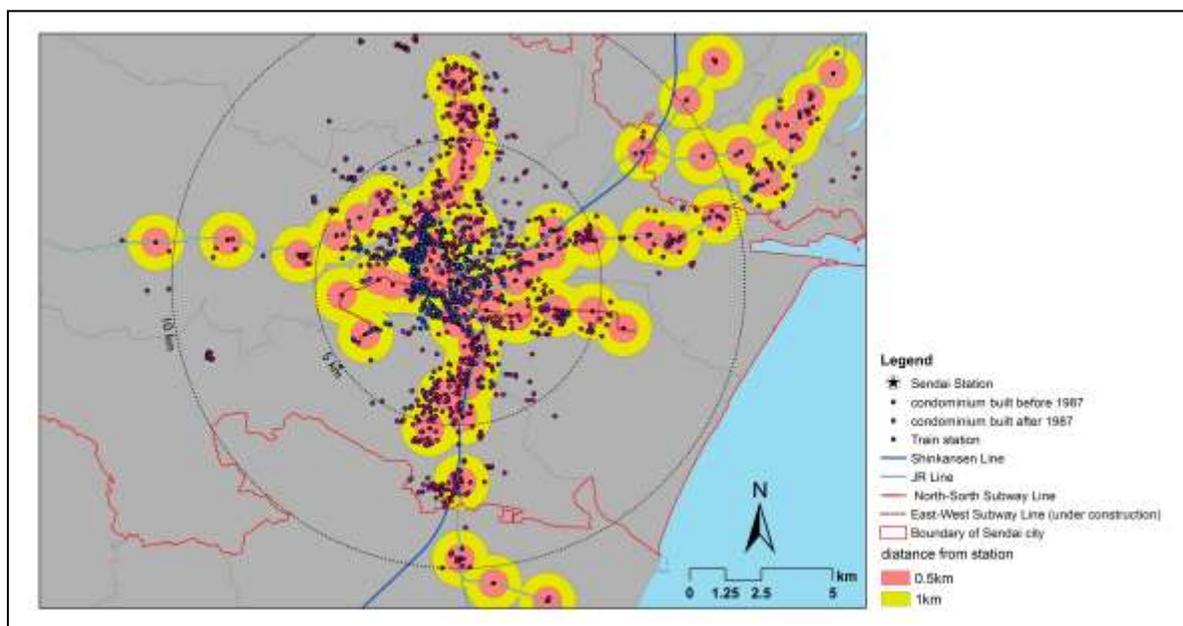


Fig. 4: Location of condominiums in Sendai metropolitan area until 2015.
Data source: Furuta planning 2007 and field work.

3.3. Impact by the location and development timing of stations

Although we confirmed the overall population and household increase in the station areas, the degree vary among stations. We found that it is closely related with (1) distance from the city centre, and (2) whether the station opened before or after the residential development of the surrounding areas. We examine these in detail.

Fig. 5 shows the population changes in areas within 1km from each stations with the stations ordered by the distance to city centre. For the stations located in within 3km from the city centre, the population decreased from 1990 to 2000, but then reversed afterwards; in the areas 3-7km from city centre, the population decreased during the whole period because of independence and separation of children brought up in those areas except some redevelopment areas 4-5km from city centre; while in the areas 7-15km from city centre, population continued to grow, particularly near the sub-centre areas; in the remote areas over 15km from city centre, population did not change too much.

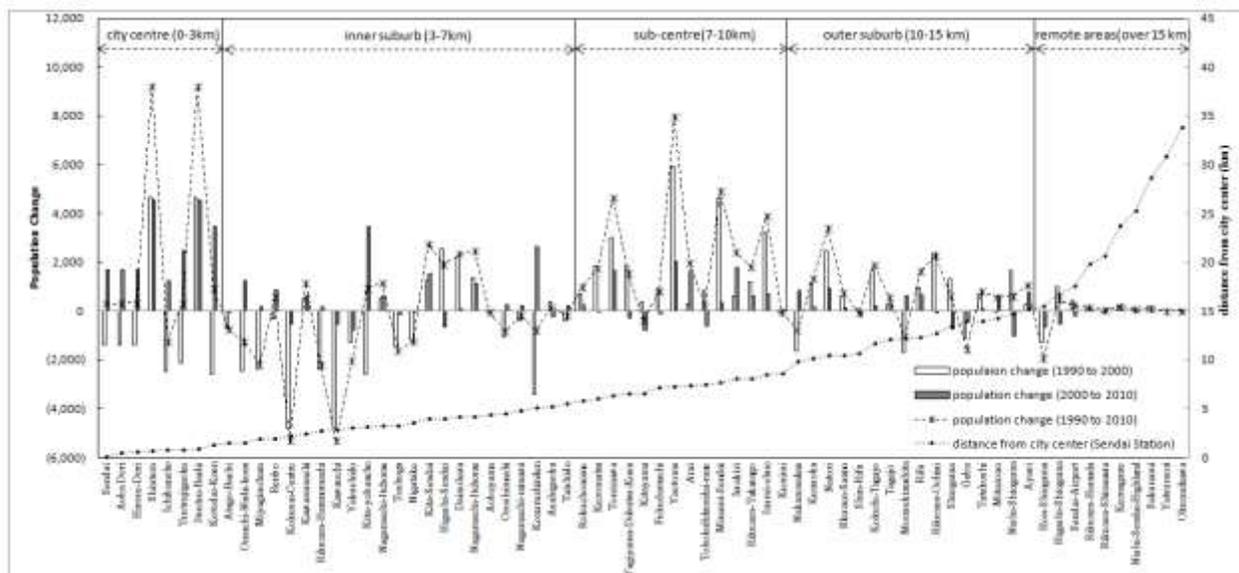


Fig. 5: Population change in station areas by the distance from city centre

Previous transit impact studies tended to neglect the importance of the order of transit investment and residential development. In the case of Sendai city, population stagnated or even decreased in some inner suburb stations and outer suburb stations (Fig. 5). The reason is that these areas were already occupied by low density single family housing before the station opened, so these neighbourhoods with car dependence characteristics almost impossible to become a high density residential area within 20 years. Therefore, it is very important to recognize that transit investment does not necessarily lead to high density if the transit investment decision was made too "late". Table I shows that population and household increase in the area within 1km or 0.5km from stations will be much reduced if the station opened after the residential development. The two important factors: location and timing are the basic determinations which impact on the significance of transit investment.

TABLE I: Population and Household Changes by the Order of Urban Development (1990 to 2010)

Order of urban development	Population change within 1km (within 0.5km)		Household change within 1km (within 0.5km)	
	1990 to 2000	2010 to 2010	1990 to 2000	2000 to 2010
Station opened before residential development	12.2% (24.7%)	11.7% (17.7%)	27.1% (42.4%)	32.3% (36.2%)
Station opened after residential development	9.7% (14.3%)	7.8% (15.1%)	23.8% (29.4%)	13.2% (20.8%)

Data source: calculation based on Census by using ESRI Arc GIS Ver.10.2.2.

4. Impact on Transit Ridership

We confirmed the overall population and household change by railway line from 1990 to 2010 (Table II). As a result, the proportion of population in areas within 1km from stations grew from 38.74% to 43.86% due to the opening of new stations during 1990 to 2010. The population increasing in station areas can be considered the incensement of small household (Table I), e.g. unmarried household and DINK family. However, the transit ridership is not necessarily associated with population growth. The population and household in Namboku Subway station areas increased 1/4 and 1/2 respectively, unexpectedly, the ridership decreased nearly 3% in these 20 years. Some possible explanations are that transit in Sendai city is in short of network effect, that is one of the rational for building Tozai Subway Line despite the Namboku Subway Line is on a deficit; the fare is very high in the case of subway, the minimum adult fare is 200 Japanese yen (about 2\$), 1.5 times higher than **JR** line, and almost 2 hours parking fee in the urban centre. As a result, similar as the population and household growth patterns, the growth of transit ridership always related with the timing of station construction. The ridership grew 6.62% in the new stations which opened before the residential area development, and decreased 7.36% on the contrary. It is ironic that the growth of ridership in the **JR** Lines are due to the passengers shift from bus use [6]. In the meanwhile, the share of car use trips grew 7% during 1992 to 2002. Individual vehicle are still the dominant mode of urban transport. The modal shift did not happen despite more population living near the stations.

TABLE II: Population and household growth in station areas and the changes in transit ridership (1990-2010)

Railway type	Population change		Household change		Ridership change (passengers per day)	
	existing stations	new stations	existing stations	new stations	existing stations	new stations
Namboku Subway Line	—	25.22%	—	49.37%	—	-2.77%
Sen-Seki JR Line	-3.58%	12.56%	17.51%	39.09%	-5.15%	11.61%
Sen-Zan JR Line	21.79%	11.98%	47.10%	55.37%	75.03%	139.73%
Tohoku JR Line	24.29%	25.16%	53.73%	36.82%	-2.70%	41.60%
Airport Line	—	47.19%	—	85.85%	—	-9.57%
Total	14.01%	18.63%	40.06	41.26%	1.89%	0.74%

Note: changes of new stations are according to the opening year to 2010, e.g. Airport Line opened in 2007, and the change was calculated from 2007 to 2010.

Data source: Statistics of Sendai, Sendai City Transport Bureau.

5. Conclusions and Discussions

This study aimed at examining the impact of transit investment on urban structure and transport mode change in a dispersed urban area. We chose Sendai Metropolitan Area as a case study, a typical city with a car dominant and low density character. Main findings are as follows:

- (1) Higher population and household growth were observed in station areas, but the degree varied among stations.
- (2) Growth were closely related with distance from the city centre; the 1970s developed inner urban areas located 3-7km from urban centre are suffering serious ageing and losing of younger population will difficult to attract new inhabitants;

(3) Whether the station opened before or after the residential development of the surrounding areas will affect the significance of growth;

(4) Despite growth in station areas, it was not necessarily associated with growth in transit ridership. The significant growth of transit ridership happened in the new stations which opened before the residential area development.

Therefore, we should recognize the importance of the order of transit investment and residential area development in changing the urban structure and moving towards a car-free city.

As some limitations in this study, we did not consider the other indicators, such as the change of employment, retail and commercial activities, etc. Due to the limitation of paper length, we did not describe the character of new inhabitants who moved to the station areas, as well as the change of population structure. Furthermore, we should point out that the re-concentration of residence function in the station area will not realize without the changing of urban planning direction. The alteration of zoning in the station areas associated with land readjustment project played an important role in this process. As further works, examination of household turnover and the effect of zoning would enable us to know how long it will take for the ridership to recover in station areas where station opened after residential development.

6. References

- [1] Y. R. Jabareen, "Sustainable Urban Forms Their Typologies, Models, and Concepts," *Journal of Planning Education and Research*, vol. 26, Issue1, pp.38-52, 2006.
<http://dx.doi.org/10.1177/0739456X05285119>
- [2] R. Cervero, "Light Rail Transit and Urban Development," *Journal of the American Planning Association*, vol. 50, Issue 2, pp. 133-147, 1984.
<http://dx.doi.org/10.1080/01944368408977170>
- [3] R. L. Knight and L. L. Trygg, "Evidence of Land Use Impacts of Rapid Transit Systems," *Transportation*, vol. 6, Issue 3, pp. 23-247, 1977.
<http://dx.doi.org/10.1007/BF00177453>
- [4] S. E. Polzin, "Transportation/land-use relationship: public transit's impact of land use," *Journal of Urban Planning and Development*, vol. 125, Issue 4, pp. 135-151, 1999.
[http://dx.doi.org/10.1061/\(ASCE\)0733-9488\(1999\)125:4\(135\)](http://dx.doi.org/10.1061/(ASCE)0733-9488(1999)125:4(135))
- [5] K. V. Vessali, "Land Use Impacts of Rapid Transit: A Review of the Empirical Literature," *Berkeley Planning Journal*, vol.11, Issue 1, pp. 71-105, 1996.
- [6] Person Trip Survey in Sendai Metropolitan area, <http://www.pref.miyagi.jp/site/pt/>
- [7] N. Peter and J. Kenworthy, *Sustainability and Cities: Overcoming Automobile Dependence*, 4th ed. Washington, DC, USA: Island Press, 1999, ch.1, pp.18-20.

7. Acknowledgement

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