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. 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.

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. In a recent meta-analysis of studies on the relationship between travel and the built environment, Ewing & Cervero (2010) concluded that there were no significant relationships between variables for urban structure and transit travel, but that the combination of several variables would likely see measurable effects between travel and built environment. Of the measured variables, destination accessibility had the strongest effect on motorized and nonmotorized travel, while density had the weakest association. Due to the nature of meta-analysis, the study is general in scope and is limited to the targets and data laid out in the studies it aggregates. It does not analyze its own standardized set of data within an exhaustive range of target cities. Lane (2008) examined a suite of variables which may affect a city's propensity for adding a light rail (LRT) system, including residential and employment density, as well as sprawl and total roadway length measures. Residential and employment density were both significant variables. The resulting model accurately predicted the introduction of LRT in 33 of 35 cities, but was limited in scope to systems in the United States. 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. Kim *et al.* (2007) investigated the factors impacting rider mode choice in access to light rail stations, finding a significant influence of land use type on passenger mode choice. As it concentrated on external urban structural factors which influence mode choice, this study also did not consider factors within the transit system itself, such as service level.

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, Handy *et al.* (2005) looked for the direction of causality between urban structure and transit use, controlling for attitudes and finding that neighborhood characteristics typically associated with reduced driving do indeed have a significant causative effect on transit use. Since this study focused mainly on how neighborhood design affects transit use, it did not take into account characteristics of the transit system itself. Sung *et al.* (2011) analyzed the effects of land use on transit ridership according to time of day and day of the week in the city of Seoul, finding that certain urban structural characteristics such as four-way intersections or residential mixed-use development had a significant effect on transit use. 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. Banister *et al.* (2011) used case studies to evaluate the non-transport benefits of rail systems at macro-, meso- and micro-economic levels, finding that there are quantifiable benefits but that there can be problems in determining causality as well as issues with double-counting. The study was not designed to incorporate urban structure in its scope of 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. Glaeser and Kahn (2010) analyzed CO_2 emissions in 48 metro areas of the United States, comparing the energy use of home heating, driving, public transportation use, and household electricity. They found that increasingly decentralized cities have higher aggregate energy use (and thus higher CO_2 emissions) due to private vehicle use. Looking at aggregate measures for transit carbon emissions, the study did not explicitly address service levels, though the data gathered could be assumed to include a general measure for service. Grazi *et al.* (2008) analyzed the relationship between urban structure and commuting behavior as affecting CO_2 emissions, concluding that in denser cities CO_2 emissions are significantly lower due to decreased automobile use. On the other hand, Heinonen and Junnila (2011) found no significant relationship between urban density and carbon emissions in a study of two Finnish metropolitan areas. Both of the above studies may be limited by localized focus, at the national level and metropolitan level respectively. Arrington (2003) addressed the relationship between TOD and LRT in four cities in the United States and examined the factors which make TOD planning a success. However, his study was a review of case studies, and as such did not feature any quantitative analysis of the effects of TOD in the United States.

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. Topp (1999), reviewed the current state of available LRT technologies and their adaptation in European cities, noting the ease with which LRT may be integrated with pedestrian spaces and the potential for creating new development in cities. Jefferson *et al.* (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 *et al.* (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. Priemus *et al.* (2001) reviewed the transit experience in France, Germany, and Japan to find economic revitalization around transit lines in France and Germany, as well as significant links between real estate development and public transit in Japan. They stressed that appropriate, well-considered policy is necessary for proper development to attract passengers during off-peak hours, but the study lacks quantitative data. 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 meters, and then clarified that the population within a radius of 500 meters 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 over one hundred thousand. It also differs from its predecessors in its consideration of pedestrian spaces for analysis.

3. Analytical method

3.1 Definition of targeted cities

In local cities in France and Germany, it is said that both public transportation and compact urban structures are well developed. Moreover, generally, it is necessary for effective use of urban public transportation that the population of city or urban area is more than one hundred thousand.

Therefore, in this study we compare the relationship between urban structure and the service level of public transportation, targeting all local cities in Japan, France and Germany whose populations are over one hundred thousand, are not in major metropolitan areas, and which have subway or railway or tramway systems,.

The definition of target cities in each country is as follows:

(1) Japan

The cities in Japan with a population over one hundred thousand as of 2005 were targeted for this study. Among them, cities located in the three major metropolitan areas in Japan (Tokyo, Osaka and Nagoya) and those having no railways and tramways as of 2005 were excluded from this study. Accordingly, the 134 local cities shown in Table 1.1 were targeted.

(2) France

The size of communes in France is small compared to that of cities in Japan and Germany. Thus, we analyzed urban areas (agglomération) which consist of multiple communes (INSEE, 2011). Based on the census implemented in 2006, we extracted all cities with a population over one hundred thousand, excluding Paris, which is the capital of France and is in the largest metropolitan area in France, as well as the metro Paris region. The list of 52 target cities and features of each city is shown in Table 1.2.

(3) Germany

Based on the resident registration in 2008, we extracted all cities with a population over one hundred thousand, excluding Berlin which is the capital in Germany. The list of 70 target cities and features of each city is shown in Table 1.3.

3.2 Population data of districts smaller than municipality

In order to implement the international comparison analysis in all target cities, we built a database of the districts which are smaller than municipalities using GIS. The outlines of the districts used in this study are described as follows:

(1) Japan

In Japan there are two kinds of division data which are smaller than municipalities' district data, called "Cho-Cho-Moku" and mesh data. In this study, we use mesh data for the division data.

The accuracy of an analysis using the division data called "Cho-Cho-Moku" is lower than that of an analysis using mesh data, because "Cho-Cho-Moku" division data have the tendency to become large, especially in suburban areas. As for mesh data in Japan, there are two kinds of data: 3rd mesh in which all sides are about 1 kilometer, and 4th mesh in which all sides are about 500 meters.

In this study, we decided to use 4th mesh as the districts for analysis because of the accuracy of the analysis. We used population data from 2005, which was current census data.

(2) France

In France, the division that corresponds to municipality is "Commune." There are two kinds of division data which are smaller than municipalities; IRIS (îlots regroupés pour l'information statistique) and ÎLOTS that were set at the census. As for IRIS, the division is set so that the population per division is less than 5,000. ÎLOTS is a division that subdivides IRIS further.

In this study, we decided to use IRIS as the districts for analysis because IRIS data cover almost all city areas. We used population data from 2006, which was currently-available census data.

(3) Germany

In Germany, the division that corresponds to municipality is "Gemeinde." Data for divisions smaller than municipalities is grouped into: Postleitzahl (division for postal code), Statistische Bezirk (division for statistics), and Wohnquartier (resident division) ordered by decreasing size. The area of each division of Postleitzahl is large, and Statistische Bezirk only covers main cities.

Thus, in this study we decided to use Wohnquartier as the districts for analysis. We used population data from 2008, which was currently-available data for this type of district.

3.3 Calculation method of service frequencies

In this study, the service frequency at the off-peak time at each station was used as an indicator to express the convenience of railways and tramways.

To begin with, the number of trains leaving stations during 9:00-16:59 was counted for each line based upon the 2005 timetable. For a station connected with multiple lines, the level of service for all lines individually were added as a whole to calculate the station total. Then, the total level of service was divided by the off-peak hours (8 hours), and the service frequencies (service/hour) were thus obtained.

3.4 Method of calculating population around the surrounding area of a station

Populations within a radius of 500 meters of all stations in targeted cities were calculated.

For grids crossing over the boundary between the surrounding area of one station and another, as shown in Fig.1, the population was calculated by proportionally dividing it based upon the area ratio of the surrounding area and its outside using GIS software. In the case that the surrounding areas of two or more stations overlap, the population in overlapped areas was calculated as that of the surrounding area of each station.

3.5 Data of pedestrian spaces

As for the pedestrian spaces in city centers, targeting all local cities in Japan, France and Germany whose populations are over one hundred thousand and which have subway or tramway systems, we built a database using city maps and GIS software.

At first, we scanned each map of city centers in each city map on the market, and then imported the data into GIS software. Next, for pedestrian space data, we made polygon data of the areas that are shown as “No Entry for Vehicles,” “Arcade,” “Pedestrian street,” “Pedestrian zone,” “Pedestrianized road” in the legend using GIS. The example of pedestrian space data is shown in Fig.2.

4. Relationship between distribution of population around the station and its service frequency

4.1 Relationship between distributions of population surrounding all railway and tramway stations and service frequencies

The populations of the surrounding area within a radius of 500 meters from stations of both railways and tramways were calculated for each service frequency classification.

As shown in Fig. 3.1-3.3, in all three countries, Japan, France and Germany, the stations with higher service frequencies tend to have a larger population in their surrounding areas. In the box-whisker plot used in this study, the upper edge of the box shows the third quartile value, the lower edge of the box shows the first quartile value, and upper whisker shows the 95th percentile, while the lower whisker shows the 5th percentile.

In Japan, there are large differences in the populations of the surrounding area between stations with service frequencies of 4-6/hour and those with service frequencies of 6-12/hour.

On the other hand, population in the surrounding area of railway stations with service frequencies of more than 12/hour is less than that in the surrounding area of railway stations with service frequencies of 6-12/hour. Almost all railway stations with service frequencies of more than 12/hour are central stations in cities which have a relatively large population among the target cities, and commerce and business spaces are required around such a station. Thus residential spaces are limited, and the population in the surrounding area within a radius 500 meters from railway stations of more than 12/hour becomes relatively less.

In France, the mean of the population in the surrounding area of railway stations with service frequencies of 6-12/hour is over 10,000. It is remarkably high compared with the other service frequency categories. The reason is that 14 stations out of 18 stations included in this classification are subway stations operated in the city center of large cities such as Lyon, Marseille, and so on.

In Germany, the stations with higher service frequencies have larger population in their surrounding areas, except for railway stations with service frequencies of less than 1/hour. As for railway stations with service frequencies of less than 1/hour, the upper whisker is larger than that of the railway station with service frequencies of 1-2/hour. This shows that some stations that have especially large populations are included in this classification. Indeed, the stations in this classification such as Ebitzweg station in Stuttgart have a large population because these stations are located near stations with much higher service frequencies.

The mean of the population of the surrounding area within a radius 500 meters from railway stations of more than 12/hour, which is the classification of the highest service frequency, is 5,268 in Japan, 8,194 in France and 5,722in Germany. In France it is relatively large, and in Japan and Germany it is the same level of about 5,500.

The difference between maximum and minimum values of the population of the surrounding area within a radius of 500 meters from railway stations in each classification is 5,298 in Japan, 11,260 in France, and 4,283 in Germany. In France, because the population of the surrounding area of railway stations with service frequencies of 6-12/hour is quite large, the difference also becomes large. Japan has the second largest difference next to France. In Japan, there are some cases that the railway stations are located in underpopulated areas where few people live. This fact creates a large difference in the population of the surrounding area of stations.

4.2 International comparison of the relationship between distributions of population and distances from railway and tramway stations

We calculated the population density surrounding railway and tramway stations in each distance from stations. As shown in Fig. 4.1-4.3, the areas with greater distance from stations tend to have lesser population density. The stations with higher service frequencies also tend to have larger population density in each distance level from stations.

In France, the population density of the surrounding area within a radius of 300 meters from railway and tramway stations with service frequencies of 3-4/h is less than that of a radius of 300 - 500 meters and 500 meters - 1 kilometer from stations. More than half of these stations including this classification are terminal stations for inter-city railways, which are often located on the perimeter of the inner city. Thus, the population density in the area far from the stations is higher than that in the area around the stations.

Next, we calculated the population density surrounding railway stations in each distance from stations. As shown in Fig. 5.1-5.3, as well as the case of the railway and tramway stations, the areas with greater distance from railway station tend to have less population density. The railway stations with higher service frequencies also tend to have higher population density in each distance from stations.

In the case of railway stations with service frequencies of more than 12/hour in Japan, the population density of the surrounding area of 500 meters - 1 kilometer from stations is highest. As described in 3.1, almost all railway stations with service frequencies of more than 12/hour are the central station in a relatively large city, and commerce and business spaces are required around such a station. Thus residential spaces are limited, and the population density in the surrounding area within a radius of 500 meters from railway stations of more than 12/hour becomes relatively less.

Moreover, we calculated the population density surrounding tramway stations in each distance from stations. As shown in Fig. 6.1-6.3, as well as the case of the railway stations, the areas with greater distance from tramway stations tend to have less population density. Tramway stations with higher service frequencies also tend to have higher population density in each distance from stations. Incidentally, at all tramway stations with service frequencies of more than 6/hour, the population density of the surrounding area within a radius of 300 meters from stations is more than 50person/ha.

4.3 Analysis on the population ratio of the surrounding area of railway and tramway stations

We calculated the ratio of the population of the surrounding area within a radius 500 meters from railway and tramway stations accounting for the population of each city. Moreover, we also calculated the ratio of the population of the surrounding area within a radius of 500 meters from railway and tramway stations with high service frequencies (railway station: greater than or equal to 3/hour, tramway station: greater than or equal to 6/hour) accounting for the population of each city.

The relationship between the ratio of the population of the surrounding area of railway and tramway stations and the ratio of the population of the surrounding area of railway and tramway stations with high service frequencies is shown in Fig. 7.1- 7.3. The city which has the highest ratio of the population of the surrounding area in each country is Hiroshima City (34.3%) in Japan, Grenoble (43.0%) in France and Karlsruhe (74.0%) in Germany.

Focusing on whether each city has an urban transportation system such as subway, tramway and so on, in almost all French and German cities which do not have an urban transportation system, the ratio of the population of the surrounding area is less than 15%. On the other hand, in some Japanese cities such as Takamatsu City, the ratios of the population of the surrounding area are relatively high, though they do not have an urban transportation system. In these cities, a part of the intercity railway system plays the role of the urban transportation.

Moreover, in France there are 2 cities where the ratios of the population of the surrounding area is more than 40%, and in Germany there are 37 cities where the ratio of the population of the surrounding area is more than 40%. The number of cities where the ratio of the population of the surrounding area is more than 40% in Germany is quite large. However, in Japan there is no city where the ratio of the population of the surrounding area is more than 40%. In Germany, there are many compact cities where the population of the surrounding area of a station is high because a high density urban transportation network has existed in the city center since the beginning of the 1900s in many cities and the urban transportation network has reached to the suburbs.

5. Relationship between distribution of pedestrian spaces and service frequencies of railways and tramways

In this chapter, targeting all local cities which have subway or tramway systems, we analyze the relationship between the degree of service frequencies of stations in the urban public transportation system and the urban structure from the viewpoint of the spatial distribution of pedestrian spaces in the city center.

First, as shown in Fig. 8, we calculated the areas of pedestrian spaces per hectare of each city center. The average of the areas of pedestrian spaces per hectare of city center in each country is 21.1m^2 of Japan, 191.7m^2 of France and 186.2m^2 of Germany. In city centers in Japan there are few pedestrian spaces, about a ninth of the total area in France or Germany.

Next, we show the relationship between the average service frequencies of all stations in city centers and the average service frequencies of the stations located within 100 meters of pedestrian spaces in Fig. 9.1- 9.3. In Japan, 5 cities such as Sapporo City have no railway and tramway station within 100 meters of pedestrian spaces. Thus, in these cities, the average service frequencies of the stations located within 100 meters of pedestrian spaces is zero. We can never say that the proximity of pedestrian spaces to railway and tramway stations in Japan is high. The number of cities where the average service frequencies of the stations located within 100 meters of pedestrian spaces is higher than that of all stations in the city center is 9 of 18 cities in France and 43 of 46 cities in Germany. There is quite a large difference between France and Germany. We can also say that the proximity of pedestrian spaces to railway and tramway stations in Germany is higher than that of France.

In France in almost all cities, urban transportation in city centers, which was mainly old-type tramways, was abolished. Since the 1990s new urban transportation which is mainly Light Rail Transit (LRT) has been introduced. Thus, the number of urban transportation routes is not high. Moreover, as for new LRT lines, the stations are located considering access to existing pedestrian spaces. Therefore, there is little difference between the average service frequencies of all stations in city centers and the average service frequencies of the stations located within 100m from pedestrian spaces. On the other hand, in Germany the abolishment of urban transportation is significantly less than that of France. Thus, in city centers a dense urban transportation network has developed in each city. Therefore, the number of urban transportation routes is high and there is a central station in city centers where many urban transportation routes arrive and depart. As for such central stations, there are high service frequencies and many pedestrian spaces around that type of station. In Germany the average service frequency of stations located within 100 meter of pedestrian spaces is about 30% higher than that of other stations in the city center, and the proximity of pedestrian spaces to railway and tramway stations is high.

6. Conclusion

In this study, we analyzed the relationship between the present distributions of populations around railway and tramway stations and the service frequencies of railways and tramways, targeting all local cities in Japan, France and Germany, where the populations are over one hundred thousand. It is very difficult to make the necessary database for such an analysis, and thus the relationship between them has not been clarified and compared internationally.

As a result of our analysis, in all three countries, generally the populations of the surrounding area of stations with higher service frequencies are confirmed to be larger. Regarding the population density surrounding railway and tramway stations in each distance classification from stations, the areas farther from stations tend to have lower population density. The stations with higher service frequencies also have higher population densities in each distance from stations.

We also calculated the ratio of the population of the surrounding area within a radius of 500 meters from railway and tramway stations accounting for the population of each city. The city which has the highest ratio of the population of the surrounding area in each country is Hiroshima City (34.3%) in Japan, Grenoble (43.0%) in France, and Karlsruhe (74.0%) in Germany. In France there are 2 cities where the ratio of the population of the influence area is more than 40%, and in Germany there are 37 cities where the ratio of the population of the surrounding area is more than 40%. The number of cities where the ratio of the population of the surrounding area is more than 40% in Germany is quite large. However, in Japan there is no city where the ratio of the population of the surrounding area is more than 40%.

Moreover, we analyzed the relationship between service frequencies at stations in the urban public transportation system and the urban structure from the viewpoints of the spatial distribution of pedestrian spaces in the city center. We made clear that there are few pedestrian spaces in city centers in Japan, about a ninth compared with France and Germany.

As for the proximity of pedestrian spaces to railway and tramway stations, we analyzed the relationship between the average service frequencies of all stations in city centers and the average service frequencies of the stations located within 100 meters of pedestrian spaces. As a result, in Japan 5 cities have no railway or tramway station within 100 meters of pedestrian spaces. We can never say that the proximity of pedestrian spaces to railway and tramway stations in Japan is high compared with France and Germany. Compared with France, Germany has more cities where the average service frequency of stations located within 100 meters of pedestrian spaces is higher than that of all stations in city centers. Thus, we can also say that the proximity of pedestrian spaces to railway and tramway stations in Germany is higher than that of France.

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Table 1.1(1) List of targeted cities in Japan

ID	City Name	Adm.	City Population			City Area	No. of	Urban
			1995	2000	2005	(ha)	Stations	Transportation*
1	Sapporo	Hokkaido	1,757,025	1,822,368	1,880,863	112,112	94	R U T
2	Fukuoka	Fukuoka	1,284,836	1,341,470	1,401,279	34,060	74	R U
3	Hiroshima	Hiroshima	1,117,117	1,134,134	1,154,391	90,501	126	R T
4	Sendai	Miyagi	971,297	1,008,130	1,025,098	73,516	44	R U
5	Kitakyushu	Fukuoka	1,019,598	1,011,471	993,525	48,766	55	R M
6	Hamamatsu	Shizuoka	766,832	786,306	804,032	151,117	55	R
7	Niigata	Niigata	766,445	779,483	785,134	64,996	27	R
8	Shizuoka	Shizuoka	714,266	706,513	700,886	137,405	24	R
9	Okayama	Okayama	641,654	652,679	674,746	65,857	43	R T
10	Kumamoto	Kumamoto	650,341	662,012	669,603	26,708	58	R T
11	Kagoshima	Kagoshima	594,430	601,693	604,367	54,695	53	R T
12	Matsuyama	Ehime	497,203	508,266	514,937	42,889	58	R T
13	Himeji	Hyogo	470,986	478,309	482,304	27,596	27	R
14	Kurashiki	Okayama	453,618	460,869	469,377	35,434	21	R
15	Oita	Oita	446,581	454,424	462,317	50,125	17	R
16	Utsunomiya	Tochigi	435,357	443,808	457,673	31,216	7	R
17	Kanazawa	Ishikawa	453,975	456,438	454,607	46,777	21	R
18	Nagasaki	Nagasaki	475,259	457,486	442,699	33,872	42	R T
19	Toyama	Toyama	417,595	420,804	421,239	124,185	61	R T
20	Fukuyama	Hiroshima	413,814	416,547	418,509	46,126	13	R
21	Gifu	Gifu	407,134	402,751	399,931	19,512	11	R
22	Nagano	Nagano	377,678	378,932	378,512	73,083	30	R
23	Wakayama	Wakayama	393,885	386,551	375,591	20,923	32	R
24	Toyohashi	Aichi	352,982	364,856	372,479	26,135	31	R T
25	Asahikawa	Hokkaido	360,568	359,536	355,004	74,760	18	R
26	Iwaki	Fukushima	360,598	360,138	354,492	123,134	14	R
27	Koriyama	Fukushima	326,833	334,824	338,834	75,706	10	R
28	Takamatsu	Kagawa	334,731	336,505	337,902	27,444	33	R
29	Kochi	Kochi	325,058	333,621	333,484	26,428	68	R T
30	Akita	Akita	331,597	336,646	333,109	90,567	11	R
31	Maebashi	Gunma	319,483	320,465	318,584	24,122	19	R
32	Naha	Okinawa	301,890	301,032	312,393	3,924	15	M
33	Aomori	Aomori	314,917	318,732	311,508	82,457	17	R
34	Miyazaki	Miyazaki	300,068	305,755	310,123	28,708	16	R
35	Kurume	Fukuoka	302,741	304,884	306,434	22,984	24	R
36	Otsu	Shiga	276,332	288,240	301,672	30,233	33	R T
37	Hakodate	Hokkaido	318,308	305,311	294,264	67,782	29	R T
38	Akashi	Hyogo	287,606	293,117	291,027	4,924	17	R
39	Fukushima	Fukushima	285,754	291,121	290,869	74,643	25	R
40	Shimonoseki	Yamaguchi	310,717	301,097	290,693	71,589	20	R
41	Morioka	Iwate	286,478	288,843	287,192	48,915	10	R
42	Tokushima	Tokushima	268,706	268,218	267,833	19,139	10	R
43	Kakogawa	Hyogo	260,567	266,170	267,100	13,851	11	R
44	Mito	Ibaraki	261,275	261,562	262,603	21,745	7	R
45	Yamagata	Yamagata	254,488	255,369	256,012	38,134	11	R
46	Fukui	Fukui	255,604	252,274	252,220	34,060	34	R T
47	Kure	Hiroshima	270,179	259,224	251,003	35,329	13	R
48	Sasebo	Nagasaki	255,463	251,232	248,041	30,754	24	R
49	Takasaki	Gunma	238,133	239,904	245,100	11,072	12	R
50	Hachinohe	Aomori	249,358	248,608	244,700	30,517	15	R
51	Fuji	Shizuoka	229,187	234,187	236,474	21,410	18	R
52	Nagaoka	Niigata	235,272	237,718	236,344	52,589	9	R
53	Matsumoto	Nagano	225,799	229,033	227,627	91,935	14	R
54	Ota	Gunma	203,599	210,022	213,299	17,649	9	R
55	Joetsu	Niigata	212,060	211,870	208,082	97,332	21	R
56	Numazu	Shizuoka	216,470	211,559	208,005	18,710	4	R
57	Saga	Saga	212,692	208,783	206,967	35,515	3	R
58	Isesaki	Gunma	184,420	194,393	202,447	13,933	6	R
59	Tottori	Tottori	197,959	200,744	201,740	76,566	13	R
60	Tsukuba	Ibaraki	182,327	191,814	200,528	28,407	4	R
61	Hitachi	Ibaraki	212,304	206,589	199,218	22,555	5	R
62	Matsue	Shimane	195,353	199,289	196,603	53,021	15	R
63	Kofu	Yamanashi	201,124	196,154	194,244	17,188	7	R
64	Suzuka	Mie	179,800	186,151	193,114	19,467	18	R
65	Yamaguchi	Yamaguchi	184,039	188,693	191,677	73,023	19	R
66	Kumagaya	Saitama	192,523	192,527	191,107	13,703	7	R
67	Higashihiroshima	Hiroshima	165,153	175,346	184,430	63,532	9	R

* R : Railway U : Underground (Metro) T : Tram M : Monorail

Table 1.1(2) List of targeted cities in Japan

ID	City Name	Adm.	City Population			City Area	No. of	Urban
			1995	2000	2005	(ha)	Stations	Transportation*
68	Kushiro	Hokkaido	199,323	191,739	181,516	22,210	6	R
69	Ube	Yamaguchi	182,771	182,031	178,955	28,769	15	R
70	Imabari	Ehime	185,435	180,627	173,983	41,969	8	R
71	Hirosaki	Aomori	177,972	177,086	173,221	27,381	18	R
72	Tomakomai	Hokkaido	169,328	172,086	172,758	56,144	7	R
73	Iwata	Shizuoka	162,667	166,002	170,899	16,408	5	R
74	Obihiro	Hokkaido	171,715	173,030	170,580	61,894	3	R
75	Matsusaka	Mie	163,131	164,504	168,973	62,380	12	R
76	Takaoka	Toyama	173,607	172,184	167,685	15,061	26	R T
77	Ishinomaki	Miyagi	178,923	174,778	167,324	55,564	12	R
78	Tsu	Mie	163,156	163,246	165,182	10,189	12	R
79	Oyama	Tochigi	150,115	155,198	160,150	17,161	3	R
80	Ashikaga	Tochigi	165,828	163,140	159,756	17,782	9	R
81	Hitachinaka	Ibaraki	146,750	151,673	153,639	9,903	13	R
82	Shunan	Yamaguchi	161,562	157,383	152,387	65,613	8	R
83	Ogaki	Gifu	149,759	150,246	151,030	7,975	12	R
84	Yonago	Tottori	143,856	147,837	149,584	13,221	13	R
85	Izumo	Shimane	146,214	146,960	146,307	54,343	24	R
86	Koga	Ibaraki	146,010	146,452	145,265	12,358	1	R
87	Kakamigahara	Gifu	141,055	141,765	144,174	8,777	16	R
88	Isahaya	Nagasaki	142,517	144,299	144,034	31,217	20	R
89	Tsuruoka	Yamagata	149,509	147,546	142,384	131,149	10	R
90	Otaru	Hokkaido	157,022	150,687	142,161	24,314	8	R
91	Yatsushiro	Kumamoto	143,712	140,655	136,886	68,024	13	R
92	Tsuchiura	Ibaraki	132,243	134,702	135,058	8,183	3	R
93	Miyakonojo	Miyazaki	132,714	131,922	133,062	30,621	5	R
94	Omuta	Fukuoka	145,085	138,629	131,090	8,155	9	R
95	Fujieda	Shizuoka	124,822	128,494	129,248	14,074	1	R
96	Karatsu	Saga	134,567	131,446	128,564	42,456	15	R
97	Kiryu	Gunma	138,193	134,298	128,037	27,457	16	R
98	Beppu	Oita	128,255	126,523	126,959	12,514	4	R
99	Ichinoseki	Iwate	133,138	130,373	125,818	113,310	17	R
100	Ebetsu	Hokkaido	115,495	123,877	125,601	18,757	5	R
101	Niihama	Ehime	128,236	125,814	123,952	23,430	3	R
102	Sano	Tochigi	128,099	125,671	123,926	35,607	9	R
103	Ueda	Nagano	123,284	125,368	123,680	17,673	20	R
104	Aizuwakamatsu	Fukushima	127,292	125,805	122,248	34,346	11	R
105	Fujinomiya	Shizuoka	119,536	120,222	121,779	31,481	4	R
106	Nobeoka	Miyazaki	126,629	124,761	121,635	28,382	10	R
107	Kusatsu	Shiga	101,828	115,455	121,159	4,822	2	R
108	Toyokawa	Aichi	114,380	117,327	120,967	6,544	9	R T
109	Yaizu	Shizuoka	115,931	118,248	120,109	4,598	2	R
110	Kakegawa	Shizuoka	109,978	114,328	117,857	26,563	9	R
111	Hofu	Yamaguchi	118,803	117,724	116,818	18,859	3	R
112	Nasushiobara	Tochigi	105,127	110,828	115,032	59,282	3	R
113	Onomichi	Hiroshima	119,579	117,407	114,486	21,233	3	R
114	Saijo	Ehime	114,706	114,548	113,371	50,904	7	R
115	Chikusei	Ibaraki	118,078	116,120	112,581	20,535	11	R
116	Mishima	Shizuoka	107,890	110,519	112,241	6,213	6	R
117	Kitami	Hokkaido	110,452	112,040	110,715	42,108	9	R
118	Tsuyama	Okayama	113,617	111,499	110,569	50,636	14	R
119	Marugame	Kagawa	106,107	108,356	110,085	11,179	4	R
120	Hikone	Shiga	103,508	107,860	109,779	9,815	8	R
121	Hakusan	Ishikawa	103,580	106,977	109,450	75,517	12	R
122	Komatsu	Ishikawa	107,965	108,622	109,084	37,113	3	R
123	Iida	Nagano	110,204	110,589	108,624	65,876	15	R
124	Kasuga	Fukuoka	99,165	105,219	108,402	1,415	3	R
125	Sanjo	Niigata	109,584	107,662	104,749	43,201	7	R
126	Shibata	Niigata	106,563	106,016	104,634	53,282	7	R
127	Mihara	Hiroshima	108,617	106,229	104,196	47,102	5	R
128	Tajimi	Gifu	101,270	104,135	103,821	7,779	5	R
129	Yokote	Akita	112,600	109,004	103,652	69,359	9	R
130	Fukaya	Saitama	100,285	103,534	103,529	6,940	1	R
131	Iwakuni	Yamaguchi	107,386	105,762	103,507	22,183	14	R
132	Satsumasendai	Kagoshima	106,737	105,464	102,370	68,350	8	R
133	Iga	Mie	101,435	101,527	100,623	55,817	22	R
134	Saku	Nagano	97,813	100,016	100,462	42,399	10	R

* R : Railway U : Underground (Metro) T : Tram M : Monorail

Table 1.2 List of targeted cities in France

ID	City Name	City Population			City Area	No. of	Urban
		1990	1999	2006	(ha)	Stations	Transportation*
1	Marseille-Aix-en-Provence	1,315,316	1,349,584	1,418,485	130,135	50	R U
2	Lyon	1,295,536	1,348,422	1,417,460	95,861	145	R U T
3	Lille	952,446	972,795	985,455	44,231	125	R U T
4	Nice	856,661	889,265	940,015	72,756	39	R
5	Toulouse	666,914	761,107	850,867	81,355	43	R U
6	Bordeaux	712,812	754,017	803,118	106,334	72	R T
7	Nantes	495,229	545,063	568,743	48,731	89	R T
8	Toulon	494,813	519,561	543,068	72,496	11	R
9	Douai-Lens	527,559	518,675	512,465	49,136	23	R
10	Strasbourg	403,310	427,184	440,256	22,356	56	R T
11	Grenoble	405,213	419,468	427,661	32,768	67	R T
12	Rouen	384,404	389,929	388,796	26,922	38	R T
13	Valenciennes	358,512	357,295	355,661	51,115	40	R T
14	Nancy	329,431	331,249	331,278	31,701	44	R T
15	Metz	315,298	322,448	322,954	36,162	13	R
16	Montpellier	256,951	288,059	318,221	15,613	57	R T
17	Tours	283,235	297,439	306,967	42,180	13	R
18	Saint-Étienne	316,877	292,166	286,398	23,167	43	R T
19	Rennes	249,416	272,182	282,551	18,532	22	R U
20	Avignon	239,616	253,581	273,360	50,902	7	R
21	Orléans	243,137	263,252	269,284	28,990	28	R T
22	Clermont-Ferrand	254,451	258,542	260,658	18,199	30	R T
23	Béthune	261,572	259,194	257,302	39,153	12	R
24	Le Havre	254,728	248,560	238,779	15,933	8	R
25	Mulhouse	228,130	234,188	238,638	21,601	33	R T
26	Dijon	230,469	237,203	238,083	16,594	4	R
27	Angers	211,714	226,912	227,767	22,959	3	R
28	Reims	208,764	215,556	212,021	9,220	2	R
29	Brest	204,386	210,058	206,395	22,468	3	R
30	Caen	191,505	199,381	196,325	13,350	35	R T
31	Le Mans	192,306	194,757	192,915	21,070	2	R
32	Pau	173,534	181,471	191,806	45,203	9	R
33	Bayonne	168,224	179,008	189,834	32,444	7	R
34	Dunkerque	190,904	191,107	182,976	16,979	5	R
35	Perpignan	157,755	162,653	178,499	18,032	3	R
36	Limoges	170,072	173,243	177,435	20,080	4	R
37	Nîmes	142,906	148,866	161,563	22,067	4	R
38	Amiens	156,140	160,767	161,311	11,268	4	R
39	Annecy	126,788	136,771	144,683	16,398	2	R
40	Saint-Nazaire	131,528	136,930	143,107	28,397	11	R
41	Besançon	129,275	134,335	134,948	12,319	2	R
42	Troyes	126,244	128,864	131,042	15,277	1	R
43	Thionville	132,494	130,429	130,437	13,799	4	R
44	Poitiers	107,604	119,403	126,654	16,752	6	R
45	Valence	114,555	117,394	120,923	16,184	1	R
46	La Rochelle	105,263	116,302	119,700	9,707	5	R
47	Chambéry	104,884	113,443	119,269	15,729	1	R
48	Genève-Annemasse	98,833	106,723	118,553	17,906	3	R
49	Lorient	115,496	116,209	116,768	11,360	1	R
50	Montbéliard	117,494	113,166	109,117	14,154	2	R
51	Angoulême	102,987	103,708	105,018	18,540	3	R
52	Calais	101,792	104,826	103,279	14,560	3	R

* R : Railway U : Underground (Metro) T : Tram

Table 1.3 List of targeted cities in Germany

ID	City Name	City Population 2008	City Area (ha)	No. of Stations	Urban Transportation*
1	Hamburg	1,772,100	75,313	139	R S U
2	München	1,326,807	31,081	261	R S U T
3	Region Hannover	1,129,797	229,700	243	R S T
4	Köln	995,420	40,534	213	R S T
5	Frankfurt am Main	664,838	24,870	225	R S U T
6	Stuttgart	600,068	20,751	180	R S U
7	Dortmund	584,412	28,089	164	R S U
8	Düsseldorf	584,217	21,777	238	R S U T
9	Essen	579,759	21,051	155	R S U T
10	Bremen	547,360	32,709	157	R T
11	Leipzig	515,469	29,941	264	R S T
12	Dresden	512,234	32,919	252	R S T
13	Nürnberg	503,638	18,729	138	R S U T
14	Duisburg	494,048	23,293	101	R S U T
15	Bochum	378,596	14,567	101	R S U T
16	Wuppertal	353,308	16,856	30	R S M
17	Saarbrücken	335,669	41,129	45	R T
18	Bielefeld	323,615	25,886	73	R T
19	Bonn	317,949	14,118	68	R T
20	Mannheim	311,342	14,485	141	R S T
21	Karlsruhe	290,736	17,355	143	R S T
22	Wiesbaden	276,742	20,489	8	R
23	Münster	273,875	30,342	7	R
24	Augsburg	263,313	14,707	88	R T
25	Gelsenkirchen	262,063	10,493	66	R S U T
26	Aachen	259,269	16,094	5	R
27	Mönchengladbach	258,848	17,082	8	R S
28	Braunschweig	246,012	19,277	81	R T
29	Chemnitz	243,880	22,127	81	R T
30	Kiel	237,579	11,046	3	R
31	Krefeld	236,333	13,756	94	R U T
32	Halle (Saale)	233,013	13,504	121	R S T
33	Magdeburg	230,047	20,326	134	R S T
34	Freiburg im Breisgau	219,665	15,311	70	R T
35	Oberhausen	215,670	7,717	18	R S T
36	Lübeck	210,892	19,283	7	R
37	Erfurt	203,333	27,055	97	R T
38	Rostock	201,096	16,689	82	R S T
39	Mainz	197,623	9,819	50	R S T
40	Kassel	194,168	10,664	104	R T
41	Hagen	192,177	16,079	9	R S
42	Hamm	182,459	22,640	3	R
43	Mülheim an der Ruhr	168,288	9,129	77	R S U T
44	Herne	166,924	5,153	19	R S U T
45	Ludwigshafen am Rhein	163,467	7,750	57	R S T
46	Osnabrück	163,286	11,982	3	R
47	Solingen	161,779	8,955	5	R S
48	Leverkusen	161,322	7,885	5	R S
49	Oldenburg	160,279	10,329	1	R
50	Potsdam	152,966	18,885	72	R S T
51	Heidelberg	145,642	10,894	71	R S T
52	Darmstadt	142,310	12,234	67	R S T
53	Regensburg	133,525	8,112	3	R
54	Würzburg	133,501	8,761	49	R T
55	Ingolstadt	123,925	13,346	2	R
56	Ulm	121,648	11,894	26	R T
57	Wolfsburg	120,538	20,480	2	R
58	Pforzheim	119,839	9,791	7	R S
59	Offenbach am Main	118,977	4,521	7	R S
60	Bottrop	117,756	10,064	3	R S
61	Bremerhaven	114,506	5,922	3	R
62	Fürth	114,071	6,324	14	R U
63	Remscheid	112,679	7,456	4	R
64	Koblenz	106,293	10,513	5	R
65	Erlangen	104,980	7,704	3	R
66	Trier	104,640	11,730	6	R
67	Salzgitter	104,423	22,457	6	R
68	Jena	103,392	11,411	53	R T
69	Cottbus	101,785	16,483	53	R T
70	Gera	100,643	15,377	47	R T

* R : Railway S : S-Bahn U : U-Bahn (Metro) T : Tram M : Monorail

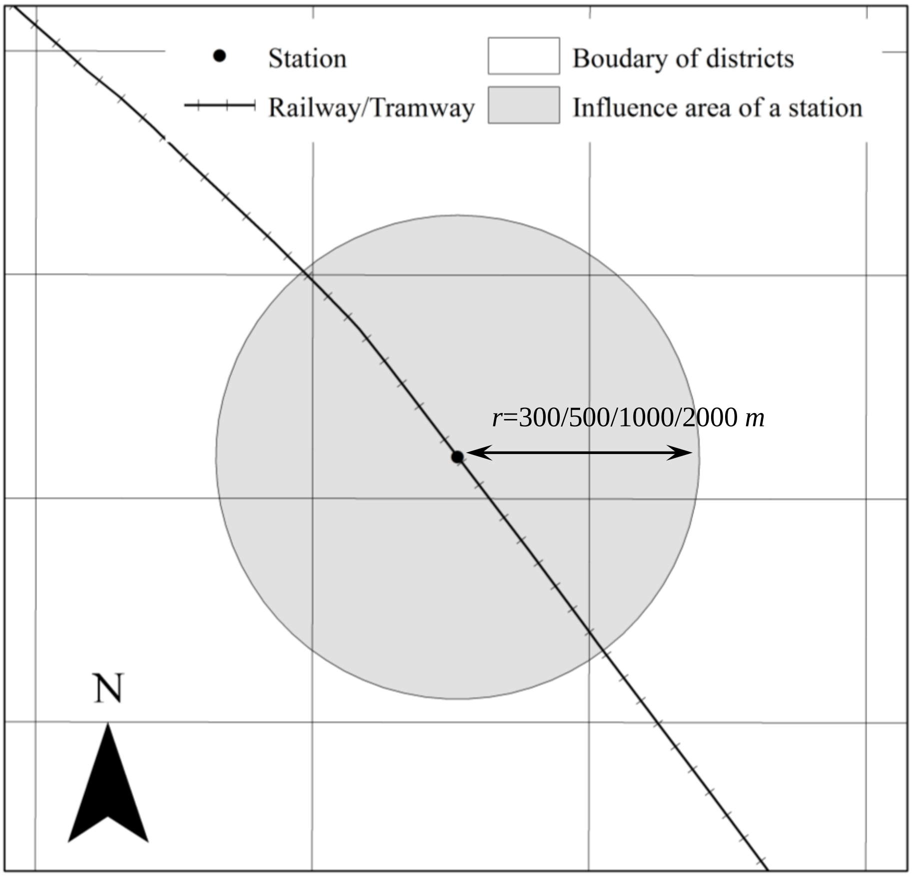

Figure 1 Calculation method of the population of the surrounding area of a station

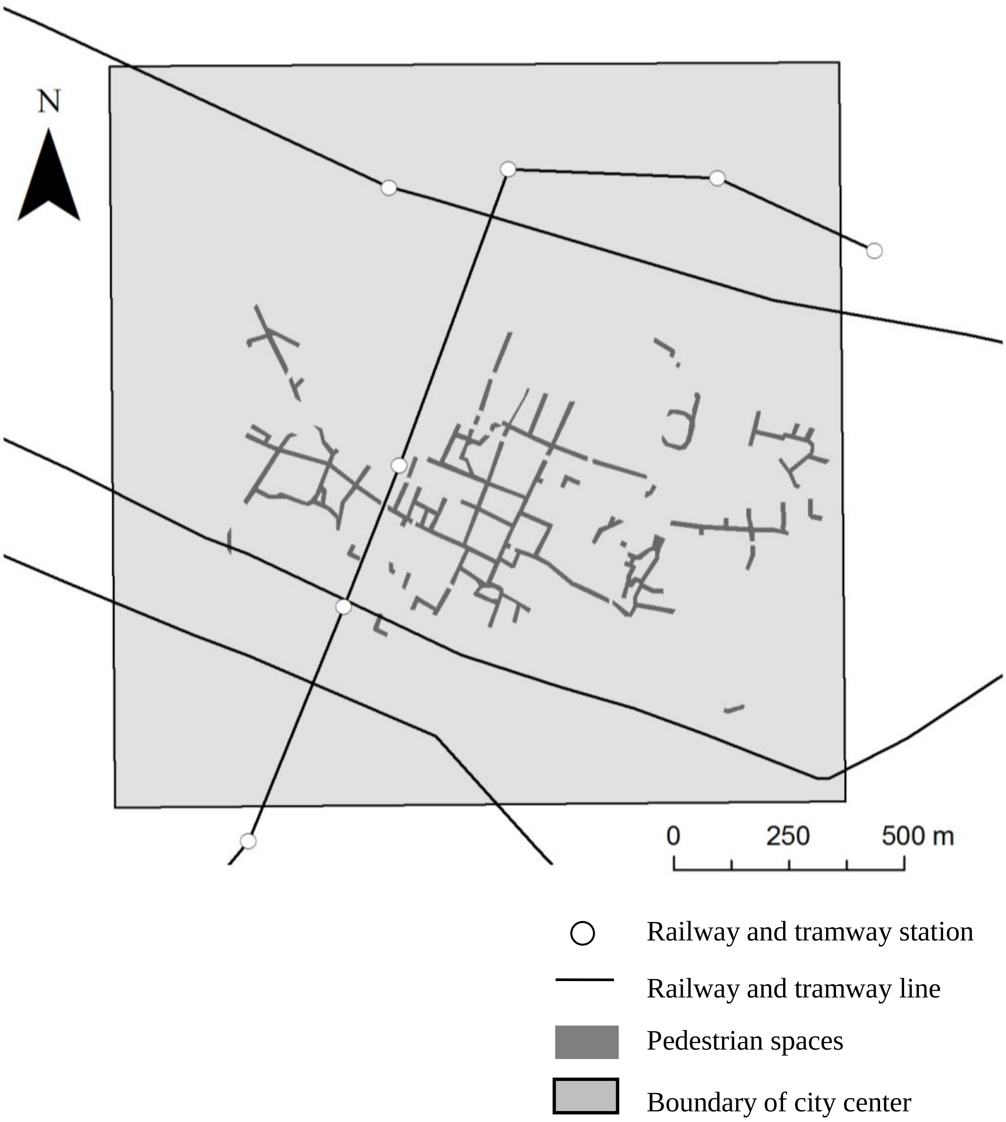

Figure 2 Example of pedestrian space data（Rouen, France）

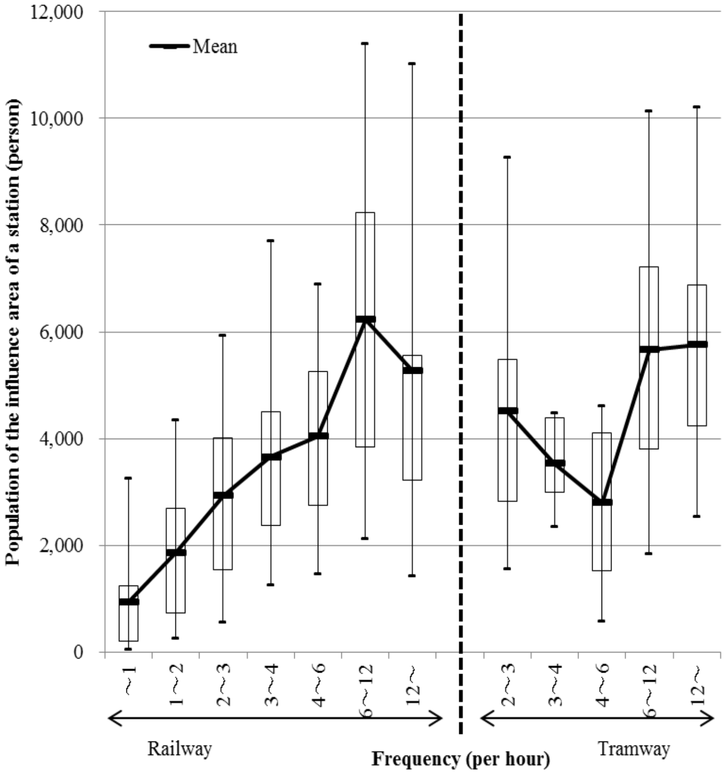

Figure 3.1 Population of the area within a radius of 500 meters from the station (Japan, 2005)

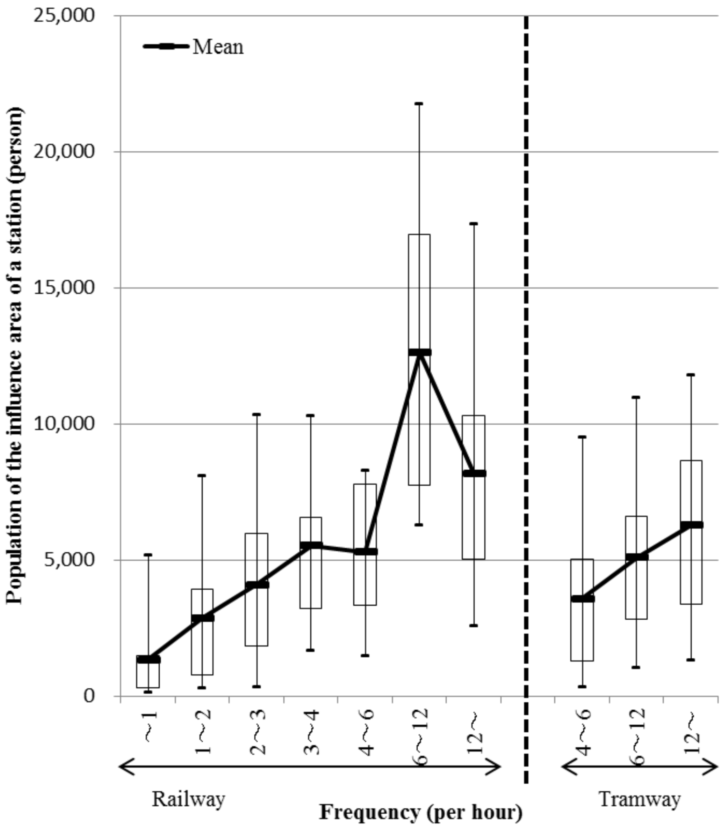

Figure 3.2 Population of the area within a radius of 500 meters from the station (France, 2006)

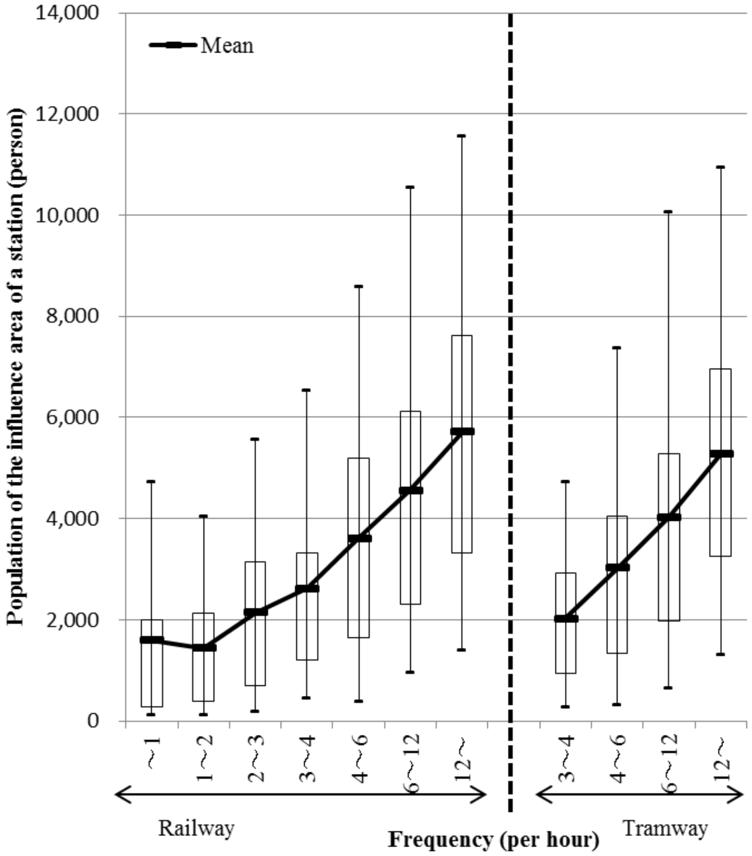

Figure 3.3 Population of the area within a radius of 500 meters from the station (Germany, 2008)

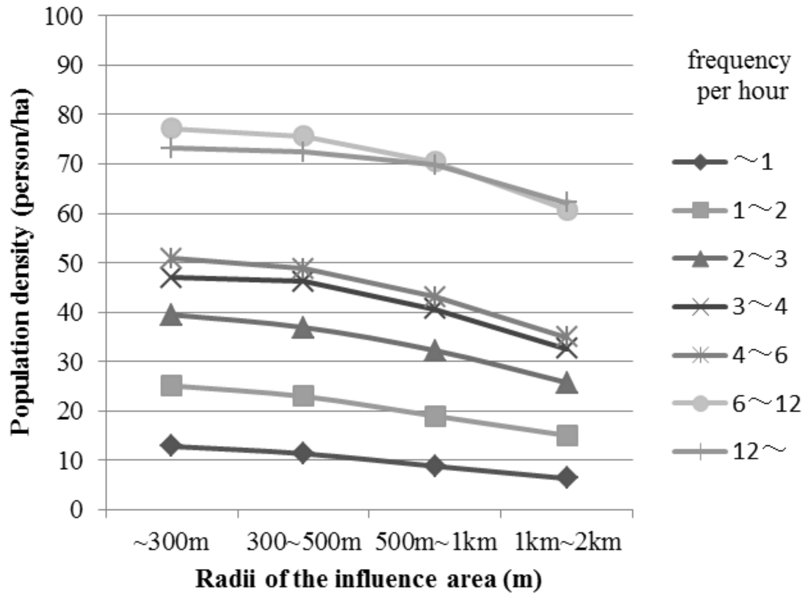

Figure 4.1 Population density surrounding railway and tramway stations in each distance from stations (Japan, 2005, railway and tramway stations)

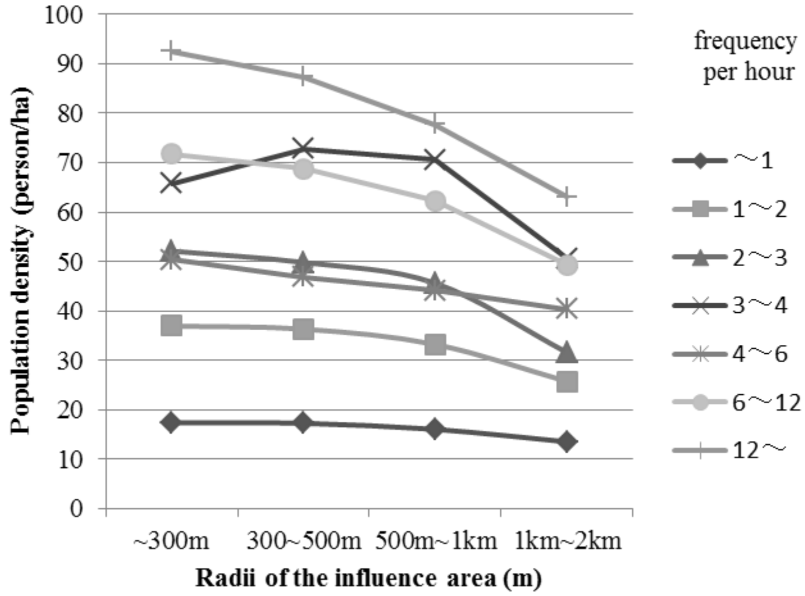

Figure 4.2 Population density surrounding railway and tramway stations in each distance from stations (France, 2006, railway and tramway stations)

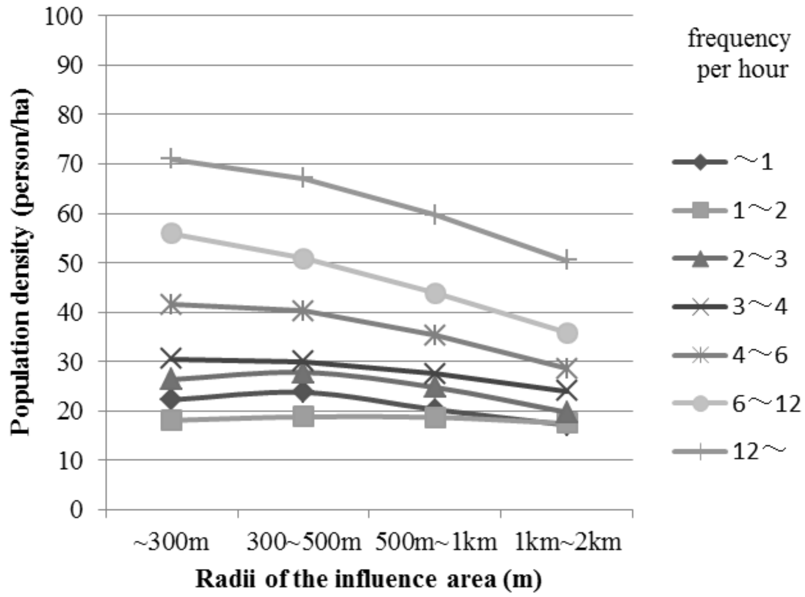

Figure 4.3 Population density surrounding railway and tramway stations
in each distance from stations (Germany, 2008, railway and tramway stations)

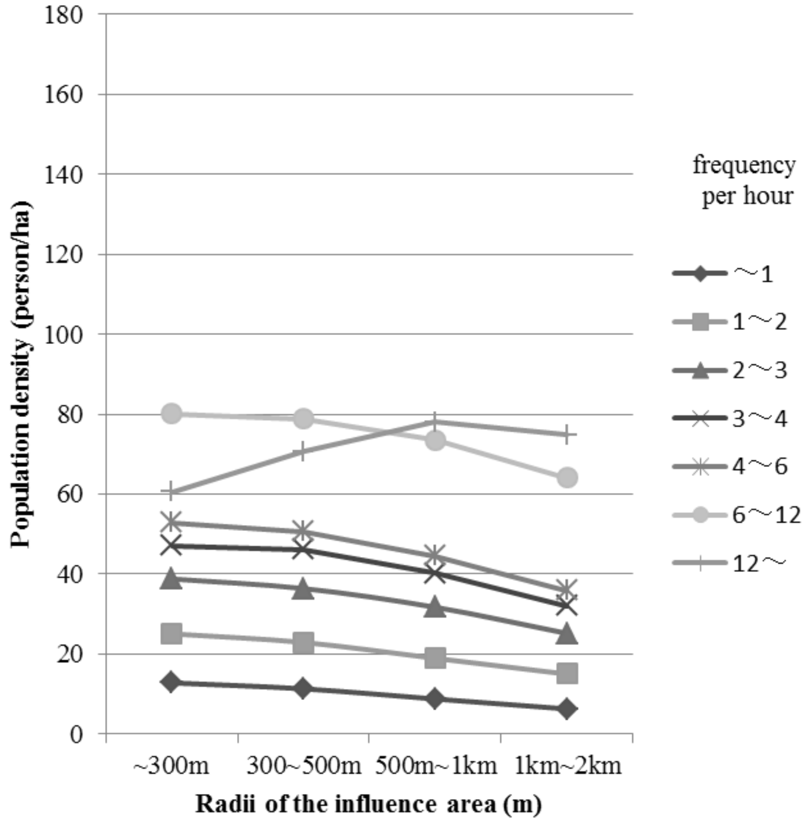

Figure 5.1 Population density surrounding railway stations
in each distance from stations (Japan, 2005, railway stations)

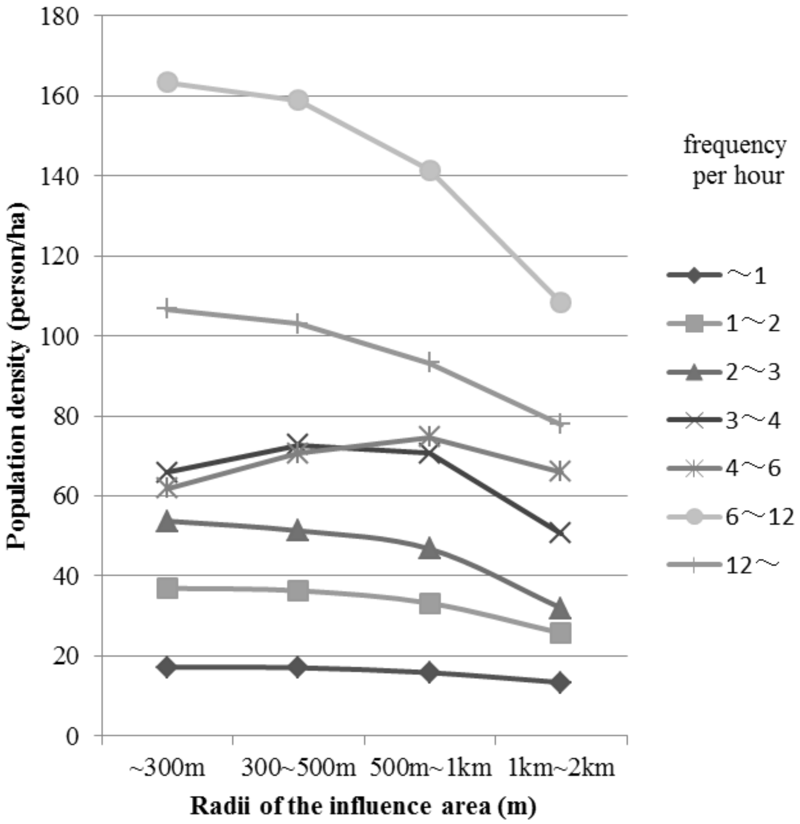

Figure 5.2 Population density surrounding railway stations in each distance from stations (France, 2006, railway stations)

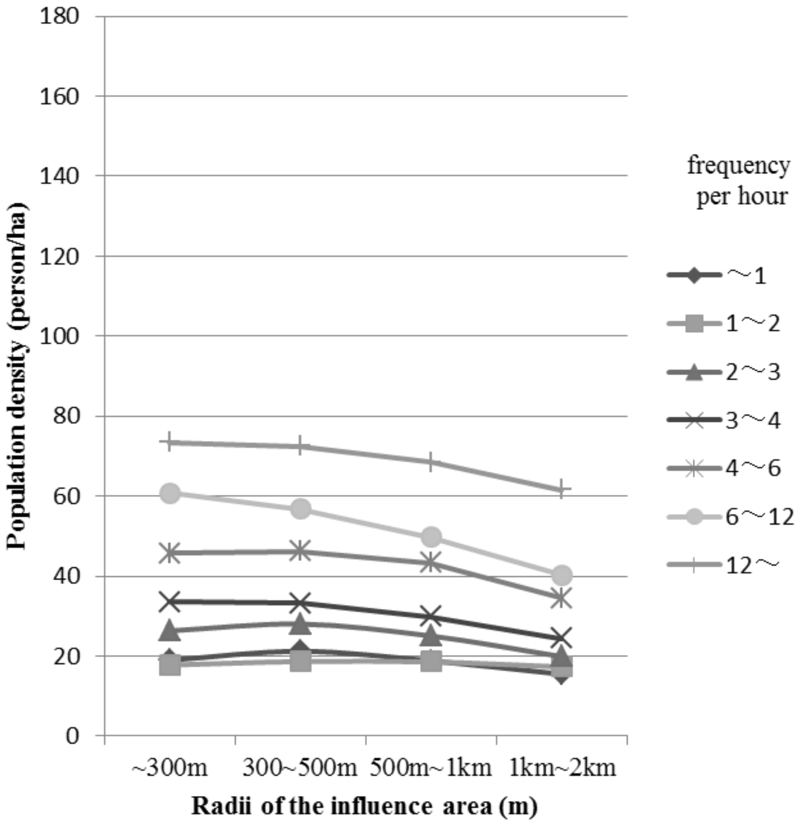

Figure 5.3 Population density surrounding railway stations
in each distance from stations (Germany, 2008, railway stations)

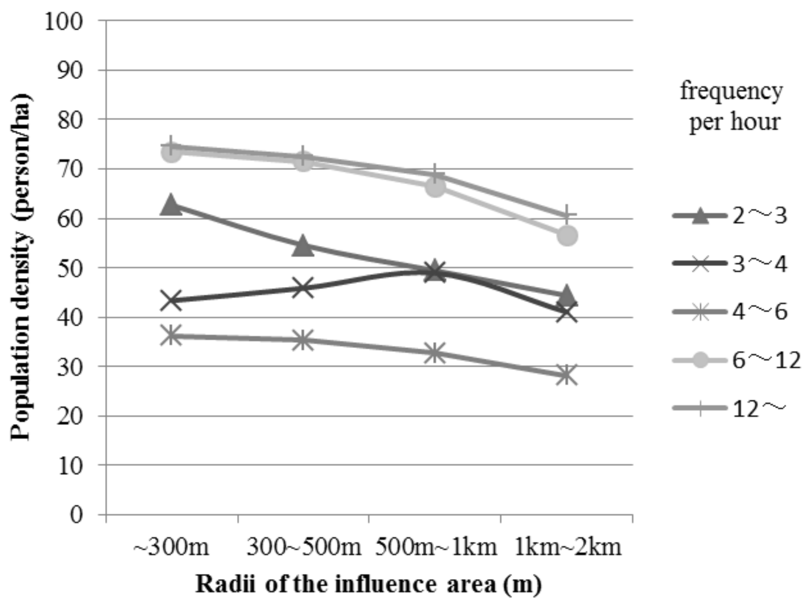

Figure 6.1 Population density surrounding tramway stations
in each distance from stations (Japan, 2005, tramway stations)

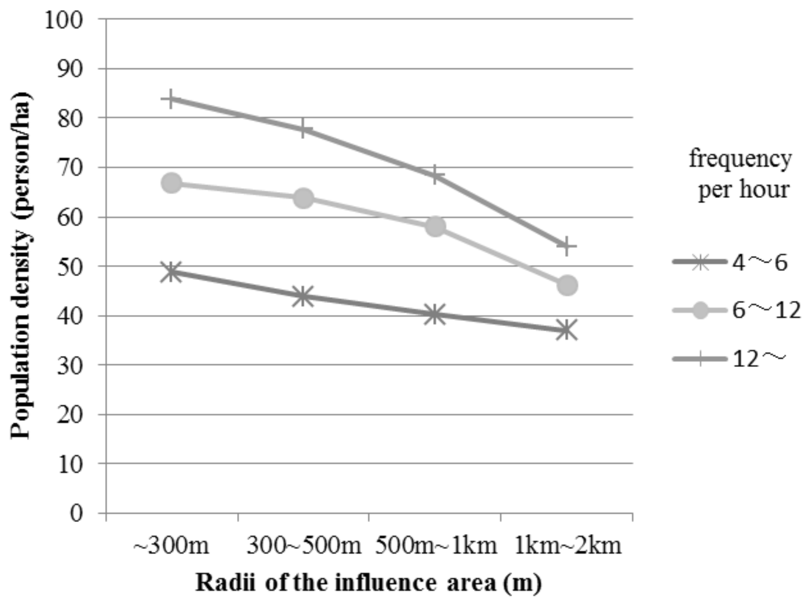

Figure 6.2 Population density surrounding tramway stations
in each distance from stations (France, 2006, tramway stations)

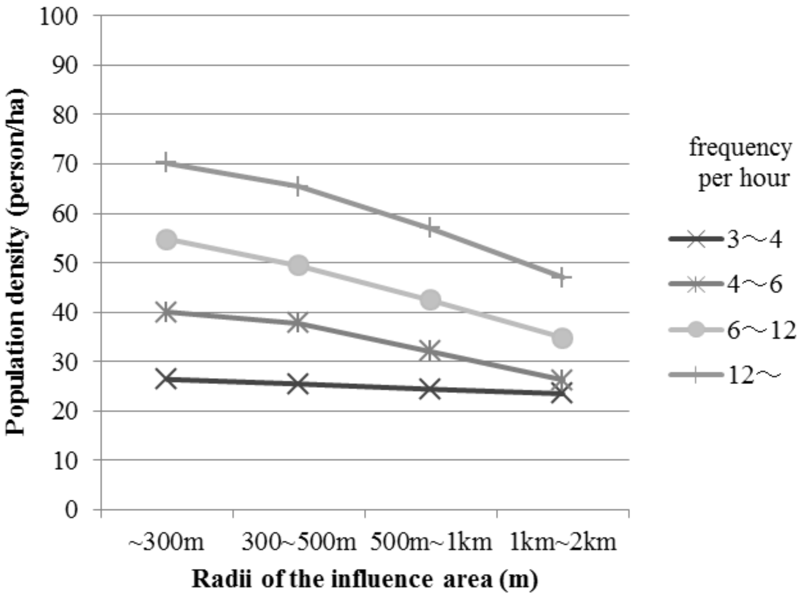

Figure 6.3 Population density surrounding tramway stations
in each distance from stations (Germany, 2008, tramway stations)

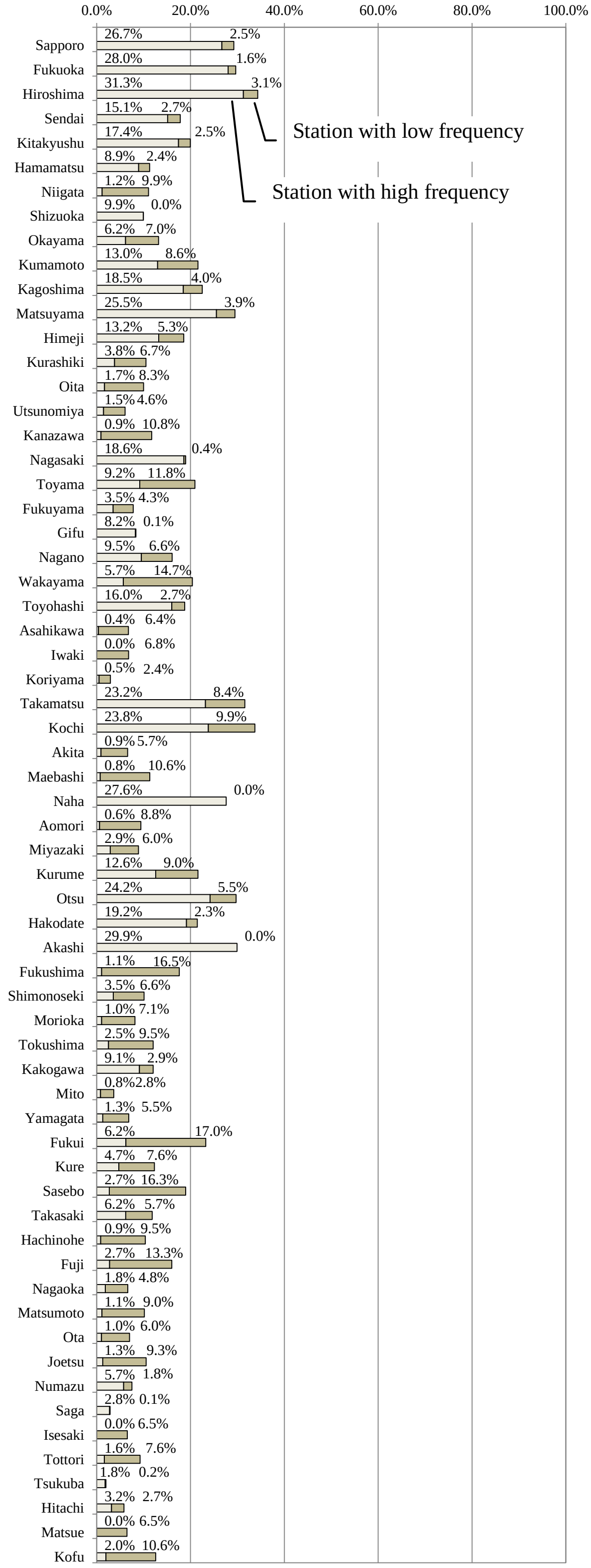

Figure 7.1(1) Ratio of the population of the surrounding area within a radius 500 meters from railway and tramway stations accounting for the population of each city (Japan)

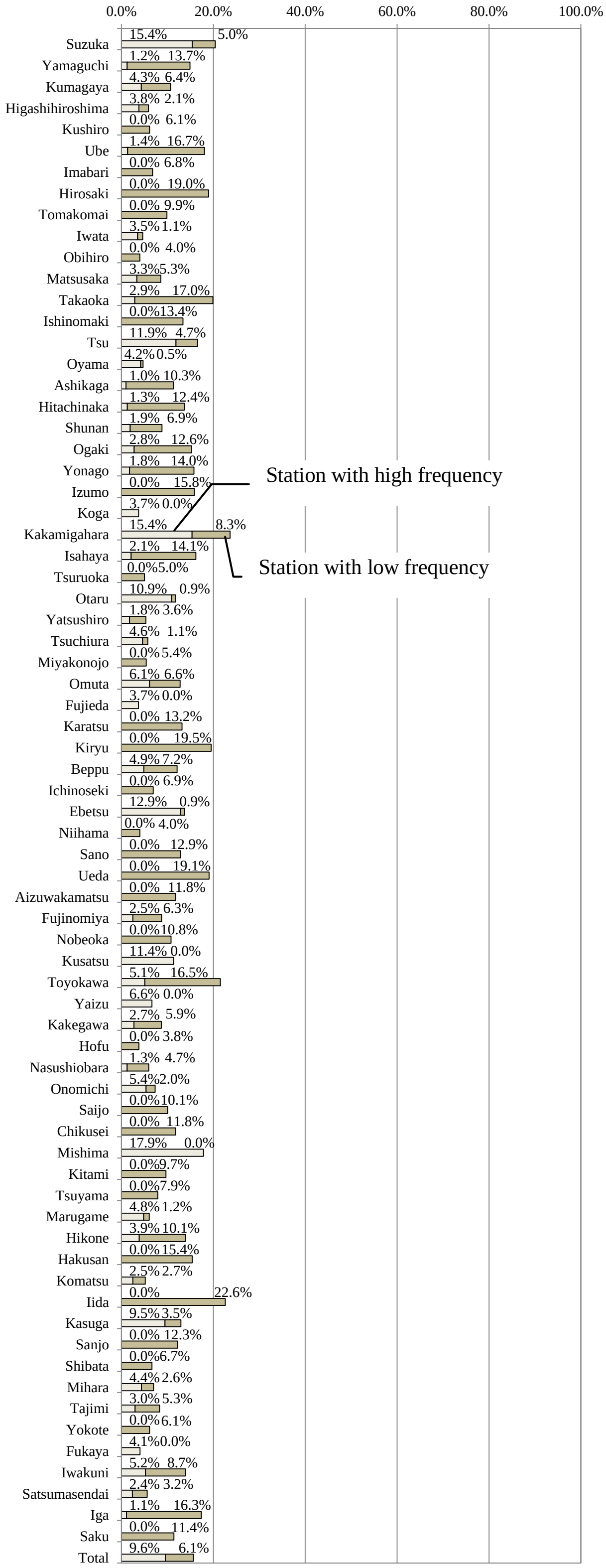

Figure 7.1(2) Ratio of the population of the surrounding area within a radius 500 meters from railway and tramway stations accounting for the population of each city (Japan)

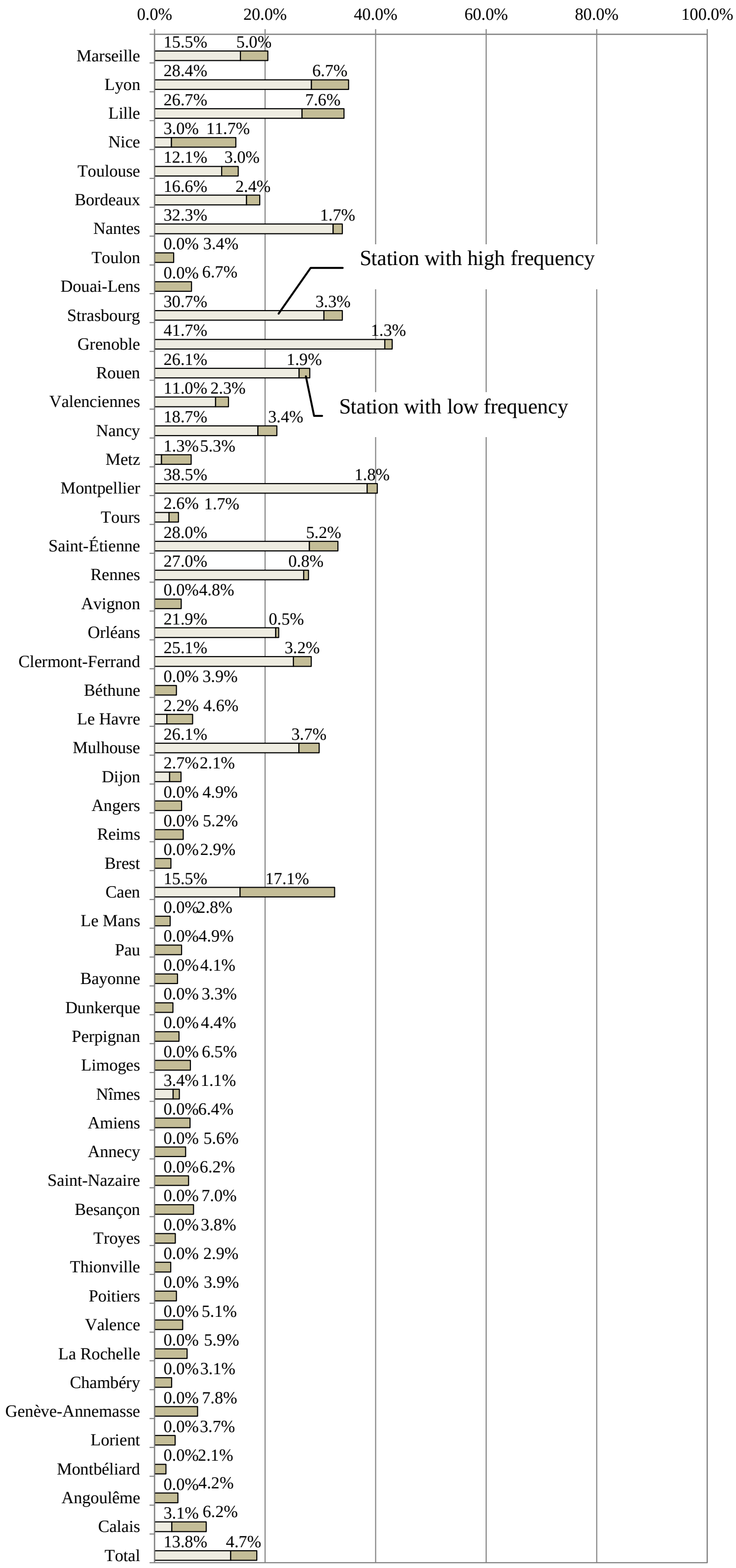

Figure 7.2 Ratio of the population of the surrounding area within a radius 500 meters from railway and tramway stations accounting for the population of each city (France)

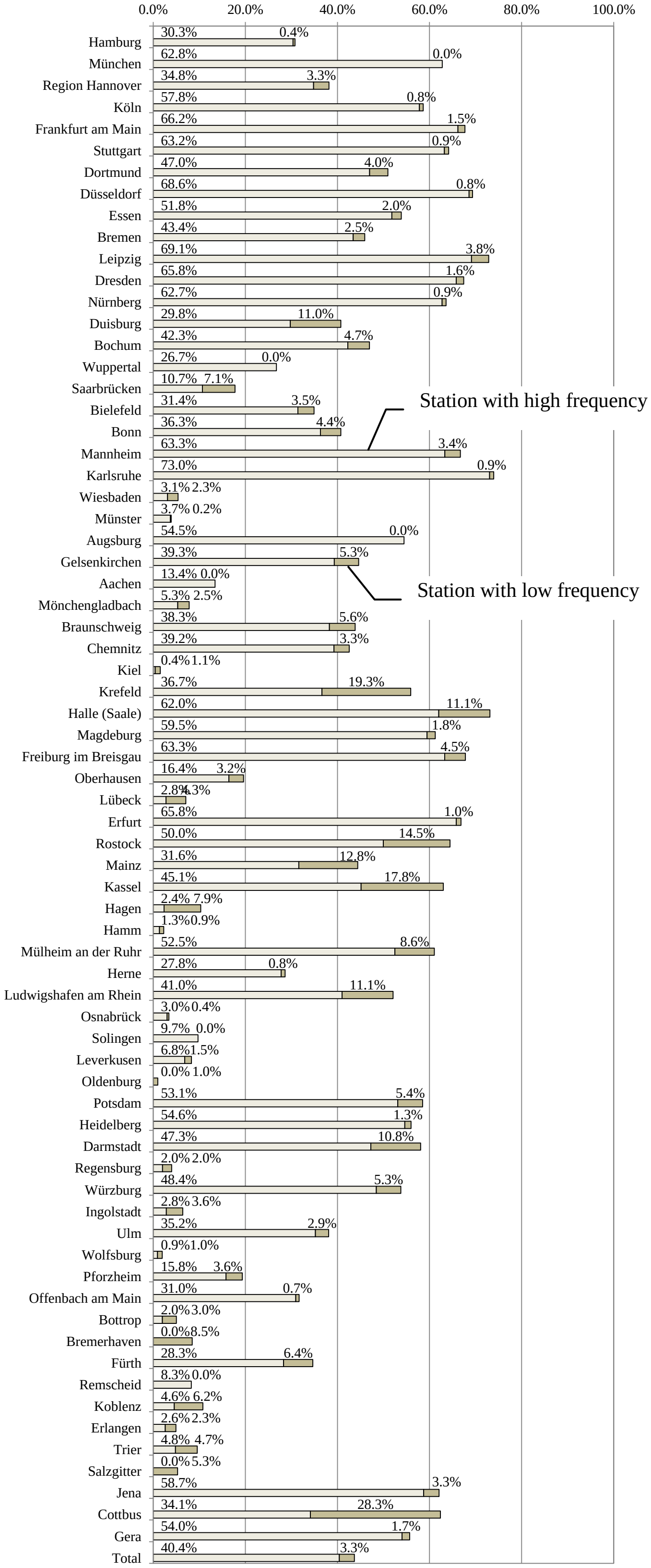

Figure 7.3 Ratio of the population of the surrounding area within a radius 500 meters from railway and tramway stations accounting for the population of each city (Germany)

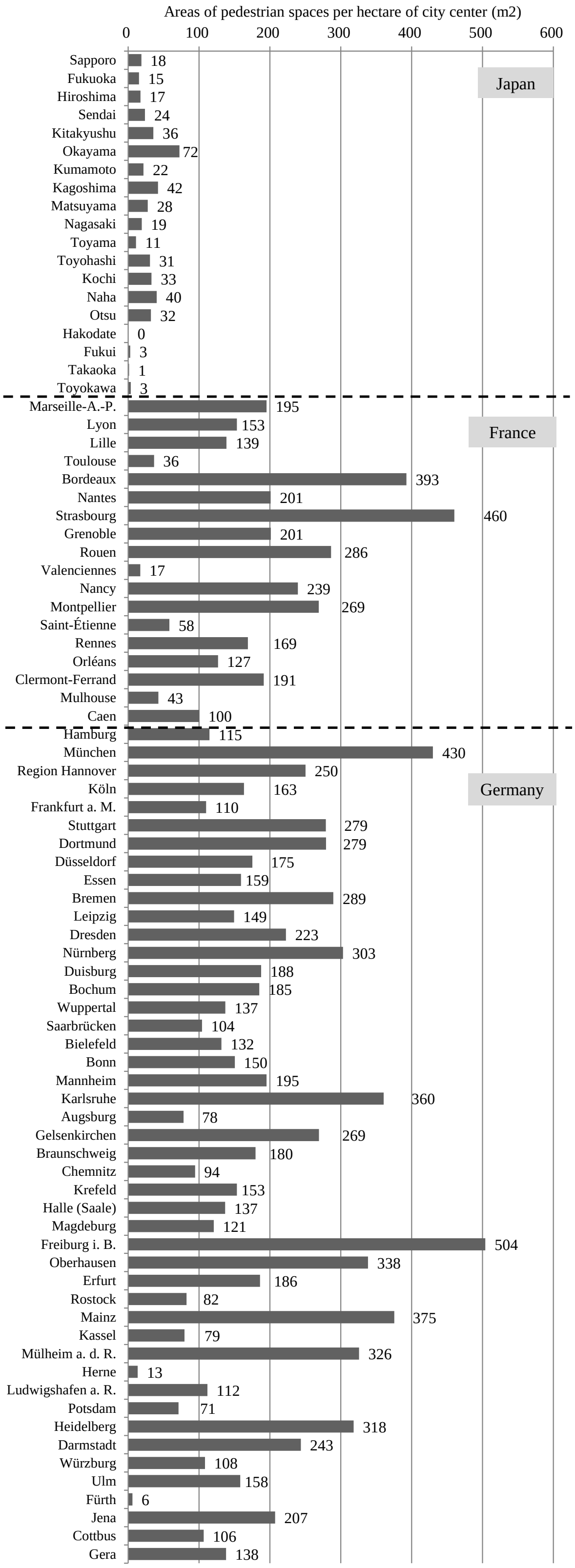

Figure 8 Areas of pedestrian spaces per hectare of city center

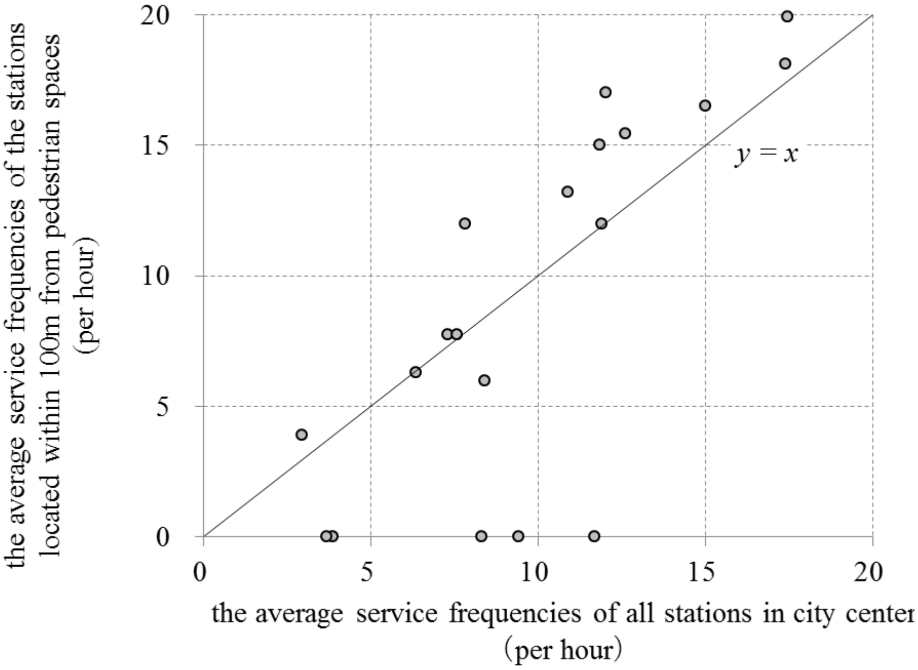

Figure 9.1 Relationship between the average service frequencies of all stations in city center and the average service frequencies of the stations located within 100m from pedestrian spaces (Japan)

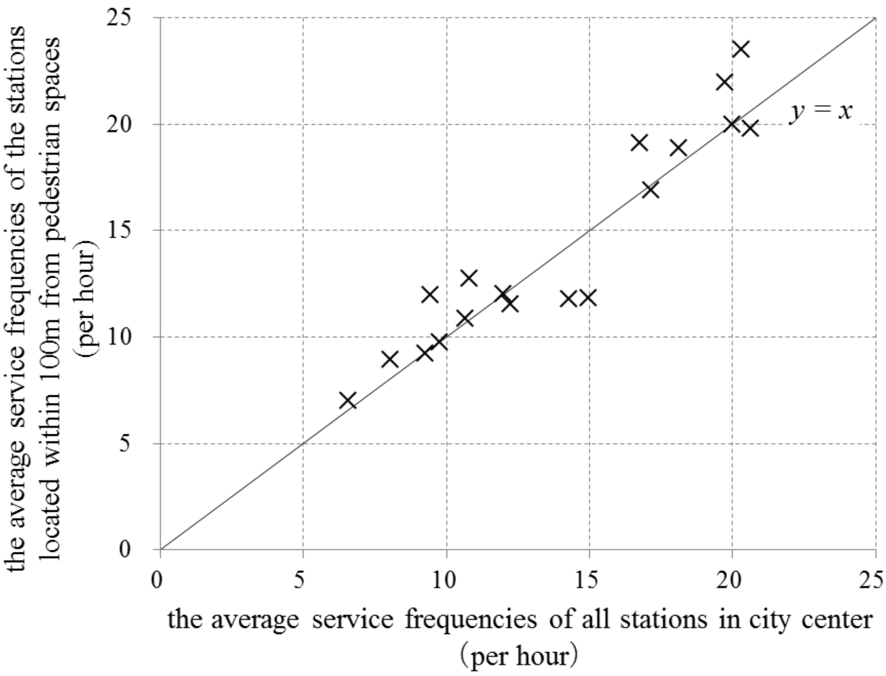

Figure 9.2 Relationship between the average service frequencies of all stations in city center and the average service frequencies of the stations located within 100m from pedestrian spaces (France)

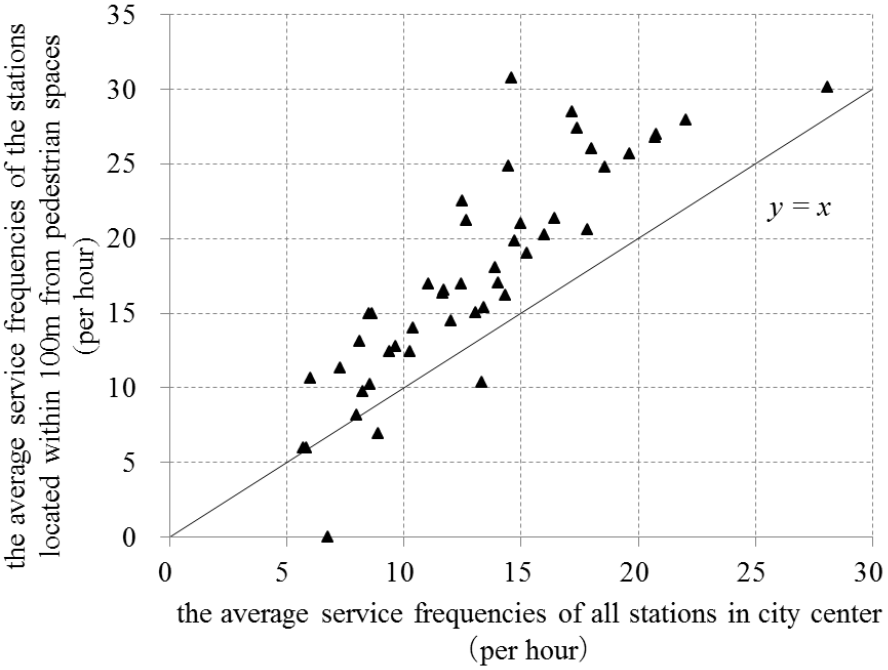

Figure 9.3 Relationship between the average service frequencies of all stations in city center and the average service frequencies of the stations located within 100m from pedestrian spaces (Germany)