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International comparison of the relationship between urban structure and the service level of urban public transportation—A comprehensive analysis in local cities in Japan, France and Germany

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ABSTRACT

It is said that one of the most important keys to realizing a compact city is to develop very convenient urban public transportation and attractive pedestrian spaces, which bring liveliness to the city center. However, existing data is incomplete and not clear enough to clarify the relationship between the development of very convenient urban public transportation systems and compact urban structure.

In this study, we quantitatively clarify the relationship between urban structure and the service level of urban public transportation including railways and tramways, and compare them among local cities in Japan, France and Germany, targeting all local cities where the populations are over one hundred thousand.

Initially, we investigate urban public transportation frequencies of railways and tramways compared to the distribution of population and pedestrian spaces in city centers of all target cities in Japan, France and Germany. Then, we analyze the relationship between service frequencies at stations of the urban public transportation system and the urban structure following two viewpoints: the spatial distribution of population around the station and the spatial distribution of pedestrian spaces in the city center.

As a result, in all three countries, generally the populations of the surrounding areas of stations with higher service frequencies are confirmed to be larger. As for the ratio of the population of the surrounding areas within a radius of 500 m from railway and tramway stations accounting for the population of each city, we showed the ratio of the population in station areas in France and Germany is high compared with that of Japan. Moreover, as for the proximity of pedestrian spaces to railway and tramway stations, we confirmed that the proximity of pedestrian spaces to railway and tramway stations in Japan is not high compared with France and Germany.

1. Introduction

Motorization has become widespread in local cities in Japan. As such, city functions and residents have been dispersed to suburbs, and daily life has become difficult without private cars. It is also said that motorization has catalyzed the decline of downtown. Recently, the concept of a compact city has been attracting attention all over the world including not only Japan but also European countries.

Generally, it is said that one of the most important keys to realize a compact city is to develop very convenient urban public transportation and attractive pedestrian spaces, which bring liveliness to the city center. In local cities in Japan, although there are public transportation networks, they are not effectively used because service frequencies are very low. On the other hand it is said that in European countries, convenient urban public transportation is provided, and compact urban structures (densely distributed population around stations and comfortable pedestrian spaces in the city center) are realized in many local cities. There is a necessity for cities having policies which support compact urban structure through public transportation with high service level, as well as urban features that are well-designed for everyday life without automobile dependence, such as pedestrian areas. Such provisions bring about vibrancy in the city center and convenient public transportation in a compact city. Furthermore, it can also be said that providing only pedestrian zones is not satisfactory to realize those conditions, and rather the necessary prerequisites for creating a compact urban structure lie also in the proximity and connectivity of public transportation, along with pedestrian zones in the city center.

However, existing data is incomplete and not clear enough to clarify the relationships between the development of very convenient urban public transportation systems and compact urban structure and also to compare them internationally.

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In this study, we quantitatively clarify the relationships between urban structure and the service level of urban public transportation including railways and tramways, and compare them among the local cities in Japan, France and Germany, targeting all local cities whose populations are over one hundred thousand. More specifically, we compare the urban public transportation frequencies of railways and tramways against population distribution in all target cities in Japan, France and Germany. Moreover, we investigate pedestrian spaces in city centers, targeting all local cities which have subway or tramway systems. Then, we analyze the relationship between the degree of service frequencies at stations of the urban public transportation system and the urban structure from two viewpoints: the spatial distribution of population around the stations and the spatial distribution of pedestrian spaces in the city center.

2. Reference review and features of this study

There are extensive existing studies focused on the relationship between urban structure or urban features and urban public transportation. Filion et al. (2006) calculated an index of service quality, which includes service level, to quantify the effects of density-distribution policies on transit use in Toronto. The study found that while densely-developed areas are likely to see higher transit use, policies encouraging density alone are unlikely to spur transit use. The service quality index has significant potential in the transport research field, but is limited by its application to a single local system. Mees (2009) discussed the relationship between urban densities and transit use, and after he calculated urban densities for residential and non-residential land, compared the relationship between urban density and method of travel to work in US, Canadian, Australian, and English cities. Kuby et al. (2004) analyzed the factors which influence light rail boardings in nine cities in the United States, developing a model for predicting demand for light rail systems. The study found several factors which positively affect light rail ridership, including employment and population density, as well as station location. However, in these studies, service levels for urban public transport have not been considered.

Concerning Japanese studies in the same field, Miyata et al. (1993) evaluated the changes of populations in cities, towns and villages along railway lines caused by the closure of local railways, and examined the effect on local societies. Nakagawa et al. (1993) verified the effect of railway development on the populations in local cities, towns and villages from transition of population and the timings of railway development. In the above research, analyses were limited to the municipal level, and neither study included consideration for urban structure. Tsuji et al. (1999), targeting cities having tramways in Japan, verified the relationship between the compactness of cities and tramways, but did not look at service levels of those trams, and concentrated only on Japanese cities with tramway systems. Oba et al. (2008) clarified that populations around railway stations are decreasing and populations in the areas separated from the stations are increasing in local cities in Japan. Matsunaka et al. (2008) compared special characteristics of tram corridors in Japan and France with overall urban characteristics, and Nakamichi et al. (2007) clarified the relationship between LRT systems and private automobile use at the national level. The above three studies did not go so far as to analyze transport service levels, and could benefit from an expanded consideration of urban structure.

Furthermore, Currie et al. (2010) analyzed the relationship between ridership, density, service level, and several other key features at the route level of systems in North America, Europe, and Australia, finding that service level has a positive effect on growing transit use. Both quantitative and international in scope, this study is quite comprehensive, but is missing crucial station-level analysis. Kenworthy (2008) rated an international set of cities based on the performance of their rail systems. The performance measure was derived from a number of criteria including residential and employment density. He found that although density was not a significant variable, the cities with the strongest rail systems also had the highest level of centralization. Though the study included measures for urban structure and transport performance, service level was not considered.

The studies reviewed above considered diverse viewpoints in addressing the relationship between urban structure and transport use. From these studies we can gain a great deal of insight on that relationship, but their methods and results are highly variable. While one study might lack quantitative analysis, another may be too local in nature. Still others are only as detailed as the route level. In contrast, the unique feature of this study is its comprehensive, quantitative analysis at the station level comparing transport service levels with urban structure.

As for existing studies focused on the relationship between pedestrian spaces and urban public transportation, Werner et al. (2010) measured the walkability of neighborhoods surrounding LRT stations in Salt Lake City, comparing an objective scale for walkability with interview results. They found that transit riders who were more likely to use transit were the ones located in neighborhoods that were both objectively and subjectively considered walkable. Limited as it was to a single urban area, the analysis would benefit from a larger, more varied data set including multiple cities. Jefferson (1996) also state that the European experience with LRT indicates that it is most compatible with pedestrians, and as such should be an appropriate platform around which to develop pedestrian spaces. As general reviews, however, neither of these studies features a quantitative analysis.

As for existing studies about international comparison, Hass-Klau and Crampton (2002) targeted cities in Europe and North America that have introduced LRT and extracted success factors by analyzing the characteristics of cities and areas along the lines including service frequencies at peak times. It is a comprehensive study but concentrates solely on LRT systems and is thus limited. Babalik-Sutcliffe (2002) identified factors for success of rail systems in cities in the USA, UK, and Canada, according to their respective systems' expected impacts. Land usage impacts varied by city, but were largely influenced by the economic conditions of the areas served, as well as strong the presence of an economically strong CBD. Though performed at the international level, the above studies are limited in scope to a relatively small sample of cities, and do not feature a comprehensive consideration of all cities above a certain population.

As above mentioned, the relationships between urban structure and urban public transportation are not thoroughly clarified in the existing studies. Compared with these studies, the feature of this study is that it targeted all stations of railways and tramways in all target cities, and performed an analysis based upon precise service frequency data by timetable and conducted an analysis on a micro-scale such as station vicinities, then quantitatively clarified the relationships between urban structure and the service level of urban public transportation.

In previous studies with similar features, Nagao et al. (2009, 2010) analyzed the relationship between the service frequencies of railways and tramways, and the population within a radius of 500 m, and then clarified that the population within a radius of 500 m increases if service frequencies are high. Compared with previous studies, this study implemented an international comparison of the relationship between urban structure and the service level of urban public transportation including railways and tramway among the local cities in Japan, France and Germany, comprehensively targeting all local cities where populations are