Study on Evaluation of Convenience of Access to the Nearest Railway Station by Residents in Housing Development Areas in the Suburbs of Kobe City in Japan - Using Utility-Based Accessibility Measures

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Abstract: This study aims to measure and evaluate convenience of access by residents to the nearest railway station in housing development areas in the suburbs. Mode choice model for access to the nearest railway station is built employing random utility theory in order to measure accessibility to the station. The results show that accessibility decreases as travel distance to the nearest railway station increases; however, even if the distance to the station is the same, the level of accessibility could be different because of differences in the slopes of routes to the station, or the number of buses in neighborhood districts within each development area. Travel modes needed to maintain accessibility to the nearest railway station, therefore, differ among the districts. It is necessary to increase the level not only of accessibility but also of railway service of the nearest railway station so that residents could utilize railway more frequently.

Keywords: Utility-based Accessibility Measures, Mode Choice Model, The Nearest Railway Station, Housing Development Areas in the Suburbs, Person Trip Survey

1. INTRODUCTION

In Japan, since the 1960’s many housing developments have taken place in the suburbs of large cities. These housing development areas were commonly found adjacent to railway stations so that residents could have easy access to the city centers. However, with the advent of a more motorized society, increases in residents’ car use have resulted in the reduction or abolition of bus services to the nearest railway station. The slopes of routes to the nearest railway station also caused quite a burden on residents approaching on foot or by bicycle because many of those development areas are located on hilly land. As a result, accessibility to the nearest railway station rapidly decreased. On the other hand, Japan is facing a rapidly aging society, and it is difficult for elderly residents who may not use cars to gain access to the city centers.

Under these circumstances, in order to improve accessibility to the nearest railway station, especially for elderly people, it is first necessary to measure and evaluate residents’ current accessibility in housing development areas accurately.

Various accessibility measures have been used to evaluate transportation or land-use policies in the past (Geurs and Wee, 2004; Handy and Niemeier, 1997). Handy and Niemeier (1997) shows that these accessibility measures can be classified into the following three types: One, “cumulative opportunities measures” count the number of opportunities (e.g. retail stores, hospitals) reached within a given travel time or cost. Two, “gravity-based
measures”, introduced by Hansen (1959), weighs the opportunities by travel impedance such as time or cost. Three, “utility-based measures” founded on random utility theory, can be defined as logsum, derived from choice behavior model such as multinomial logit model or nested logit model (Ben-Akiva and Lerman, 1985).

In earlier researches, accessibility to railway stations has been measured mainly based on walking distance (e.g. Currie, 2010; El-Geneidy et al., 2014; Lin et al., 2014) or time (e.g. Mavoa et al., 2012; TfL, 2010; Yigitcanlar et al., 2008). Recently, Kizawa and Takami (2008) and Kita et al. (2012) proposed accessibility measures to public transit stops by both walking and bicycle, and taking into consideration the slopes of routes to those stops.

However, in order to measure and evaluate accessibility to railway stations accurately, it is necessary to take into account the slopes of routes and level of bus services to the railway stations, in addition to walking distance and time, as factors defining accessibility. Although cumulative opportunities and gravity-based measures are the simplest to calculate, it is difficult to reflect the influence of individual or household attributes, level of services of travel modes, and geographical features. On the other hand, utility-based measures can express the influence of the above factors (Curl, et al., 2011; Geurs and Wee, 2004; Handy and Niemeier, 1997). Transportation and land-use policies have been evaluated using utility-based measures on many past researches (e.g. Bowman and Ben-Akiva, 2000; Geurs et al., 2010; Niemeier, 1997).

This study aims to measure and evaluate convenience of access by residents to the nearest railway station in housing development areas in the suburbs of Kobe City, based on person trip survey data.

Comparing the past researches on accessibility to railway stations, this study has the following features; utility-based accessibility measures, which have theoretical and empirical advantages, are employed. Every available travel mode for an individual is taken into account in measuring accessibility, not only walking or bicycle but also bus or car, as access modes to the railway stations. Then, in addition to traditional travel distance or travel time, some other factors, such as the slopes of travel routes and the level of bus service to the stations, are incorporated into accessibility measures. The result of this study will contribute to evaluation of current accessibility to the nearest railway station and also to prediction of improvement in accessibility brought by some transportation policies.

In this study, a mode choice model of residents in accessing the nearest railway station is first built using multinomial logit model, introducing the above choice factors. Secondly, accessibility to the station is measured, which is defined as logsum derived from the mode choice model. Thirdly, contribution of each travel mode on the accessibility of neighborhood districts is analyzed in whole study area. Then spatial distribution of the calculation results is also drawn in one of the largest development areas of the study area on the map so as to find out districts with low levels of accessibility. Finally, the authors clarify the influence of accessibility to the nearest railway station on the probability of choosing the railway.

2. OUTLINE OF STUDY AREA AND DATA USED IN THE STUDY

2.1 Study Area

Kobe city is the leading city in housing development in suburban areas in Japan and its total number of development areas reached to 51 areas (in kita-ku and nishi-ku of Kobe city). Figure 1 shows the map of the study area: 37 housing development areas adjacent to railway stations in the suburbs of Kobe City. The size of these housing development areas ranges from
0.1 to 5.8 km² and the populations from 500 to 50,000 people.

In the study area, four railway lines are operated by two railway companies, and the total number of railway stations is 29. The number of trains on each line ranges from 80 to 170 trains per day. Bus services are operated by five companies and connect housing areas to the nearest or other nearby railway stations (some bus services provide direct connections to the city center). The number of buses serving stop in housing areas to the railway stations ranges 10 to 120 buses per day, showing a great difference among housing areas.

Figure 1. Map of housing development areas in the suburbs of Kobe City, Japan

2.2 Data Used

In this study, the results of the person trip survey of 2010 were used (Keihanshin Metropolitan Area Transport Planning Council, 2010). Of this data, we used home based trip data of respondents living in the study area. The total number of trips is 9,238, and each trip shows the movement between two postal code zones or inside a zone (in most cases, each zone includes a number of neighborhood districts).

The number of trips to access railway stations is 2,420. Figure 2 shows the percentage of respondents using travel modes to access railway stations. Walking is, by far, the highest, 60.2%, followed by bus 20.1%, bicycle and car.

Figure 3 represents the percentage which those using the nearest railway station account for of all railway users. In this study, the nearest railway station is defined as the one which has the shortest distance from each neighborhood district. From this figure, it is found that 83.5% of railway users choose the nearest railway station among alternative railway stations. The nearest railway station plays an important role for railway users. Therefore, the authors focus on the nearest station, and evaluate and measure accessibility to it.
3. CONSTRUCTION OF MODE CHOICE MODEL FOR ACCESS TO THE NEAREST RAILWAY STATION

3.1 Outline of Mode Choice Model

In this study, a mode choice model for access to the nearest railway station is built using multinomial logit model in order to calculate the accessibility measure to the station.

The choice set of travel modes are walking, bicycle, bus and car. Motorcycle is excluded from the choice set since only a few respondents use it as shown in Figure 2. As for the availability of each alternative travel mode for individuals, walking is given for all respondents. Bicycle and car are given for respondents who own at least one respectively in each household. Bus is given for respondents living in districts where bus stops serving bus routes to the nearest railway station are located.

Trips by respondents who satisfy the following two requirements are selected for model

Figure 2. Percentage of respondents using travel modes for access to railway stations

Figure 3. Percentage of respondents using the nearest railway station
estimation from 2,420 trips mentioned above: 1) using railway via the nearest railway station, and 2) having a choice set containing two or more alternatives access modes to the station. As a result, total number of trips for the estimation was 1,430.

As for explanatory variables, travel distance to the nearest railway station is used as specific variable for three travel modes, walking, bicycle and car. (Travel distance is not used as a specific variable for bus since the sign of estimated parameter is not reasonable.) The slope of route to the nearest railway station is used as specific variable for walking and bicycle. Travel distance to bus stop and the number of buses serving a stop per day are used as specific variable for bus.

### 3.2 Estimation Result

Table 1 summarizes the estimation result. This model has relatively good overall convergence as the adjusted likelihood ratio is 0.21 (Domencich and McFadden, 1975). Signs of all estimated parameters are plausible, and significance of other parameters, except those of distance to the nearest railway station by bicycle and car, are 1 %.

The estimation result demonstrates that the utility of each travel mode (walking, bicycle and car) decreases as travel distance to the nearest railway station increases. In particular, the respondents feel walking impeded by travel distance. Then, as the slope of route to the nearest railway station increases, the utility of walking or bicycle decreases, and the slope strongly affects the utility of walking since the absolute value of the parameter of walking is higher than that of bicycle.

The parameter of travel distance to bus stop and the number of buses per day represent negative and positive signs respectively. Therefore, the utility of bus increases as travel distance decreases and the number of buses increases.

<table>
<thead>
<tr>
<th>Estimated parameter</th>
<th>Estimated parameter</th>
<th>$t$ statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel distance [walking]</td>
<td>-1.541</td>
<td>-7.33 **</td>
</tr>
<tr>
<td>Travel distance [bicycle]</td>
<td>-0.366</td>
<td>-1.77</td>
</tr>
<tr>
<td>Travel distance [car]</td>
<td>-0.326</td>
<td>-1.39</td>
</tr>
<tr>
<td>$Ln$ (slope of route) [walking]</td>
<td>-0.954</td>
<td>-15.19 **</td>
</tr>
<tr>
<td>$Ln$ (slope of route) [bicycle]</td>
<td>-0.355</td>
<td>-5.17 **</td>
</tr>
<tr>
<td>Travel distance to bus stop [bus]</td>
<td>-4.689</td>
<td>-4.74 **</td>
</tr>
<tr>
<td>Number of buses serving a stop per day [bus]</td>
<td>2.333</td>
<td>4.49 **</td>
</tr>
<tr>
<td>N</td>
<td>1,430</td>
<td></td>
</tr>
<tr>
<td>Adjusted likelihood ratio</td>
<td>0.21</td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1 % level

a) $Ln$ denotes natural logarithm.
4. CONTRIBUTION OF EACH TRAVEL MODE TO ACCESSIBILITY TO THE NEAREST RAILWAY STATION

4.1 Relationship between Travel Distance and Accessibility to the Nearest Railway Station

As mentioned before, accessibility can be defined as the logarithm of the denominator of the multinomial logit model, known as the logsum (Ben-Akiva and Lerman, 1985). Accessibility for an individual $n$, $ACC_n$ can be written as

$$ACC_n = \ln \left( \sum_{j \in J_n} \exp \left( V_{jn} \right) \right)$$

where $V_{jn}$ is the systematic component of the utility of alternative $j$ and $J_n$ denotes choice set for individual $n$.

In this study, by calculating the logsum derived from the mode choice model in section 3, accessibility to the nearest railway station is measured in the study area. The estimation of model parameters is based on trip data between postal codes zones, but the authors calculate accessibility for every neighborhood district included in each postal code zone in the study area.

Figure 4 shows the calculation result of accessibility for each neighborhood district when all available travel modes (walking, bicycle, car and bus) for each respondent can be used. In this figure, accessibilities of all neighborhood districts are plotted on the graph, with letting level of accessibility be the vertical axis, and distance to the nearest railway station the horizontal axis.

From this figure, the level of accessibility decreases as distance to the nearest railway station increases. Even if the distance to the station is the same, the deviation of accessibility level becomes larger because of differences in the slopes of routes to the railway stations or the level of bus services among districts.

![Figure 4. Level of accessibility by travel distance with all available travel modes](image-url)
4.2 Contribution of Each Travel Mode to Accessibility by Travel Distance

In this study, accessibility in each district is calculated when one of available travel modes could not be used (without-case), and compared these results with accessibility when all available travel modes (walking, bicycle, car and bus) can be used (with-case) (calculation results in previous section 4.1). The difference between the two calculation cases is assumed to represent the degree to which each travel mode contributes to accessibility to the nearest railway station.

Figure 5 a), b) and c) show the decreases in accessibility for each district by travel distance from each district to the nearest railway station when one of the three available travel modes, bicycle, car or bus, cannot be used ($V_{jn}=0$ in Eq.1; $j$=bicycle, car or bus). From this, in all three conditions, decreases in the level of accessibility and their deviations become larger as distance to the nearest railway station increases. Comparing the three travel modes, decreases in the level of accessibility and its deviations are larger when bicycle or bus cannot be used. On the other hand, at any distance, decreases in the level of accessibility when car cannot be used are smaller than for bicycle or bus. Therefore, it is surmised that car does not contribute much to accessibility to the nearest railway station.

![Decreases in accessibility](image)

Figure 5. Decreases in the level of accessibility by travel distance without one of available travel modes

4.3 Spatial Distribution of Accessibility to the Nearest Railway Station

Figure 6 represents the spatial distribution of the level of accessibility (with-case) in the Seishin Chuo area, which is one of the largest development areas in the study area. This area is 5.84 km², and has a population of 49,000. A railway station is located in the center of the area, and all bus routes within this area are connected to this railway station. The slopes
within this development area are relatively gentle, compared with other development areas. From this figure, it can be seen that the level of accessibility proportionally decreases as distance increases from the railway station.

Figure 7 a), b) and c) show the spatial distribution of the decrease in the level of accessibility when one of the available travel modes, bicycle, car or bus, could not be used respectively (without-case). From this, the following can be shown.

In both the case of bicycle and bus, the decrease in the level of accessibility increases as distance to the railway station increases. However, the contribution of each travel mode on accessibility is different depending on the district. For instance, in district X shown in figure 7, bicycle plays an important role in reaching to the railway station since the level of bus service is relatively lower than in other districts. For this reason, accessibility is greatly decreased when a bicycle cannot be used. Since the level of bus service in districts Y and Z is higher than in other districts, accessibility in these districts greatly decreases when bus cannot be used.

In case of car, the decrease in accessibility in all districts is equally small. Therefore, in this development area, it is surmised that accessibility in districts far from the railway station is supported by bicycle or bus service.

Figure 6. Spatial distribution of the level of accessibility in Seishin Chuo area with all available travel modes
5. INFLUENCE OF ACCESSIBILITY TO THE NEAREST RAILWAY STATION ON THE PROBABILITY OF CHOOSING RAILWAY

5.1 Analysis of Factors Influencing on the Probability of Choosing Railway

Binary logistic regression model shown in equation (2) is employed to analyze the impact of accessibility to the nearest railway station on the probability of choosing railway.

\[ P(Y = 1) = \frac{1}{1 + e^{-fx}} \]  

where \( P(Y=1) \) is probability of dependent variable \( Y(Y=1 \text{ or } 0) \), \( x \) is a vector of explanatory variable, and \( \beta \) denotes a vector of parameter.

Trips for the analysis in this section are selected from 9,238 trips by all respondents. Respondents who use railway with their trip length less than 5.0km account for only 1.8% of all respondents, then 3,439 trips by respondents who have the possibility of using railway (their trip length is 5.0km or longer than 5.0km) are used for the analysis.

The dependent variable is whether respondents choose railway via the nearest station or not (\( Y=1 \): if choose railway, \( Y=0 \): otherwise). Explanatory variables are the level of accessibility to the nearest railway station (calculated in section 4) and the number of trains serving the nearest railway station per day.

Table 2 represents the estimation result. As shown in this table, both parameters are
significant at 1%, and their signs are positive. The probability of choosing railway via the nearest station increases as the level of accessibility and the number of trains at the station increases.

Figure 8 draws changes in the probability of choosing railway via the nearest station for different level of accessibility and numbers of trains. In this figure, the vertical axis denotes the probability, and the horizontal axis level of accessibility. Actual level of accessibility in the study area ranges from −0.03 to 4.23. From this figure, it can be deduced that it is difficult to maintain a high probability of choosing railway via the nearest station under low levels of accessibility. Therefore, it is necessary to increase both accessibility and the number of trains at the nearest railway station so that residents utilize railway via the nearest station more frequently.

Table 2. Estimation result of logistic regression model

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Standardized coefficient</th>
<th>Wald statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility to the nearest railway station</td>
<td>0.378</td>
<td>0.347</td>
</tr>
<tr>
<td>Number of trains serving the nearest railway station per day</td>
<td>0.015</td>
<td>0.679</td>
</tr>
<tr>
<td>constant</td>
<td>-3.214</td>
<td>573.7 **</td>
</tr>
<tr>
<td>N</td>
<td>3,439</td>
<td></td>
</tr>
<tr>
<td>Chi-square value</td>
<td>611.2</td>
<td></td>
</tr>
</tbody>
</table>

** significant at 1% level

Figure 8. Changes in the probability of choosing railway via the nearest station for different level of accessibility and number of trains
5.2 Relationship between the Level of Accessibility to the Nearest Railway Station and Share of Travel Modes

Figure 9 represents the share of travel modes by the level of accessibility to the nearest railway station. It should be noted that accessibility to the nearest railway station is calculated for all respondents including those not using railway via the nearest railway station. It can be seen that the percentage of using a car, bus and railway via other nearby stations increases as the level of accessibility decreases.

6. CONCLUSION

The main purpose of this study was to evaluated utility-based accessibility to the nearest railway station in suburban housing development areas in Kobe city, Japan. The main findings are as follows.

(1) A mode choice model for access to the nearest railway station was built using multinomial logit model, based on person trip survey data, and the estimation result was reasonable. Then, accessibility to the nearest railway station was measured which is defined as logsum derived from mode choice model. As a result, it was possible to evaluate the accessibility to the nearest railway station, considering not only travel distance, but also other factors such as the slope of route to the railway station and level of bus services to reach the station quantitatively.

(2) Accessibility decreased as travel distance to the nearest railway station increased, however, even if the distance to the railway station was the same, the level of accessibility could be different because of differences in the slopes of routes to the railway station, or the number of buses in the districts. By drawing the spatial distribution of the level of accessibility on the map of one of the development areas in the study area, it was found that travel modes needed to maintain accessibility to the nearest railway station differ among districts. In this particular area, bus service contributed to maintain the level of accessibility in districts more than 1.0 km away from the station.
(3) The probability of choosing railway via the nearest station was explained well by accessibility to the station and the number of trains at the station by employing logistic regression model. The percentage of using a car or other public transportation (bus or railway via other nearby stations) increases as the level of accessibility decreases.

The following points are mentioned as possible avenues of future research based on this study.

(1) Accessibility measure in this study should be applied to predict and examine the effects of policies to improve access to the nearest railway station, such as the introduction of mini-bus services within areas and park or kiss and ride systems at those stations. If measures are applied, the mode choice model of our study needs some modification to take other choice factors, including easiness of approaching the stations by cars or buses, and availability of parking spaces into consideration.

(2) Level of accessibility may differ depending on individual attributes. For instance, it is expected that the elderly tend to feel more impedance to travel distance than the non-elderly. Therefore, it is necessary to measure accessibility for individual groups characterized by some attributes such as age, gender and physical condition.

(3) This study made it possible to measure and evaluate accessibility to the nearest railway station since most users chose the nearest railway. On the other hand, 16.5% of railway users chose other railway station. Possible reasons are as follows: the exit station of other railway is closer to their destination, or level of service of other railway is higher than the nearest railway, etc. Therefore, it is necessary to develop choice model among the nearest railway station and other railway stations considering above factors influencing choice behavior of railway stations and measure accessibility to them.

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