Empirical Analysis on the Railroad Development Impact on Local Population Density in Japan

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Abstract: We investigated the relationship between railroad station and areal population density in Japan. A cross-sectional analysis and a series of longitudinal analysis on the station development and changes in population density are conducted. The overall trend of higher density near the station is observed with a relatively high level of variance. Also, it is pointed out that railroad service is necessary for dense inhabitation while it is not sufficient. Further, the longitudinal analysis confirmed that the station development induced the population density growth within 2 to 3 km from the station. A detailed analysis proposed that while the difference of density growth relative to the regional difference or proximity to the station is not observed, the collaborative development of railroad and housing would have a largest potential in improving population density.

Key Words: *Railroad Development, Population Density, Mesh Data*

1. INTRODUCTION

Recent development in automobile and other transportation technologies brought rapid expansion of urban areas. As a result, the rapidly growing use of convenient automobile is causing serious environmental impact on a worldwide basis. Together with concerns on the increasing demand of drying-up fossil fuels, there have been a number of studies and discussions on mitigating automobile dependency.

Transit-oriented development (TOD) is one of such solutions that is proposed and implemented. This technique attempts to build densely inhabited regions along public transportation corridors developed outwards from the city center, expecting the compactness of urban region and the growth in public transportation use. TOD also intends to form commercial cores around transit nodes to promote mixed land use, locating residents, jobs and other activities nearby. This achieves less and shorter trips within the area and improves viability of transit services (Beimborn *et al.* 1992). A typical urban form under this technique shapes “fingers” spreading from a “palm” in the city center, as seen for example in Copenhagen, Denmark. This idea has been put into practice not only in Asian and European cities, where the demand for public transportation is relatively high, but also in highly automobile-dependent American cities principally through subways and light rail transits (LRTs) development (Porter, 1998; Glick, 1992; Cervero 1984). In some cities, such as Curitiba, Brazil and Ottawa, Canada, bus transit system is also utilized to implement TOD and the land along major bus routes is densely developed (Nakamura, 1995). Conditions and principles for TOD are summarized in Dunphy *et al.* (2006) and le Clercq *et al.* (2000).

Dunphy *et al.* states that compact and high-density population distribution is essential for promoting public transportation use, as shown in Figure 1, arrow A. He also recommends mixing residential and commercial land use, or locating residential and job concentrations separately on the same transit corridor. Polzin *et al.* (2000) also indicates that urban density and size influence significantly on public transportation ridership. Through the analysis of relationship between population density and transportation in 46 major cities around the world, Newman *et al.* (1999) confirmed that dispersed urban structure results in further automobile dependence, and densification in urban population is an important factor in public transportation use. Pushkarev *et al.* (1977) proposed that the minimum density for public transportation development and operation is 12 dwellings per acre (3000 dwellings per sq km) for rapid transit, 9 per acre (2200 per sq km) for LRT, and 7 per acre (1730 per sq km) for local bus. Nakamura (1995) also suggested that securing the bus right-of-way is fundamental to provide reliable and convenient bus transit service in bus-dependent cities.

On the other hand, there have been another argument on the public transportation impact on land use (Figure 1, arrow B)。 Polzin (1999) mentioned that the *mutual* relationship exists between public transportation and land use, though much of them remaining unclear. Giuliano (2004) also states through reviewing preceding studies that the impact of railroad system development on land use is smaller than that of highway system, is highly localized and significantly different between stations and regions, is subject to other conditions, and is hard to generalize. When claiming that public transportation development will induce change in land use, we have to notice that “this is not how the world works” (Rubin *et al.* 1999), since transportation is an induced demand. Still, to attempt to promote modal shifts from automobile, land use change and compactness of urban areas, it is meaningful to analyze public transportation impact on land use. As shown in later section, few studies on population density can be found while there are several on housing and property values.

In this study, we feature railroad station location as an indicator for public transportation provision and population density for land use. For an entire region in Japan (regions not surveyed in census are excluded), we examine the relationship between station proximity and population density, together with the impact of railroad station development on population density changes. In the following chapter, preceding studies on the public transportation impact on land use are reviewed. Data used in the analysis are introduced and basic characteristics are presented in chapter 3. In chapter 4, a cross-sectional analysis of the impact of station proximity on the density is provided, and a series of longitudinal analyses of the impact of station provision on the density is shown in chapter 5. Finally, summaries and conclusions are given in chapter 6, together with possible further researches. The bus network is ignored because of the limitation of the availability of bus network data. The development of railroad system may induce further road development around stations to improve accessibility and to deal with increasing traffic volume, which may result in growth of car use. In this study, this phenomenon is not separated as the effect of road development but is treated as the impact of railroad development.

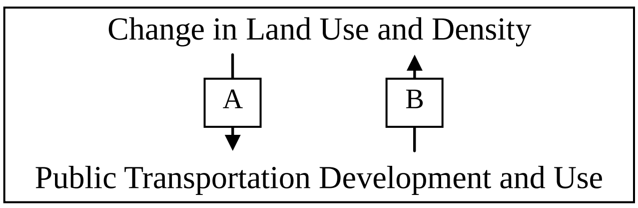

Figure 1 Relationship between land use and public transportation

2. PRECEDING STUDIES

Knight *et al.* (1977) is often referred to as one of the early studies reviewing the preceding studies on impact of public transportation development on land use. He summarized that there was no clear evidence that new transit system development would increase the overall level of regional development, and that there was no rationality in claiming that public transportation development would change land use. A reason for this was that urban region was already served by convenient automobile, and public transportation development did not contribute to additional improvement in regional accessibility. Further, he listed four important factors for transit development to contribute to regional growth and change in land use: local government policies encouraging development, regional development trends, availability of developable land, and physical constraints of the site.

More recently, the impact of MARTA, a transit system in Atlanta, Georgia, development on the neighborhood population and employment is analyzed (Bollinger *et al.* 1997). They found that the development of MARTA did not have either positive or negative impact on the total population and employment near the stations, though some changes in composition of employment, in terms of growth in public sector, was observed. Also in San Francisco, California, the impact of BART, a regional rapid transit system, on the land use was small, and was significantly different between stations and regions (Cervero *et al.*, 1997; Moon 1990). Cervero *et al.* (1997) also found that the development of BART caused regional clustering and a significant growth of employment density in Central San Francisco. Further, they indicated that few stations enjoyed growth in population density, due to the relatively low potential of BART in accessibility improvement and oppositions in some stations against densification.

Land and property values and rents are employed in some studies as indicators for land use in analyzing the impact of public transportation. In our study, these values are not employed. However, since there may be a possibility that increase in land values will promote more extensive land use, resulting in contributing to the regional densification, several studies on land values are briefly reviewed. We can expect that transportation development will push up the land value regarding the increase in regional accessibility and strong linkage with city center, while downgrading of the value through worsening noise, congestion and crime rate is also possible (Gatzlaff *et al.*, 1993). Tamura *et al.* (1993) analyzed the relationship between land values and distance from transportation facilities and city center in Sapporo, Japan. They found that land values were higher near the stations and were also impacted by the frequency of trains, and explanatory power of the station proximity on land values was greater in suburban areas. In addition, they confirmed the 27% growth of land values near newly built station under a land adjustment project. Iwakura *et al.* (1990) also confirmed that several station developments in Japan provided higher land values nearby. In the United States, LRT is found to increase office rent in San Jose, California (Weinberger, 2001). He also estimated that the impacted areas were within 0.5 miles (0.8 km) radius from the station. This value is consistent to that indicated in Lewis-Workman *et al.* (1997), which analyzed the relationship between transit proximity and property values in Portland, Oregon. On the other hand, Gatzlaff *et al.* (1993) concluded that the announcement of Monorail development in Miami, Florida, had small impact on the neighborhood housing values. Further, house prices were even lower near the stations in Manchester, United Kingdom (Forrest *et al.*, 1996). Thus, the impact of public transport development on land and property values is different between and within urban regions, implying the possibility of other factors influencing these values.

We can summarize these studies that the impact of public transportation development on land use is generally small and different between regions, and existence of other factors is vital for the development to influence land use. Compared to these studies, our study is unique in directly analyzing the mutual relationship between public transportation development and population density with considering the whole country instead of a single transportation system or region, and in incorporating both cross-sectional and longitudinal analyses.

3. DATASETS AND BASIC CHARACTERISTICS

As mentioned above, the whole region of Japan is targeted in this study. The country is gridded into meshes, size of which is approximately 1 km by 1 km (northern meshes are slightly smaller than those in the south). The total number of meshes is 380,841. Census data conducted every 5 years from 1970 to 2000 (Sinfonica/Statistics Bureau of Japan, various years) are employed as the data source of population and are attributed to each mesh. The land area data are from the National Digital Information Data (MLIT, various years). Density for each mesh is calculated by dividing population by land surface area excluding water surface (sea, rivers, lakes, etc.). Since surveyed years of land area data do not correspond to those of census, a land area data nearest to each census year is chosen for calculation.

Total population and average density are shown in the left hand side of Table 1. The population grew 21 million in 30 years and gross density increased 70 persons/sq km, or about 25%, as a result. The growing trend is persistent throughout the period. Indices on railroad system are shown in the middle of Table 1. Toward 1985, privatization of Japan National Railway (JNR) caused an extensive disuse of railroad lines in rural areas, resulting in the decline in total railroad length and the number of stations. After, further development of suburban railroads and subways again improved the railroad system stock. In 30 years, 2128.5 km of new railroad lines in 68 operators, 238 sections are constructed and opened, while 2109.9 km of JR (Japan Railway, former Japan National Railway) lines are abandoned in the same period. However, data on the abandoned lines are not included in the railroad network data utilized in this study (Mitsui Zosen Systems Research, 2004). Therefore, railroad lines abandoned before 2000 are not considered in this study. As a result, in our dataset, total length of railroad lines and number of stations are continuously increasing. JR and other private railroad lines, monorails, trams and new transportation systems are all included in this study. However, in view of the purpose of our study, Shinkansen high-speed trains, as well as funiculars and ropeways in mountain areas, are excluded.

As an indicator of the level of public transportation development, distance from each station to each mesh is employed and meshes are divided into 4 categories, as shown in Figure 2. First, meshes having at least one station within them are designated as Mesh A. Next, meshes sharing a boundary with Mesh A are designated as Mesh B. Then, meshes sharing a boundary with Mesh B are designated as Mesh C. Other meshes are considered “outside.” The upper mesh category is applied to each mesh: for example, if a mesh is Mesh B to a station and Mesh C to another, the mesh is designated as Mesh B. This procedure is conducted for every census year. If a station is located at the center of Mesh A, the expected distance from the center of Mesh C to the station is 2 to 2.8 km. Compared to the preceding studies, this value is larger; however, this distance is employed in this study considering the impact range of the station. The number of meshes in each year is shown in the right hand side of Table 1. In 2000, Mesh A accounts for 2.5% of total meshes, and the sum of Mesh A to C for 24%. The number of stations and that of Mesh A’s are different since there are several meshes having more than one station, and several stations locating on the boundary of meshes. The geographical density distribution and station location in 2000 are presented in Figure 3. An extensive concentration of population and railroad facilities in three major metropolitan areas, namely Tokyo, Nagoya and Osaka, is clearly recognizable, while density is also high around the stations even in other regions.

Table 1 Basic indices on demography and railroad system in Japan

Year	Population[a]	Density (sq km)	Railroad System[b]		# Meshes		
			Total Length in Operation (km)	# Stations	Mesh A	Mesh B	Mesh C
1970	105,869,805	280.61	27,104	10,306	8,774	38,608	40,478
1975	111,939,457	296.69	26,866	9,752	8,929	39,173	41,022
1980	117,060,314	310.27	26,916	9,519	9,003	39,322	41,033
1985	123,427,433	340.64	26,619	9,466	9,114	39,548	41,187
1990	123,611,156	343.67	27,407	9,847	9,271	39,998	41,494
1995	125,569,768	346.42	27,318	9,947	9,359	40,170	41,590
2000	126,925,768	350.16	27,438	10,114	9,410	40,289	41,685

Source: Sinfonica/Statistics Bureau of Japan, various years (a) and MLIT, 2003 (b).
Freight lines included in operation length.

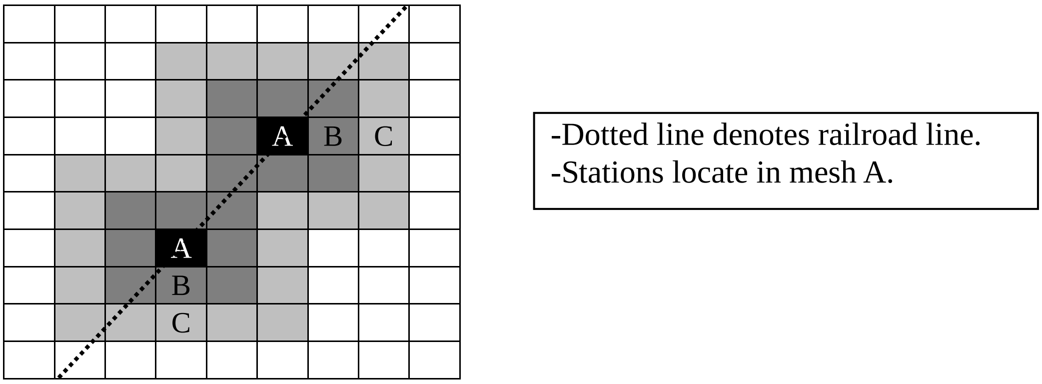

Figure 2 Notion of mesh categories

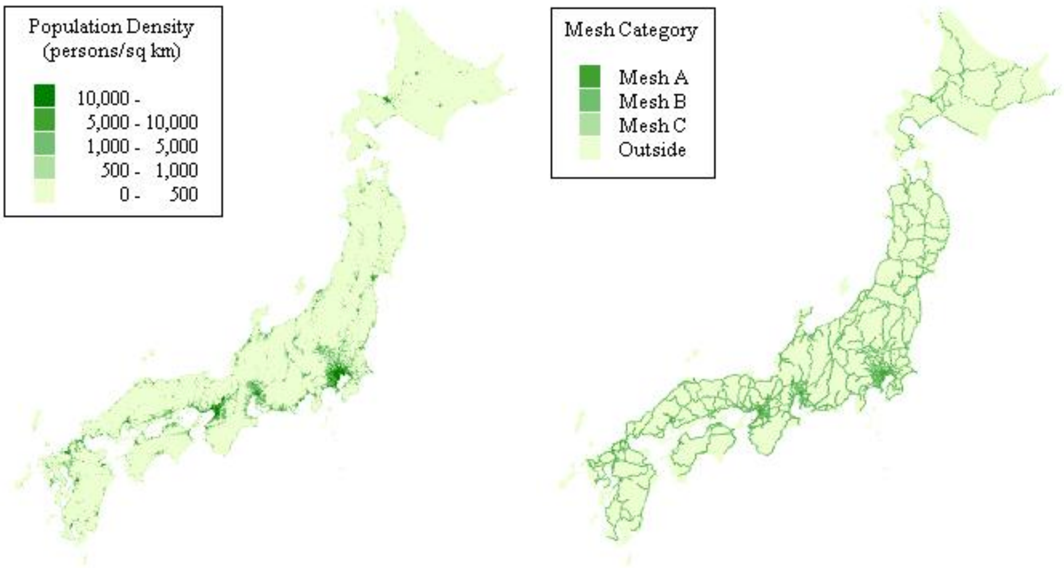

Figure 3 Population density and railroad station locations in 2000

4. CROSS-SECTIONAL ANALYSIS ON RAILROAD PROXIMITY AND DENSITY

The relationship between railroad proximity and density is analyzed. It is expected that, due to the relatively high accessibility and values of land and properties, areas near the stations are denser than those away from them. Average population density for each mesh category from 1970 to 2000 is shown in Figure 4. The density is highest in Mesh A, and diminishes as meshes step away from the station. It is remarkable that the density in Mesh A is three times as high as that in Mesh B, only with 1 to 1.4 km difference in distance from the station. On the other hand, density in outside meshes is as low as less than 100 persons/sq km. Density in Mesh C is comparable to nationwide average density, which implies that railroad proximity bonus on density is effective within 2 to 3 km in radius from the station. In addition, the difference in average density of each mesh category is small between years. Therefore, a cross-sectional analysis of the relationship between railroad proximity and population density is conducted only for 2000. As indicated in Table 1, the number of Mesh A is 9,410, Mesh B 40,289 and Mesh C 41,685 in 2000.

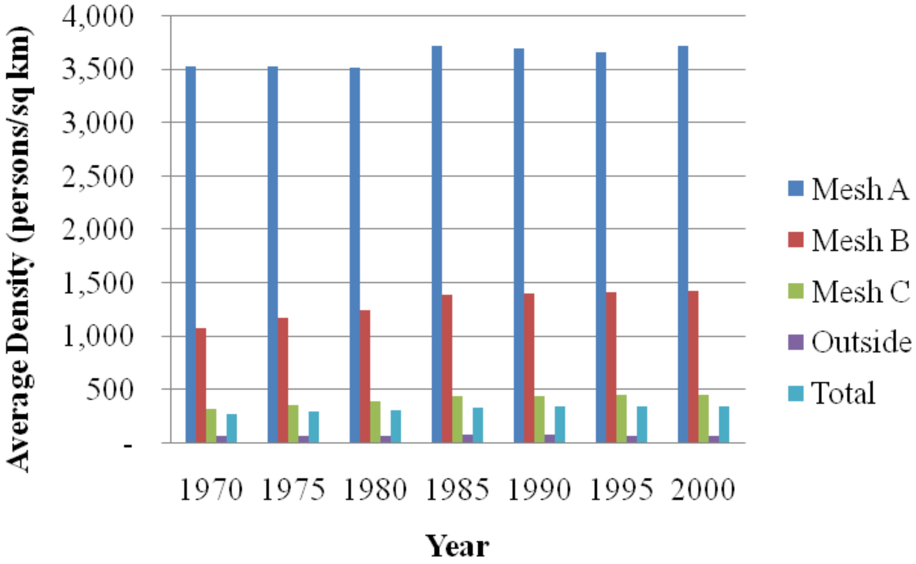

Figure 4 Average density for mesh categories

The density variation within each mesh category is shown in Figure 5. More than 60% of meshes with at least one station have the density of more than 1,000 persons/sq km, and half of them even have more than 5,000 persons/sq km. The proportion of these high density meshes declines as moves away from the station, and more than 90% of outside meshes have the density of less than 500 persons/sq km. It is clear that density in areas near the station is high and declining as getting away from the station. Further, it is notable that while extremely high density meshes with more than 10,000 persons/sq km rarely exist in outside areas, extremely low gross density meshes with less than 500 persons/sq km takes about 20% of Mesh A. This implies that, while the existence of railroad stations is a requirement for higher densification of the area, it is not sufficient to induce dense inhabitation. Some examples of sparsely populated areas with railroad services may be industrial areas, airports, and large parks.

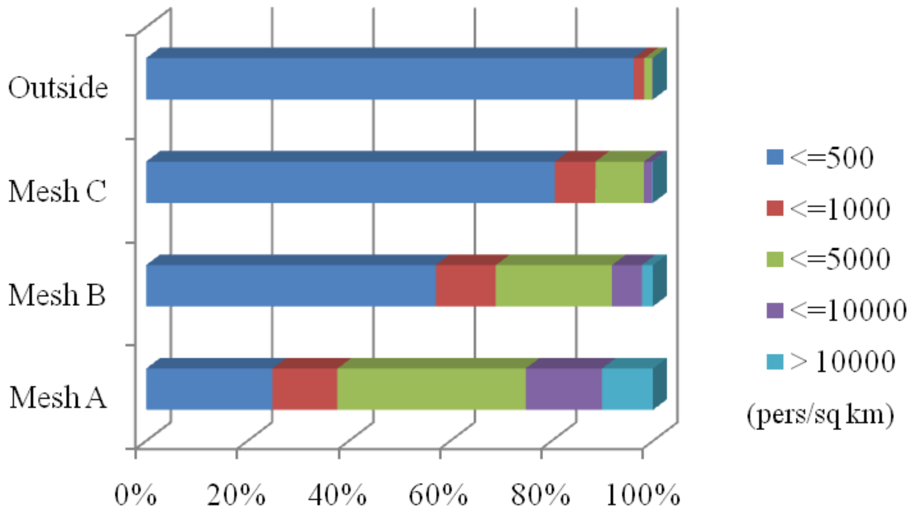

Figure 5 Density variation in 2000

The effect of station proximity on population density growth is examined with the regression analysis. Whether each mesh can be categorized into a certain mesh category is treated as 3 independent dummy variables. Dependent variable is the population density of each mesh. Total of 380,841 meshes are observed. The result is shown in Table 2. All independent variables are found to be significant at the 1% significance level. The result indicates that, compared to meshes far away from the station, Mesh A is 3,453 persons/sq km higher in density and even in Mesh C, which is 2 km away from the station, density is approximately 292 persons/sq km higher than those without railroad services. However, it should be noted that the value of adjusted R square is significantly low, indicating less than 0.3. Considering this point, it can be concluded that not only the existence of railroad station does affect growth in population density, but other factors might dominate the overall effect on density.

Table 2 Regression analysis results for cross-sectional data for 2000

Independent Variables	Coefficient	Standard Error	t-statistics
Constant	82.086*	2.254	36.425
Mesh A (dummy)	3534.960*	12.700	278.341
Mesh B (dummy)	1325.167*	6.447	205.547
Mesh C (dummy)	374.467*	6.352	58.957
Adjusted R square	0.229		
Observations	380,841		

*: Significant at the 1% significance level.

5. LONGITUDINAL ANALYSIS ON RAILROAD DEVELOPMENT AND DENSITY

The previous chapter confirmed the increasing trend of the population density in the areas near the stations. Preceding studies generally concluded that the growth in population density contributes to promote public transportation use. However, the effect of public transportation development on the change of population density before and after the development process is not fully discussed. In this chapter, the change of population density before and after the construction of railroad station is analyzed. Setting the period from 1970 to 2000, meshes with one or more inhabitants and with mesh category upgrades (i.e. became closer to the station) are targeted in this analysis. The total number of meshes employed here is 3,245. One thing should be noted here that while data on operation inauguration date for every railroad line are obtained, those on every station are not. There are some cases that stations begin operation separately after the inauguration of railroad lines. However, in this chapter, it is assumed that all stations are opened simultaneously with the opening of new lines. In addition, as noted above, abandoned lines and stations are not considered. Therefore, the downgrading of the mesh category is not reflected in the analysis.

The six cases of transition in mesh categories and the number of observations for each case are shown in Table 3. Transitions from outside meshes to Mesh A, B or C takes more than two-thirds of the entire observations. This indicates that new constructions of railroad services to non-railroad areas are conducted more extensively than the addition of services to already-railroad-served areas from 1970 to 2000.

The trend of average population density before and after the new station development for each transition case is shown in Figure 6. The band in the center of the figure shows the period of development. The density prior to the development is already high in Mesh B and C, indicating approximately 8,000 persons/sq km and 3,000 persons/sq km respectively. On the other hand, most of the densities outside the railroad service had the population density of less than 1,000 persons/sq km. Besides the high density in the areas near the station, it demonstrates the fact that some railroad developments are also conducted in low-density areas. It seems that there is no threshold value of population density on the possibility of railroad development or, if any, the value is quite low. Examining the density of the meshes that was outside mesh or Mesh C before the development, meshes with higher density got closer to the new station. This implies that if the distance from existing stations is equal or far enough, areas with higher density will have the higher possibility of another station development closer to the existing one. This trend of growing density in meshes closer to the station continues after the station development: especially for meshes that were outside mesh before the station development, those transferred to Mesh A enjoyed considerably larger population density growth than the others.

Table 3 Transition in mesh categories, 1970-2000

Transition Case	Observations
Outside to Mesh A	235
Outside to Mesh B	1,038
Outside to Mesh C	1,148
Mesh C to Mesh A	131
Mesh C to Mesh B	502
Mesh B to Mesh A	258
Total	3,245*

*: Total is not equal to the sum of 6 cases, since several meshes experienced two (or even three) cases of transition.

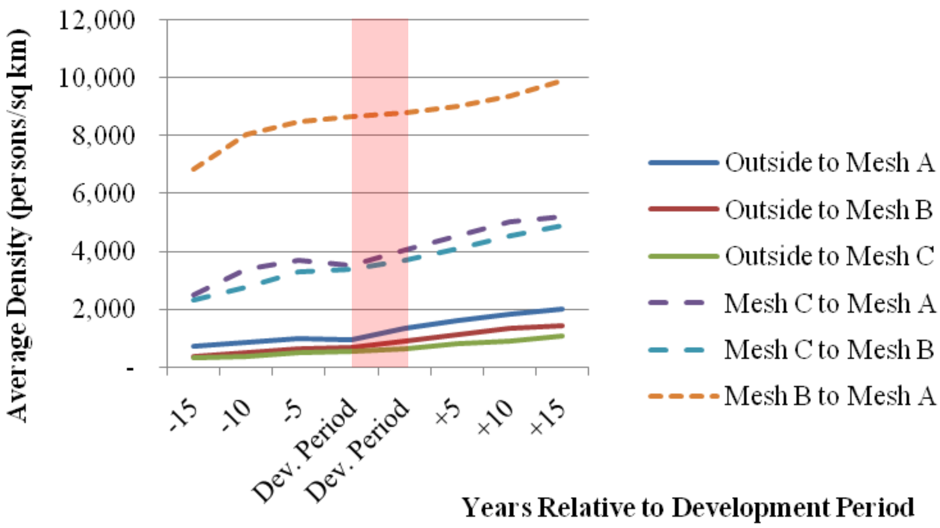

Figure 6 Average density before and after station development

The change in average density before and after the station development is shown in Figure 7. A vertical line on the center of the figure indicates the development period. The population density growth fifteen years before the station development is significant. The largest factor for this would be the Second Baby Boom occurred between 1971 and 1974. However, it seems that the effect of this factor is small in outside areas, which implies that the trend of rapid population growth is weak in areas away from the railroad network. Further, the density growth five years before the station construction is significantly low. Reasons might be the end of Baby Boom and a possible saturation of development around the existing stations: at any rate, the strong trend of population density growth is clearly not the requirement for the introduction of new stations. After the inauguration of station operation, a consistent growth in population density is observed for all transition cases. From this fact, it can be pointed out that the provision of railroad station is one of the important factors supporting the regional growth of population density.

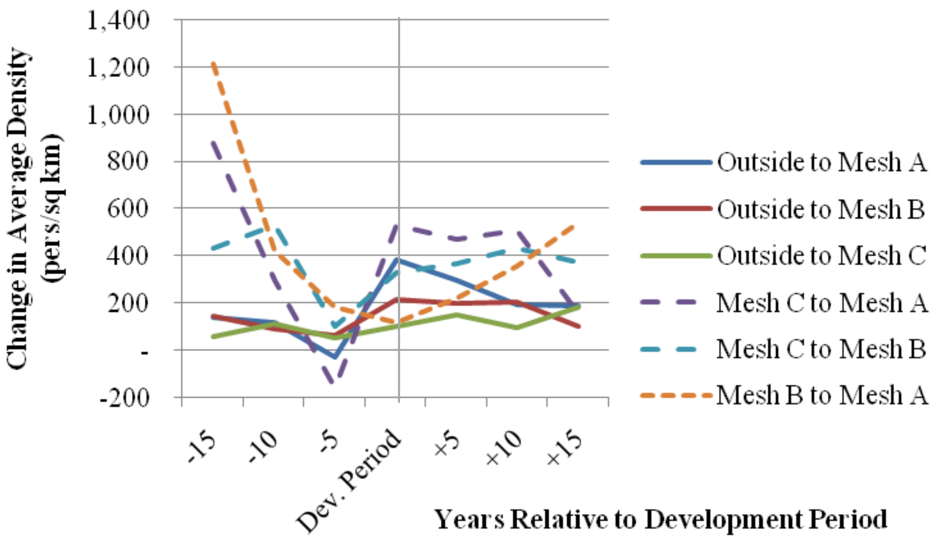

Figure 7 Changes in average density before and after station development

For 3,245 meshes experienced the railroad service improvement in 30 years, the geographical distribution and other aspects of railroad station development impact on density changes are analyzed in more detail. As shown above, the station development induced population density growth to surrounding areas on average terms. However, a wide variation in density changes, even declines, is observed. Six aspects of density changes are discussed one by one. The difference of density between 1970 and 2000 is considered and the period of station development is not taken into account. Six transition cases posed earlier is treated all together here. Of 3,245 meshes, 1,232 (approximately 38%) experienced decline in population density. On the other hand, the density is more than ten times greater in 2000 than in 1970 in 440 (approximately 14%) meshes.

Overall geographical distribution. Both growth and decline in population density is observed both in urban and rural areas. However, the declined meshes are less observed in two largest metropolitan areas in Japan, namely Tokyo, as shown in Figure 8, and Osaka, as shown in Figure 9. Especially in Tokyo, almost all meshes enjoyed growth in density with only a few exceptions. In other areas, both growth and decline in density is observed and the geographical trend on the distribution is not clear. It can be said that railroad station development in metropolitan areas has a premium effect on population densification compared to that in rural areas. Still, station provision elsewhere may provide further growth in population density on average terms.

Proximity to the station. Overall, there is no clear tendency that the change in population density is related to the distance from the station. A sufficient mixture of changing trend of population density is observed. Among them, three railroad lines seem to be experienced the concentration of density-declining meshes near the stations. These lines include Akita Nairiku Jukan Railway, Tarumi Railway and JR Etsumihoku Line. These are similar in aspects that they are (1) rural lines, (2) inland lines, (3) not electrified and (4) formerly JNR lines. However, these characteristics are also true to several other lines that does not have the similar trend. Therefore, it is hard to generalize that stations on these lines may have a mischief in deadening the motivation of densification. In addition, there is a possibility that the convenient automobile infrastructure may soak up the population from station areas. In fact, these three lines have national highway routes along them. However, this is also the case for others.

Accordance with housing development. An extensive growth of population density is observed in housing complexes and new towns, which are extensively constructed in accordance with railroad development. Some of the examples include Tama, Kohoku and Chiba New Towns in Tokyo area (circled A1 to A3 in Figure 8 respectively), Seishin, Semboku and several other new towns in Osaka area (circled A4 to A6 in Figure 9 respectively). In these areas, the highest concentration of meshes with high population density growth is observed. Also in Sendai and Hiroshima, the housing development corresponding with the introduction of new railroad lines induced an extensive growth in density. This implies that a strong collaboration with railroad and housing development will effectively concentrate the population along the railroad line.

Reclaimed bayside areas. Reclaimed area in Tokyo and Osaka (circled B in Figures 8 and 9 respectively) is another candidate for the greatly densified areas. This creates new land areas for additional residential, commercial and industrial development as well as an introduction of new railroad services, resulting in further densification around the area. The relationship of this cause and effect is somewhat similar to that for new towns mentioned above.

Areas surrounding airports. Two major international airports are opened during this period, namely Narita Airport in Tokyo and Kansai Airport in Osaka (circled C in Figures 8 and 9 respectively). Both are constructed with newly introduced access railroad lines. It is notable that population density in Narita area is significantly declined. The largest reason for this may be the major conflict and opposition against airport construction in 1970's and 80's. For Kansai Airport, the density increased since it is built on a reclaimed land. For the cases of railroad introduction to the existing airports, there is no general trend in density changes. In summary, the railroad will impact less on population density if it is constructed mainly for airport access.

Difference between modes. Though railroad system is discussed as a whole throughout this study, it includes a variety of modes such as heavy rails, light rails, trams, monorails, funiculars and so on. Therefore, a regression analysis is conducted to quantify the magnitude of impact of different modes on density. Four modes are incorporated in this analysis, namely JR (former JNR) heavy rail lines, other private heavy rail lines, people movers including monorails and guideway transits, and subways. Trams are not considered here since there is no introduction of new tram service since 1970. The result is shown in Table 4. All variables are significant at the 1% significance level. JR lines indicated the largest impact on density growth, followed by subways. The potential of private railroads for density growth is relatively low. Other factors than railroad impact on density growth should be taken into account since adjusted R square value is extremely low.

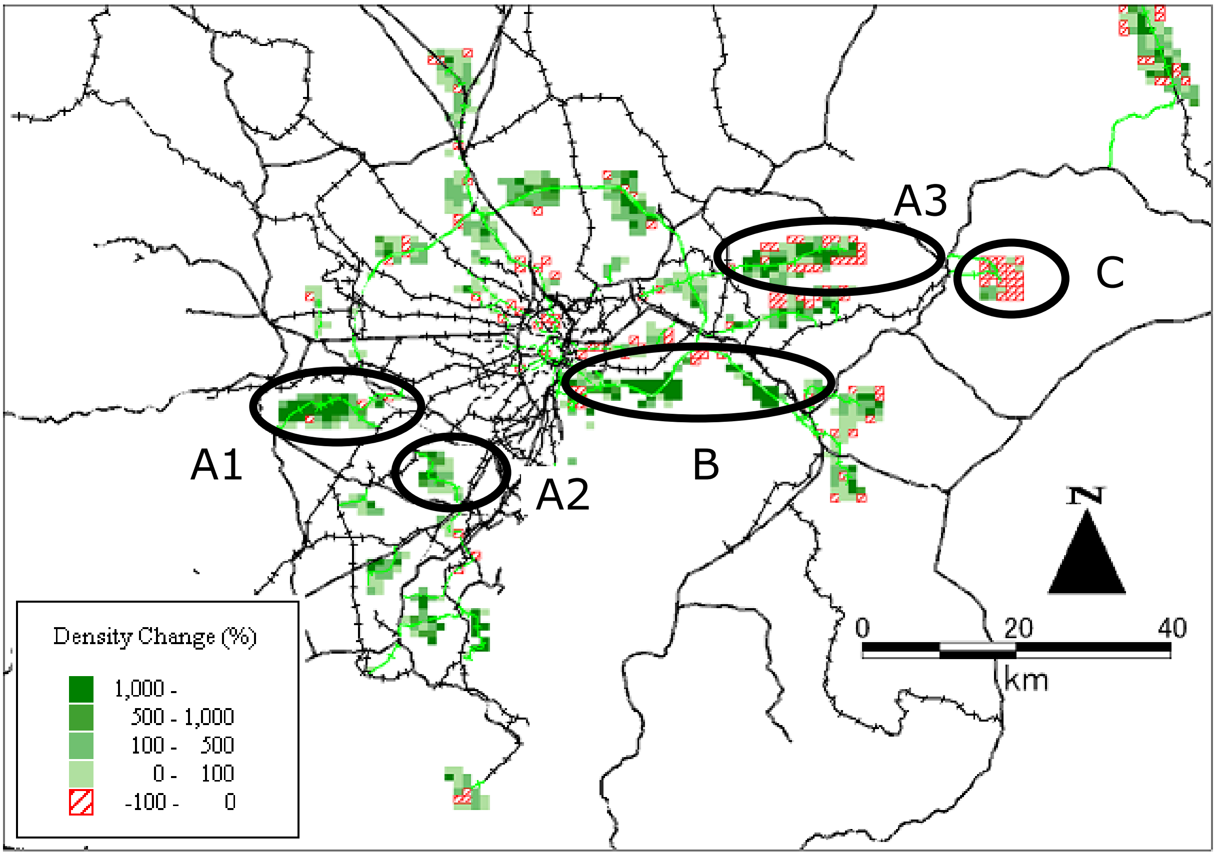

Figure 8 Distribution of population density changes in Tokyo metropolitan area

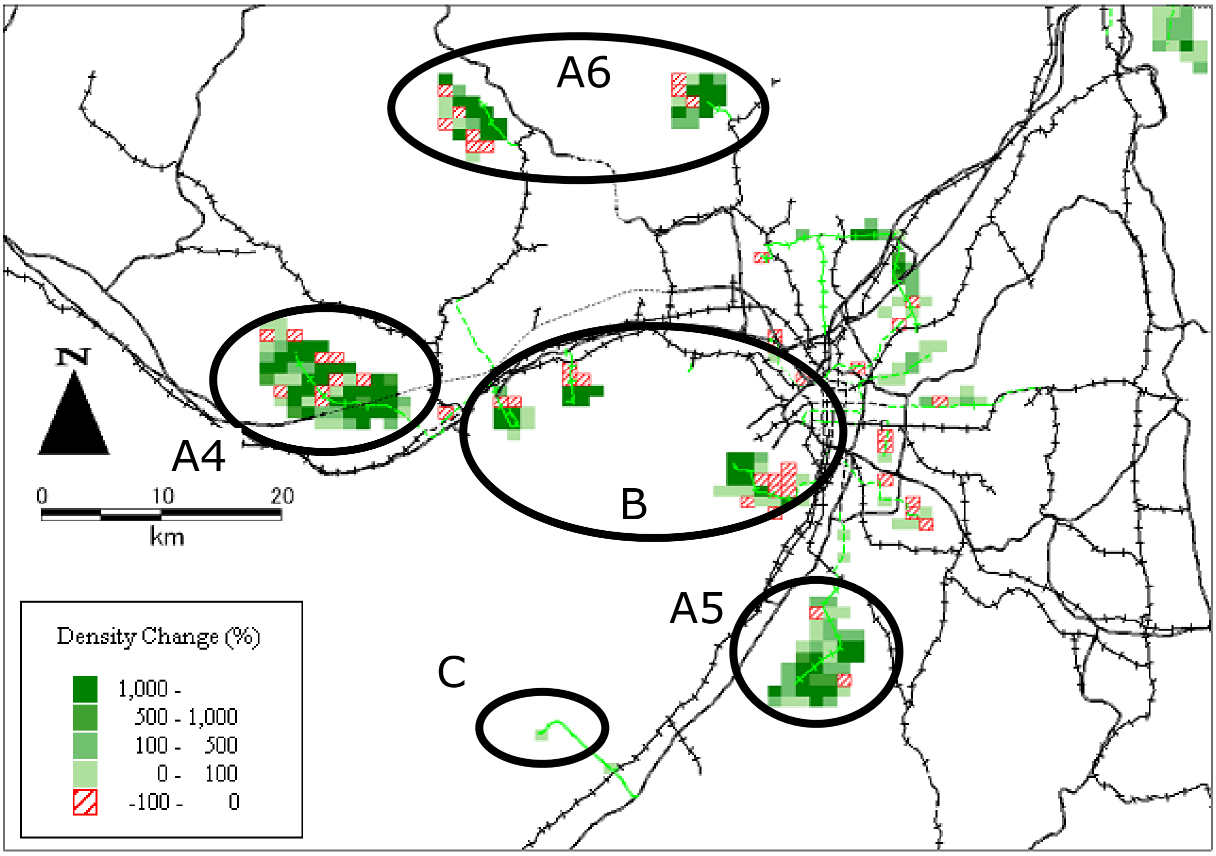

Figure 9 Distribution of population density changes in Osaka metropolitan area

Table 4 Different railroad development types and their impact on densification

Independent Variables	Coefficient	Standard Error	t-statistics
Constant	244.670*	7.355	33.266
JR rails (dummy)	919.014*	56.588	16.240
Private rails (dummy)	379.264*	43.833	8.652
People movers (dummy)	592.505*	71.735	8.260
Subways (dummy)	645.177*	52.350	12.324
Adjusted R square	0.008		
Observations	74,252		

*: Significant at the 1% significance level.

6. CONCLUSION

This study deepened the empirical knowledge on the relationship between railroad station development and regional density using census population data and spatial data of railroad facilities in Japan. Further, the changes of density before and after the railroad development are analyzed to verify the impact of railroad station development on the population density growth.

First, through cross-sectional analysis, the population density around the station is clearly higher than that away from the station. The trend becomes stronger as getting nearer to the station but higher density is still observed in areas 2 to 3 km from the station. The existence of railroad service might be required for the emergence of high-density areas, though it is not a sufficient condition because there are a few exceptions.

From longitudinal analyses, a clear threshold value of population density for the possibility of railroad development is not confirmed. There may be no threshold or, if any, the value is very low. If the distance from the nearest station is equal, areas with higher density will have an advantage in additional railroad development. Detailed discussions on the distribution of density growth indicated several implications. First, the impact of railroad development is greater in major metropolitan areas than the others, while other regional trend is not clear. Second, a simultaneous development of railroad in new towns and reclaimed lands will provide an extensive densification of population. Third, the effect of railroad development on density is poor when the line is built for a special purpose, such as airport access. Lastly, while every rail mode demonstrated a significant effect on density growth, JR lines and subways has the strongest potential.

From the point of view of promoting TOD and compact city in general, measures and policies are taken into action to induce the densely popularized area along the public transportation corridors to realize more efficient transportation and less environmental impact. Further, it is widely agreed that the densification of region is necessary to promote public transportation use. However, especially by studies conducted in the United States, the impact of public transportation on land use is said to be small and ungeneralizable, and the development of public transportation is not regarded as a tool for promoting urban densification. In this study, conducted in the country with relatively high density and high level of public transportation use, we propose a long-term linkage between railroad station development and regional densification. Further, a collaborative development of railroad and housing complexes will perform one of the strongest roles in population density growth.

REFERENCES

Beimborn, E., Rabinowitz, H, Mrotek, C., Gugliotta, P. and Yan, S. (1992) Transit-based approach to land use design. In **Transportation Research Record: Journal of the Transportation Research Board, No. 1349**, TRB, National Research Council, Washington, D.C., 107-114.

Bollinger, C.R. and Ihlanfeldt, K.R. (1997) The impact of rapid rail transit on economic development: The case of Atlanta's MARTA, **Journal of Urban Economics, Vol. 42**, 179-204.

Cervero, R. (1984) Light rail transit and urban development, **Journal of the American Planning Association, Vol. 50, No. 2**, 133-147.

Cervero, R. and Landis, J. (1997) Twenty years of the Bay Area Rapid Transit system: Land use and development impacts, **Transportation Research Part A, Vol. 31, No. 4**, 309-333.

Dunphy, R.T. and Porter, D.R. (2006) Manifestations of development goals in transit-oriented projects. In **Transportation Research Record: Journal of the Transportation Research Board, No. 1977**, TRB, National Research Council, Washington, D.C., 172-178.

Forrest, D., Glen, J. and Ward, R. (1996) The impact of a light rail system on the structure of house prices, **Journal of Transport Economics and Policy, Vol. 30**, 15-29.

Gatzlaff, D.H. and Smith, M.T. (1993) The impact of the Miami Metrorail on the value of residences near station locations. **Land Economics, Vol. 69, No. 1**, 54-66.

Giuliano, G. (2004) Land use impacts of transportation investments. In Hanson, S. and Giuliano, G. (eds.) **The Geography of Urban Transportation**. The Guilford Press, New York, NY.
Glick, F. (1992) Light rail transit and effective land use planning: Portland, Sacramento, and San Diego. In **Transportation Research Record: Journal of the Transportation Research Board, No. 1361**, TRB, National Research Council, Washington, D.C., 75-80.
Iwakura, S. and Yai, T. (1990) A study on the provision process of a new station in urban development project, **Journal of the City Planning Institute of Japan, Vol. 25**, 109-114.
Knight, R.L. and Trygg, L.L. (1977) Evidence of land use impacts of rapid transit systems, **Transportation, Vol. 6**, 231-247.
Le Clercq, F. and de Vries, J.S. (2000) Public transport and the compact city. In **Transportation Research Record: Journal of the Transportation Research Board, No. 1735**, TRB, National Research Council, Washington, D.C., 3-9.
Lewis-Workman, S. and Brod, D. (1997) Measuring the neighborhood benefits of rail transit accessibility. In **Transportation Research Record: Journal of the Transportation Research Board, No. 1576**, TRB, National Research Council, Washington, D.C., 147-153.
Ministry of Land, Infrastructure and Transport (various years) **National Digital Information Data**. Available: http://nlftp.mlit.go.jp/ksj/ Accessed on January 8, 2009.
Ministry of Land, Infrastructure and Transport (2003) **Domestic Transportation Statistics Handbook, 2002 Edition**. Institution for Transport Policy Studies, Tokyo, Japan.
Mitsui Zosen Systems Research Inc. (2004) **Road Map V2004/9**. Mitsui Zosen Systems Research Inc., Chiba, Japan.
Moon, H. (1990) Land use around suburban transit stations, **Transportation, Vol. 17**, 67-88.
Nakamura, F. (1995) Trend of bus-based transit oriented development and its applicability, **Journal of the City Planning Institute of Japan, Vol. 30**, 607-612.
Newman, P. and Kenworthy, J.R. (1999) **Sustainability and Cities: Overcoming Automobile Dependence**. Island Press, Washington, DC.
Polzin, S.E. (1999) Transportation/land-use relationship: Public transit's impact on land use, **Journal of Urban Planning and Development, Vol. 125, No. 4**, 135-151.
Polzin, S.E., Chu, X. and Rey, J.R. (2000) Density and captivity in public transit success: Observations from the 1995 Nationwide Personal Transportation Study. In **Transportation Research Record: Journal of the Transportation Research Board, No. 1735**, TRB, National Research Council, Washington, D.C., 10-18.
Porter, D.R. (1998) Transit-focused Development: A progress report, **Journal of the American Planning Association, Vol. 64, No. 4**, 475-488.
Pushkarev, B.S. and Zupan, J.M. (1977) **Public Transportation and Land Use Policy**. Indiana University Press, Bloomington, IN.
Rubin, T.A., Moore II, J.E. and Lee, S. (1999) Ten myths about US urban rail systems, **Transport Policy, Vol. 6**, 57-73.
Statistics Bureau of Japan (various years) **Population Census Datasets.** Sinfonica, Tokyo, Japan.
Tamura, T., Masuya, Y. and Saito, K. (1993) Impact study on the land price effects on railway improvement in Sapporo urban area, **Journal of the City Planning Institute of Japan, Vol. 28**, 313-318.
Weinberger, R.R. (2001) Light rail proximity: Benefit or detriment in the case of Santa Clara County, California? In **Transportation Research Record: Journal of the Transportation Research Board, No. 1747**, TRB, National Research Council, Washington, D.C., 104-113.