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ANALYSIS ON THE STRUCTURAL CHARACTERISTICS OF THE STATION CATCHMENT AREA IN JAPAN

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ABSTRACT

This paper analyses the structural characteristics of station catchment areas in Japan. For the case study, the authors selected a corridor through which three railway companies have parallel operations. The station catchment area is calculated for each mode of transportation. The relationships between the size of the station catchment area and the station type and interval are analysed. The major findings match the authors' predictions: 1) the station catchment areas for each transportation mode differ in size. In descending order of size, these are car, bus, two-wheels, and walking; 2) the larger the station interval, the larger the station catchment area; 3) stations at which express trains stop tend to have larger station catchment areas. A direction for further research is also suggested.

INTRODUCTION

The decision to locate a station in a particular area takes into consideration two viewpoints: the user viewpoint and the operational viewpoint. From the operational viewpoint, the problem is how to determine the station intervals. Equal station intervals provide operational efficiency, with longer intervals allowing higher speeds between stations. The optimal locations of express stations can be determined rationally from the frequency of train runs and the station intervals. From the user viewpoint, however, shorter station intervals provide greater convenience, and station intervals should be determined by urban development along the railway. Of course, the user viewpoint affects the number of users. Since one of the aims of public transportation is to efficiently transport as many passengers as possible, rail lines must consider not only operational convenience but also user benefit. Thus, their objective is to maximise the number of users and minimise the total travel time. (Takeuchi, 2000)

The location of a station determines the station's catchment area, which is a key term in this study. Takeuchi (2000) defines a station catchment area as the area that generates the traffic that uses the station's public transportation systems, such as rail. When the surrounding area and the transport network are uniform, the station catchment area is a circle with the station at its centre. Therefore, a station catchment area can be discussed in terms of its radius. Factors affecting the radius of the station catchment area are the type of station (express station, local station, etc.) and the terminal transport mode (bus, car, two-wheels, and walking). Sumi *et al*. (1984) defined the station catchment area as the area in which the people who routinely use a station are distributed. A railway operator forecasts demand by multiplying the population in the station catchment area by the railway usage ratio, and then calculating the number of users of the station. The size of the station catchment area, therefore, affects the number of users, so the station catchment area concept is basic to railway planning. In this paper, the station catchment area concept is used to determine the distances that people travel to use a station.

In practice, the station catchment area varies because the surrounding area is not uniform. The Department of Civil Engineering for Aichi Prefecture (1984) in Japan used the station catchment area concept to construct the Tokadai line, a new rail transportation system. In built-up areas, the station catchment area around each station has a radius of 500 m, while in newly developing areas, the station catchment area has a radius of 1,000 m.

As is well known, Japan's railway system is unique. Many private companies operate railways, most of which are self-financed, so the number of passengers is crucial from a financial viewpoint. One strategy of the railway companies is to attract people to work or reside in the station catchment area. For that purpose, rail companies sometimes diversify into the real estate business. They also may construct new stations or change a station's type. Private companies in urban areas often compete against each other. In order to transport as many passengers as possible, railway companies must understand the station catchment area concept, since a station's users are the population residing or working in the station catchment area.

This paper analyses the structural characteristics of station catchment areas in Japan. For the case study, the authors chose a corridor in which three railway companies have parallel operations. The station catchment area is calculated for each transport mode. The relationships between the size of the station catchment area, the station type, and the station interval are analysed.

DATA AND STUDY AREA

The data used in the study was collected in the Osaka metropolitan area of Japan (TKK, 2008). The database originally contained data on all 1,279 stations in the metropolitan area and consisted of basic station data, travel behaviour data, and statistical data. The basic station data covers express stations, station facilities, and so on. Some of this data came from the "Tetsudoueki to Machi Iinkai" [Railway Stations and Towns Committee], but data for only 330 of the 1,279 stations was available. The travel behaviour data is based mainly on a household travel survey conducted in 2000 in the metropolitan area and includes the number of users per day, terminal mode characteristics, and so on. The terminal mode characteristics include the terminal travel time by bus, car, two-wheels, and walking. The statistical data includes the number of residents, number of retail stores and so on, around a station. This statistical data is not used in this study.

The Osaka metropolitan area is the second largest metropolitan area in Japan, with about 19 million residents. The area contains three main cities: Kyoto, Osaka, and Kobe. This study focuses on the Osaka–Kobe corridor, which has some interesting characteristics, including three major rail lines: JR (former Japanese National Railways), Hankyu, and Hanshin. The study area is depicted in Figure 1. Osaka Bay forms the southern border of the corridor, while Rokko Mountain forms the northern border. These natural features create a narrow corridor that is densely populated. The stations in this study are located along the three rail lines running through the corridor between Osaka (Umeda) stations (in Osaka) and Sannomiya stations (in Kobe). Many factories are located along the Hanshin line, while upper-income housing is located along the Hankyu line. The JR line has a mixture of these two characteristics. Because of the close proximity of the three parallel rail lines, the residents in this corridor may have three (or more) stations on separate lines to choose from. This choice offers interesting insights.

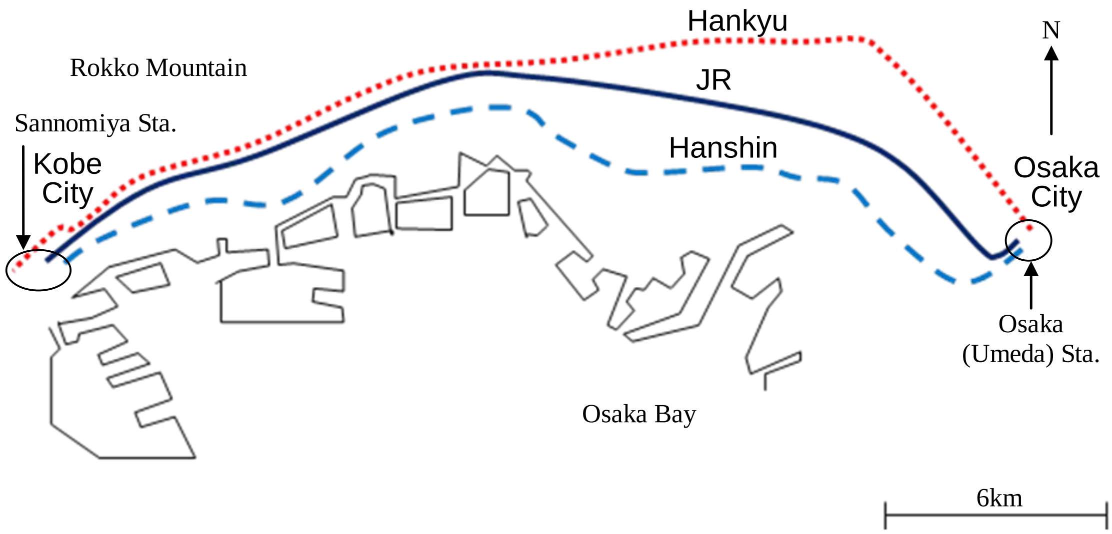

Figure 1: Study area

While the three lines are almost parallel, the level of service varies. Many types (more than two types) of trains are in operation, so there are many types of stations. For analytical convenience, the stations are divided into two categories: express stations and local stations.[1]

Table 1 shows that, because the three lines operate in the same corridor, they have very similar lengths. However, each line has a very different number of stations. Hanshin has the greatest number of stations, followed by Hankyu, and then JR. Accordingly, the average distances between stations also differ greatly for the three lines. The three lines

[1] Express train (station) in this study indicates a rapid service train (station) for JR and a limited express train (station) for Hankyu and Hanshin.

have almost identical numbers of express stations: 6 for JR, and 5 for Hankyu and Hanshin. JR, Hankyu, and Hanshin express trains between Osaka (Umeda) and Sannomiya take 26, 28, and 30 minutes, respectively. These times differ little because the express trains for all three lines stop at a similar number of express stations. However, the times required by local trains are 35, 40, and 55 minutes for JR, Hankyu, and Hanshin respectively, reflecting the number of stations on each line. JR has a much faster express train that covers the distance between Osaka and Sannomiya in 20 minutes. For the sake of simplicity, however, this train is not put into a special category.[2] Each of the lines offers more than 500 service runs per day, or more than ten service runs per hour in each direction, which is adequate.

Table 1: Level of service between Osaka (Umeda) and Sannomiya

	Length (km)	Number of stations [a]	Time required (min.) [b]	Average distance between stations (km) [c]	Service runs (per day) [d]
JR	30.6	13 (6)	35 (26)	2.55	654
Hankyu	32.3	16 (5)	40 (28)	2.15	510
Hanshin	31.2	33 (5)	55 (30)	0.98	529

a: Total number of stations are shown outside parentheses; number of stations where express trains stop are shown inside parentheses.
b: Time required by local trains is shown outside the parentheses; time required by express trains is shown inside the parentheses.
c: Length in km divided by the total number of stations minus one.
d: Number of trains at Sannomiya stations (basic station data from TKK (2008)).

ANALYSIS

Station Catchment Area

Terminal mode information in the travel behaviour data is used to calculate the size of the station catchment area. Since each transport mode has terminal mode information for the trip time, the trip time data is converted to trip length data. (For example, the number of passengers that travel to the station on foot for 1–5 minutes is known.) To convert the data, the average speed of a bus, car, two-wheels, and walking is assumed to be 10 km/h, 20 km/h, 10 km/h, and 4 km/h, respectively. The 90th percentile of the trip length is used to define the station catchment area; when the station catchment area is 5 km, 90% of the passengers have an access/egress distance of 5 km or less. There is no good reason to use the 90th percentile of the trip length, but the analysis requires one index for the size of the station catchment area. For comparative purposes, the correlation between the 90th and 50th percentiles of the trip length was calculated for the size of station catchment area of all transport modes. The result was 0.66. Sensitivity analysis may be needed when other percentiles are used.

Basic Analysis

The station catchment area is calculated for the terminal modes of bus, car, two-wheels, and walking, as well as for all modes combined (Table 2). For bus, car, and all modes

[2] This much faster express train is called the special rapid service.

combined, JR has the largest station catchment area (due to its significantly fewer stations and much longer interval), followed by Hankyu and Hanshin. Demographic characteristics also affect the size of the station catchment area, since the mountains to the north restrict Hankyu’s station catchment areas and the sea to the south restricts Hanshin’s. For two-wheels, JR and Hankyu have nearly identical station catchment area sizes, while Hanshin’s are similar in size. For walking, JR and Hankyu have identical station catchment area sizes, while Hanshin’s is slightly smaller. For two-wheels and walking, passengers seem unwilling to travel more than a certain distance, so the station catchment areas are relatively similar in size. However, Hanshin’s smaller station catchment area for walking may be due to the line’s shorter station intervals. Generally, the sizes of the station catchment area are, in descending order, car, bus, two-wheels, and walking, as expected.

Table 2: Station catchment areas (km)

		All modes	Bus	Car	Two-wheels	Walking
JR	Average	2.73	5.35	7.88	2.98	1.27
	N	13	13	13	13	13
Hankyu	Average	2.51	4.64	7.19	3.02	1.27
	N	16	15	16	16	16
Hanshin	Average	1.73	4.58	6.39	2.80	1.09
	N	33	25	21	29	33
All	Average	2.14	4.79	7.03	2.90	1.17
	N	62	53	50	58	62

N: Number of stations
Some stations do not have some terminal modes, such as bus, car, or two-wheels, and the number of stations differs.

Regression Analysis

For the regression analyses, the dependent variable is the station catchment area, defined as the 90th percentile of the trip length. The explanatory variables include a constant, the stopping dummies for JR and Hankyu express and local trains, Hanshin express train, and the distance to the next station. (Note: The stopping dummies for JR express and local trains are unities for JR express stations since both trains stop at express stations. This is also true for the Hankyu line.) Note that this study divides the stations into six categories and does not include the stopping dummy for the Hanshin local train. The explanation of the explanatory variables is shown in Table 3.

Table 3: Explanation of explanatory variables

Explanatory variables	Explanation
JR express train stopping dummy	1: JR express stations; 0: otherwise
JR local train stopping dummy	1: JR express and local stations; 0: otherwise
Hankyu express train stopping dummy	1: Hankyu express stations; 0: otherwise
Hankyu local train stopping dummy	1: Hankyu express and local stations; 0: otherwise
Hanshin express train stopping dummy	1: Hanshin express stations; 0: otherwise
Distance to the next station (km)	The average distance to the next station in both directions for the intermediate stations and the distance to the next station for the terminal stations (Osaka (Umeda) and Sannomiya)

The regression analysis results are shown in Table 4.[3] For the bus model, Rbar-squared is very low, which suggests that the model does not describe the station catchment area very well and further analysis is required. Except for the bus model, the distance to the next station is a positive estimate; the farther the next station, the larger the station catchment area. For the bus model, negative estimate for distance to the next station must be very carefully analysed. Based on the positive estimates for the JR, Hankyu, and Hanshin express train stopping dummies, stations where express trains stop tend to have larger station catchment areas. For the car model, this can be due to the faster speeds of express trains. For the two-wheel model, it can be due to express stations having more parking spaces. The smaller magnitude of the estimates for the walking model suggests that express stations do little to increase the size of the station catchment area. For the car and two-wheel models, the longer distance to the next JR or Hankyu station compensate for the negative estimates for the stopping dummies for JR and Hankyu local trains. For the walking model, most of the dummy variables are less significant, suggesting that walking behaviour is not affected by station type.

Table 4: Regression results

Explanatory variables	All modes	Bus	Car	Two-wheels	Walking
	Coef. (*t*-stat.)	Coef. (*t*-stat.)	Coef. (*t*-stat.)	Coef. (*t*-stat.)	Coef. (*t*-stat.)
Constant	1.18 (4.69)**	4.49 (6.76)**	4.39 (4.09)**	2.43 (8.01)**	1.02 (16.86)**
JR express train stopping dummy	0.461 (1.05)	0.192 (0.19)	4.19 (2.61)**	0.885 (1.75)*	0.00477 (0.05)
JR local train stopping dummy	0.318 (0.70)	1.59 (1.45)	-1.28 (-0.74)	-0.171 (-0.33)	0.118 (1.08)
Hankyu express train stopping dummy	0.117 (0.27)	1.80 (1.75)*	5.65 (3.60)**	1.10 (2.23)**	0.0577 (0.56)
Hankyu local train stopping dummy	0.458 (1.22)	0.229 (0.24)	-1.28 (-0.88)	-0.00754 (-0.02)	0.127 (1.40)
Hanshin express train stopping dummy	1.04 (2.75)**	2.07 (2.25)**	3.68 (2.51)**	1.83 (3.76)**	0.0948 (1.04)
Distance to the next station (km)	0.395 (1.90)*	-0.320 (-0.63)	1.10 (1.41)	0.123 (0.51)	0.0486 (0.97)
N	62	53	50	58	62
R-squared	0.374	0.189	0.410	0.312	0.236
Rbar-squared	0.305	0.084	0.328	0.231	0.153

Some stations do not have some terminal modes, such as bus, car, or two-wheels, and the number of stations differs.
*: Significant at 10% level; **: Significant at 5% level.

[3] For all modes model, the following interpretation is available:

- Hanshin local stations do not have a dummy variable. The station catchment area is 1.18 + 0.395 * (distance to the next station (km))
- For Hanshin express stations, the station catchment area is 1.18 + 1.04 + 0.395 * (distance to the next station (km))
- For Hankyu local stations, the station catchment area is 1.18 + 0.458 + 0.395 * (distance to the next station (km))
- For Hankyu express stations, the station catchment area is 1.18 + 0.458 + 0.117 + 0.395 * (distance to the next station (km))
- For JR local stations, the station catchment area is 1.18 + 0.318 + 0.395 * (distance to the next station (km))
- For JR express stations, the station catchment area is 1.18 + 0.318 + 0.461 + 0.395 * (distance to the next station (km))

CONCLUSIONS AND DISCUSSIONS

This study analysed the structural characteristics of station catchment areas in Japan. Because private railway companies in Japan compete against each other, the authors selected as a case study the Osaka-Kobe corridor, where three railway companies have parallel operations. The station catchment area is calculated for each transport mode. The relationships between the size of the station catchment area and the station type and interval are analysed.

In this study, the station catchment area is calculated from converted travel time data for the terminal mode. Since travel time information is available for each transport mode, the station catchment area is calculated for each transport mode as well as for all transport modes combined. The authors adopted the 90th percentile of the trip length as the index for the station catchment area.

A basic analysis produced the following findings. For bus, car, and all modes combined, JR had the largest station catchment areas, followed by Hankyu and then Hanshin. The number of stations and the demographic characteristics affect the size of a station catchment area. For two-wheels and walking, there seems to be a limit to the distance people will travel by these modes to access the stations. In the case of Hanshin and the walking mode, however, the limit may be affected by the smaller station catchment area resulting from the shorter station interval. Generally, the sizes of the station catchment areas are, in descending order, car, bus, two-wheels, and walking, as expected.

A regression analysis produced the following findings. For the bus model, Rbar-squared is very low, which suggests that the model does not describe the station catchment area very well. Except for the bus model, the farther the next station, the larger the station catchment area. Stations where express trains stop tend to have larger station catchment areas. Walking behaviour is not affected by the station type.

Although some findings were obtained about the relationships between the size of station catchment area and certain station characteristics, a direction for further research is suggested. Statistical data was obtained about the station's surroundings, such as the numbers of residents and retail stores. An analysis of the station catchment area and this statistical data has not been done. Regression analysis showed that the size of a station catchment area could be estimated for a new station. This study was conducted in an area where three railway companies compete against each other; comparing these results with those for an area with a single line would have some research value.

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