Effect of urban railroads on the land use structure of local cities

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Abstract

The period of rapid economic growth in Japan brought about equally rapid motorization, which has led to private vehicles becoming an intrinsic element of the modern Japanese lifestyle. These trends have resulted in the sprawling of urban functions away from city centers toward the outskirts of cities. Consequently, life without a private vehicle has become increasingly difficult. Hence, the question of how to create compact cities, which employ public transport functions and do not rely on private vehicles, has become an ever more pressing issue. This research examined 61 cities throughout Japan by performing a detailed analysis of the convenience of each city's public transport (railroad) infrastructure with a particular reference to the population distribution. Then whether current city designs allow citizens to benefit from the convenience offered by public railroads was investigated. Our results showed that although some cities are formed in such a way to allow citizens to reap maximum benefits from railroad convenience, none of these cities show particularly high levels of public transport utilization. Next, by comparing the urban structure of cities currently reliant on private vehicles to that of an ideal city designed to maximize the usage and convenience of railroads, we identified points of coherence between the two as well as demonstrate how recent policies intended to revitalize public transport and encourage greater utilization have been successful in increasing this coherence.

Keywords: urban railroads, urban structure, population density.

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1 Introduction

The structures of Japanese local cities used to be relatively compact as the population gathered in the city center where shopping streets and residential area were formed. However, since the 1970s with the movement towards motorization, the lifestyle of citizens and the structures of cities changed dramatically. That is, cities have begun to sprawl toward suburban areas with lower densities, and city centers have declined.

Moreover, from the viewpoint of a modal split, although private vehicle use has increased, public transportation has decreased, and accordingly, train and bus services have been reduced. Diversion of such an urban structure and transportation has led to increased energy consumption and inefficient use of infrastructure. On the other hand, many railroad routes, which began over 50 years ago, are still being operated in cities throughout Japan. However, with some exceptions, they are local routes with infrequent service.

In an ideal situation, a compact city, which has a low environmental consumption, would be established around a railroad station. However, cities have sprawled because such railroads routes are inconvenient and cannot compete with cars. Thus, these railroad infrastructures, which should be at the core of an urban structure, are not fully utilized.

Herein, this study analyzes the effect of railroads on local urban structures for 61 cities, which cover all Japanese cities with populations in excess of 140,000, with the goal of effectively utilizing the railroad infrastructure in order to realize a compact urban structure. Moreover, select cities, which are diffuse, but contain numerous railroads, are analyzed in-depth to examine the relationship between the possibility of railroad use and urban structure.

2 Reference review

As papers that have analyzed the relationship between public transportation and the urban structure in Japan, Nakagawa and Mochizuki [1] and Mochizuki *et al* [2,3] have clarified the role of the Toyama light rail project, which was opened as the first new LRT (Light Rail Transit) route in Japan. In addition, Ito *et al* [4] has clarified the role of the railroad network in the local urban structure in cities. Hayakawa *et al* [5] has described the situation of TOD (Transit Oriented Development) of the LRT introduction in the local city. Moreover, Uoji [6], Sabo [7], and Kaido [8] have conducted studies, which analyze the compactness of the urban structure in an actual city. However, compared to these conventional studies, the current study more precisely analyzes the quantitative relationship between a railroad and urban structures by building a detailed database of many cities using GIS.

3 Railroad and urban structure

This chapter investigates how the availability of a railroad is connected to the local urban structure for 61 cities (all cities with populations in excess of

140,000, except for cities in the metropolitan areas around Tokyo, Osaka, and Nagoya.)

Initially the population of the entire city was divided into two categories: the population residing within a 1 km circle from a railroad station and the population residing outside of a 1 km circle from the nearest railroad station. The rate of former to the total population is termed, "the rate of the station area population (RSAP)". Then the relationship between a railroad and an urban structure was analyzed by comparing this RSAP to the rate of automobile occupation, population density, etc.

RSAP was calculated by census data using GIS. A station area included all station areas in the city containing a streetcar. This is the first time RSAP has been calculated in Japan. Consequently, the largest RSAP was about 60%, and the smallest was about 10%. (Two cities did not have a railroad; RSAP = 0)

(1) Relationship between RSAP and the number of cars per capita

Figure 1 shows the relationship between RSAP and the number of cars per capita. The number of car owners per capita tends to become small as the RSAP increases. However, similar to the findings of Toyama, Takaoka, and Fukui, although RSAP is high, the number of cars per capita is also high. Typically, the dependence on a car is directly proportional to railroad availability; however, these cities do not display such a trend. Although many railroads exist in these cities, they are not utilized sufficiently.

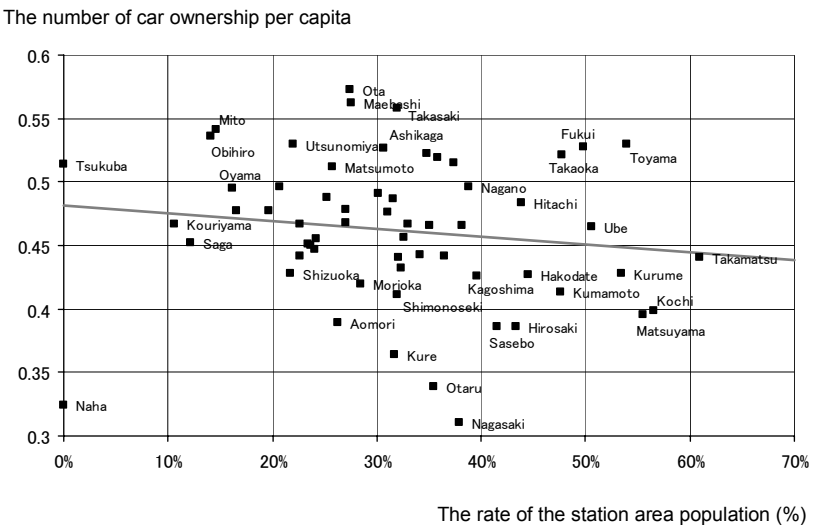

Figure 1: RSAP and the number of car ownership per capita.

(2) Relationship between RSAP and population density

Figure 2 depicts the relationship between RSAP and the population density of the entire city. Cities with a high RSAP tend to have high population densities throughout the city, indicating that the city is compact. However, there are some

exceptions such as Toyama and Fukui, which have a low overall population density and a high RSAP.

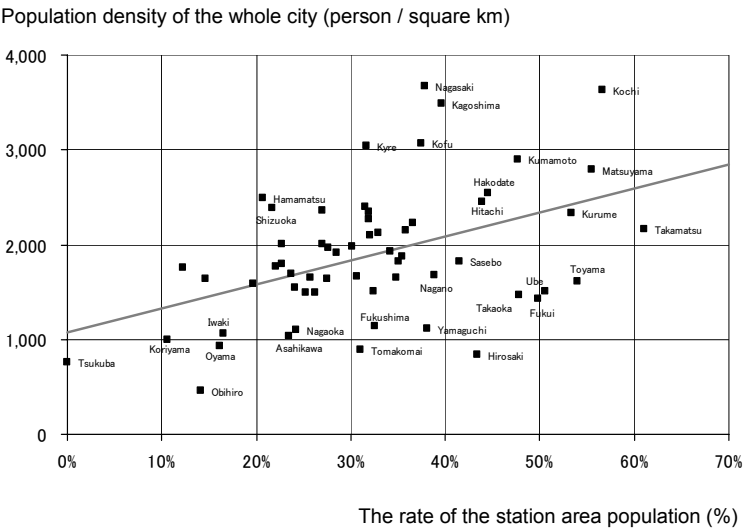

Figure 2: RSAP and the population density of the whole city.

Figure 3 shows the relationship between RSAP and the population density within a 1 km sphere of a station area. The population density within 1 km of the

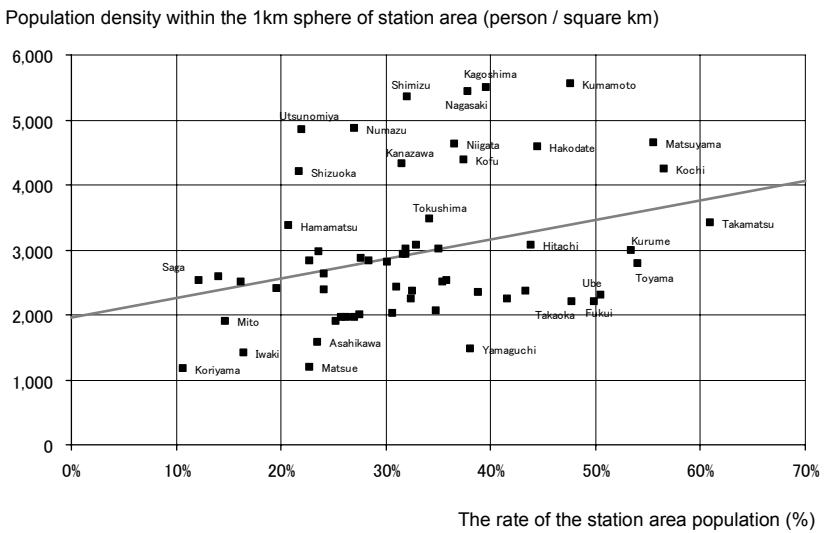

Figure 3: RSAP and the population density within the 1km sphere of station area.

station area displays the same trend as the entire city; cities with a high RSAP are compact, especially Kochi and Matsuyama. On the other hand, some cities such as Toyama, Fukui, and Takaoka where the population density of the entire city is low have a low density around a station despite a high RSAP, suggesting that the grade of accumulation to the station area is strongly related to the compact structure of the entire city.

Next, for the 61 cities, the ratio of the population residing in the vicinities of a railroad station relative to the ideal population residing in a densely populated region (4,000 person/km^2) was calculated.

Table 1 lists the values for the top ten cities and the subordinate ten cities. Takamatsu is city where more than 90% of the densely populated areas are within 1 km of a station. On the other hand, in some cities, only 10% or 20% of the population resides in a densely populated area that includes a station. Hence, in a lot of cities, the residents live in areas that are further than 1 km from the nearest station.

Table 1: Ratio of the population which resides in railroad station area among population which resides in the densely resided region (4,000 person / squire km).

Cities	Ratio(%)	Cities	Ratio(%)
(Top 10)		(Subordinate 10)	
Takamatsu	91.22%	Matsumoto	26.30%
Kochi	72.33%	Hamamatsu	24.90%
Toyama	68.68%	Iwaki	24.51%
Fukui	65.26%	Asahikawa	21.87%
Matsuyama	65.10%	Outa	21.69%
Kurume	63.86%	Kushiro	18.30%
Takaoka	59.30%	Mito	16.38%
Kumamoto	57.51%	Obihiro	13.05%
Ube	56.07%	Saga	11.19%
Yamaguchi	56.02%	Kouriyama	8.58%

4 Detailed analyses

In the above analysis, we found that some cities with a high RSAP have a high number of car ownership per capita, but a low population density. Toyama, Takaoka, and Fukui are typical examples. Below is further analyses, which is conducted by building a more detailed database about these cities.

Figure 4 shows Toyama's trend of RSAP and its constitution. Although the total population is increasing, the population in station areas is decreasing. Thus, RSAP is constantly decreasing. The other two cities are the same position, and the trend of an enlarged inhabited area as the concentration decreases in the city center is clear.

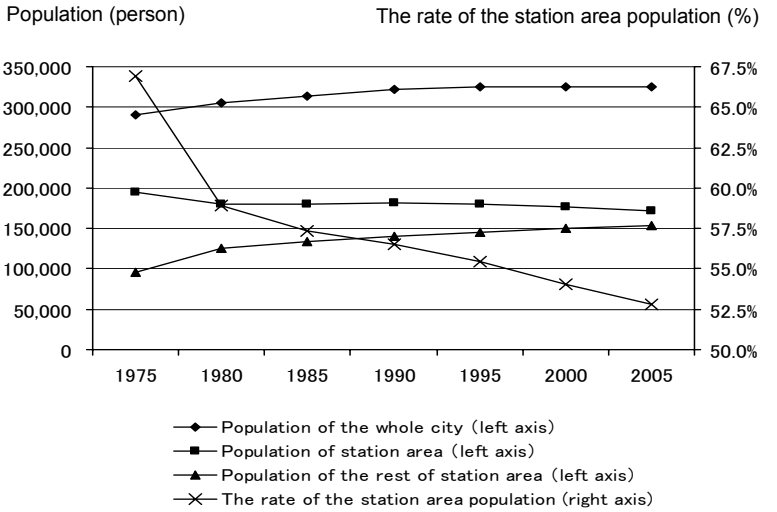

Figure 4: Trend of RSAP and its constitution.

Next, for the same three cities, the average distance to the nearest railroad station, which was defined by the following formula, was calculated.

$$dis\_ave = \frac{\sum_i p_i d_i}{\sum_i p_i} \tag{1}$$

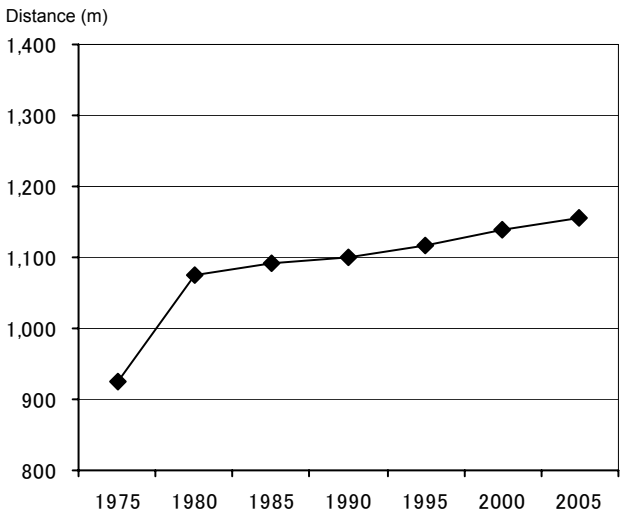

Figure 5: The trend of average distances to the nearest railroad station (Toyama).

where dis_ave is the average distance to the nearest railroad station (m), p_i is the population of each district (person), and d_i is the geographical distance from center of the district to the nearest railroad station. Similar to the Toyama case shown in Fig. 5, the average distances to the nearest railroad station for these three cities are continuously increasing. Hence, the trend of an enlarged city size and habitation far from railroad station is observed.

Furthermore, the population density distribution of Toyama in 1975 and 2005 is shown in Figs. 6 and 7, respectively, while Fig. 8 shows the distribution of the percentage of population change in each district of the city. Comparing the population distribution in 1975 to that in 2005 clearly indicates that the area with a high population density has expanded. The percentage of population change in the city center remained low or decreased, while the converse is true for suburban areas. The increase in areas not containing a railroad station is especially large. Therefore, it is concluded that suburbanization not utilizing railroad stations at its core of development is increasing.

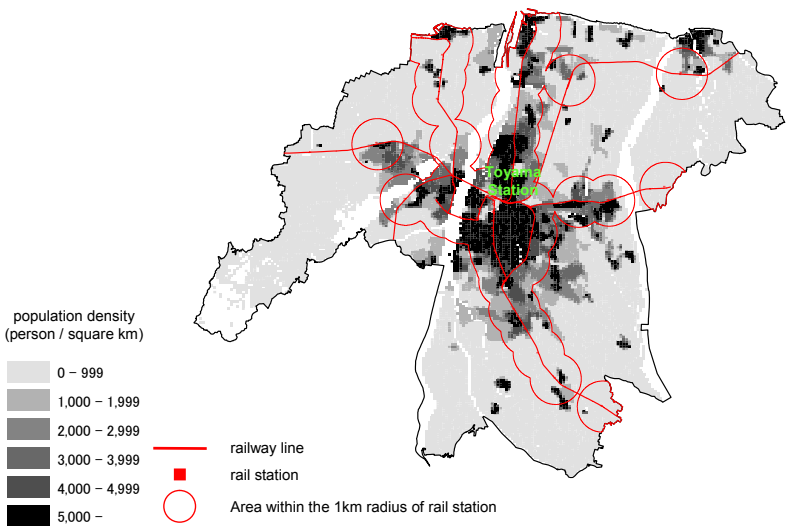

Figure 6: Population density of each district (Toyama, 1975).

5 Conclusions

In this study, a detailed database was created by analyzing the relationship between railroads and the local urban structure for 61 cities in Japan as well as a time series change spanning 30 years in the urban structure for three typical cities. Consequently, all the analyses indicate a clear trend: inhabitance has increased in areas not near railroad stations. Although a city may have a railroad with few cars as its compact core, not all cities have achieved this. One reason may be the inconvenience of railroads, and thus, railroads are not effectively

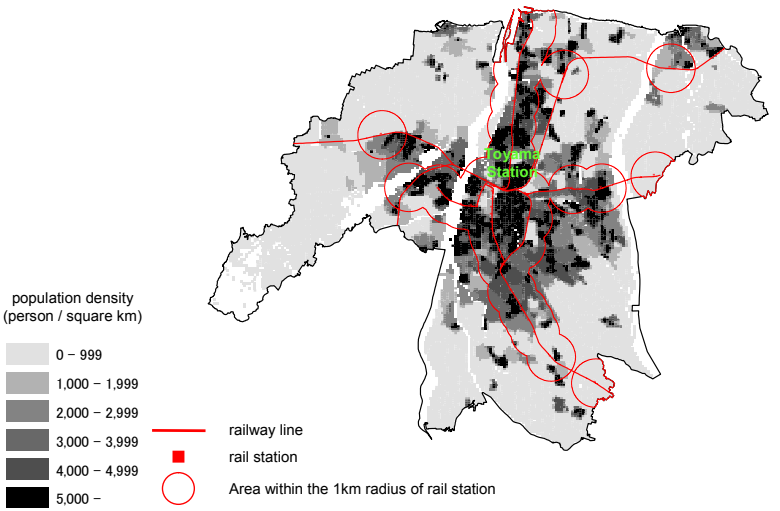

Figure 7: Population density of each district (Toyama, 2005).

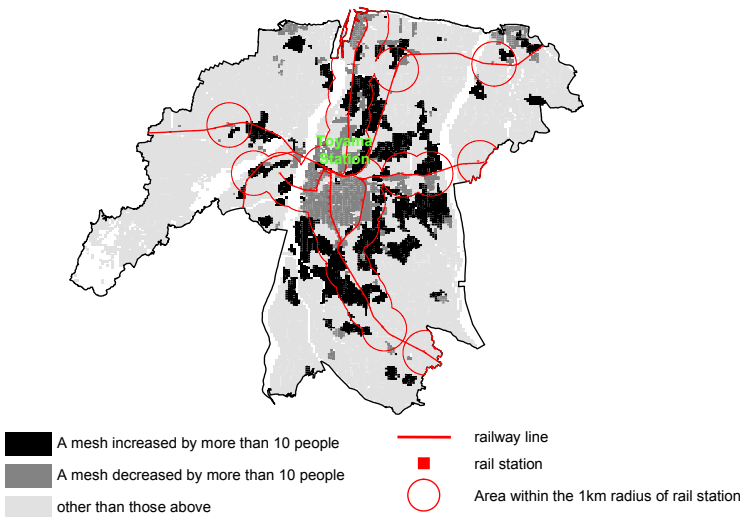

Figure 8: Percentage of population change of each district (Toyama, 1975 to 2005).

utilized as the urban structure core. Because Japanese railroads are managed by private companies, a lower ridership results in a lower level of service, which in turn, results in a lower ridership. Consequently, this type of downward spiral effectively lowers a railroad as the core of urban development.

In this study, we have shown by constructing detailed data concerning the relationship between the railroad and the urban structure in many cities in Japan

that the most railroads are not effectively utilized to create compact cities. However, many Japanese cities do have existing local railroads that could be used to develop compact cities if effective policies, which make railroads more convenient, were implemented.

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