Development of a Method to Evaluate Ease of Intermodal Transfer between Rail and Bus Services Considering the Characteristics of a Station's Surroundings

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This research aims to establish a method for evaluating the convenience of rail to bus transfer routes, focusing on physical and structural characteristics. An online survey was conducted to obtain passenger opinion about rail to bus transfer convenience. With the data obtained, a model was developed to evaluate the convenience in making such transfers, in order to quantify the effect of physical characteristics of transfer routes on such an evaluation. Besides horizontal walking distances, use of stairs, features outside stations, including safety concerns and bus stop structures, were also considered. The developed models were then applied to a sample case to demonstrate how transfer convenience can be evaluated in practice.

Keywords: station, bus, transfer, convenience, evaluation

1. Introduction

Railways are one of the most important transport modes in Japan. For example, rail transport accounts for 30% of as many as 85 million trips within the Tokyo Metropolitan Region, which has a population of around 35 million inhabitants as of 2008 [1]. As concerns grow about the aging of society, energy security and environmental issues, railways should be further enhanced to provide residents and businesses with convenient and efficient transport services.

When taking trains, passengers require other transport modes to access railway stations, such as bikes, cars and so on. In other words, using railway requires transfers. In 2010, two-thirds of railway passengers in Tokyo travelled to railway stations from their homes on foot, followed by bikes, which accounts for nearly one-fifth of total access means [2]. On the other hand, the bus share, the most common motorized access mode to stations, has been declining; from 14% in 2000 to 10% in 2012 [2]. Survey data [3] has also indicated that the majority of stations where bus use is low have relatively few bus services; for example no longer distance bus stops or fewer bus times. This implies that inconvenient transfers may be a factor which discourages people from using the bus as a means of access. Making rail-bus transfers more convenient would not only facilitate access to the railways themselves, but also make bus transport a more attractive option for passengers going to stations, and for providing them with further opportunity to make the most of transit use.

A number of previous studies on rail-to-rail transfer convenience within stations were carried out with particular emphasis on the physical burden of horizontal and use of stairs within stations [4], passenger preference in using escalators for changing floor levels [5], passenger opinions on better rail-to-rail transfer environments [6], and estimated cost of transfers in terms of in-vehicle minutes [7]. These findings were also incorporated into a cost-benefit analysis to justify investments into improving transfer facilities [8][9][10].

These studies are not satisfactory for evaluating transfers between railways and other modes. Of the few previous pieces of research [11] which actually examined rail-bus transfer, the objective was not to evaluate the convenience of transfer routes.

The present research analyses how passengers evaluate rail-bus transfer convenience. Evaluation criteria may be related to a wide range of factors, including ease of walking, abundance of signage to bus stops, provision of facilities such as post offices, shops, police stations and washrooms, and connectivity between rail and bus operation schedules. For the purposes of this research, however, the focus was placed primarily on the physical and structural characteristics of transfer routes having significant effect on transferability between stations and bus stops.

This paper attempts to reveal how and to what extent each physical characteristic along a transfer route affects their user-friendliness. Data obtained from an online survey was utilized to quantify the effect of physical characteristics on transfer convenience by developing evaluation models. These models were then applied to a sample case, namely the evaluation of a rail-bus transfer route renovation, in order to illustrate how transfer convenience can be calculated and evaluated practically.

2. Methodology

The first step taken in this paper is to clarify passenger viewpoints on transfer convenience. To obtain a workable volume of data samples, an online survey was conducted. Short video clips, each showing a different rail-bus transfer route, were prepared. Each respondent was asked to evaluate mode transfer convenience between two randomly selected clips. Details of the survey are given in Chapter 3 below, and the results are summarized in Chapter 4.
The evaluations and physical characteristics of the transfer routes in the video clips were then utilized to develop models to quantify the effect of each physical characteristic on the evaluation. The method used to develop the model is explained in Chapter 5.

A sample calculation of transfer convenience was made to demonstrate how this model can be put into practice, and is discussed in Chapter 6. Finally, conclusions and possible further studies are given in Chapter 7.

Framework of this research is summarized in Fig. 1.

### 3. Survey

#### 3.1 Preparing video clips

Before conducting the survey, the video clips to be used for the survey were filmed in actual stations. Thirty transfer routes in 27 stations in the Tokyo Metropolitan area were selected for filming. They were chosen to maximize the range of physical characteristics and variety in geographical location.

Video clips were filmed during the day on clear and cloudy days in October and November 2011. Each video clip attempted to reproduce the sensation and vision a passenger would have moving through the station starting from an exit all the way to a bus stop.

Filmed clips were then modulated to reduce camera shake. Place names, which can easily be found at shops and intersections, were concealed to prevent respondent bias due to recognition of place names. Faces of other pedestrians were also masked for privacy.

Subtitles were added to help respondents recognize what could be found on each route, for example:

- Going upstairs/downstairs;
- Using escalators;
- Waiting for the green signal, and;
- Crossing the road.

Thirty video clips, selected screenshots of which are shown in Fig. 2, were filmed. The shortest clip was 22 seconds, while the longest was 135 seconds. These clips were then uploaded to be added to the online survey.

#### 3.2 Questionnaire

The questionnaire used in the survey was based on these short video clips. Each respondent was first provided with 2 randomly selected clips out of the 30. The respondents were then asked to compare the transfer convenience of the two routes, and to answer which route was more convenient in their view. Convenience was evaluated on a scale of 1 to 10, “1” indicating “the route in the first clip is definitely convenient,” and “10” indicating “the route in the second clip is definitely convenient.” For the same route pair, each respondent was asked to evaluate the convenience assuming two cases of carrying a small bag or carrying a large trunk.

Respondents were also required to assess ease of transfer criteria through additional questions. Twenty-three predetermined criteria were provided including:

- Because the route is shorter;
- Because the route is equipped with escalators;
- Because the route is covered by a roof, and;
- Because the route has no level crossing involving a road.

The complete list of criteria is in the next chapter. Multiple answers were allowed to reflect every possible aspect of convenience evaluation.

#### 3.3 Respondents

The survey was carried out online in December 2011. Persons meeting the following criteria were selected to take part:

1) Residents of either a city in the Tokyo Metropolis or a Government Ordinance city;
2) Aged between 20 and 59, and;
3) Frequent rail-bus transfer user, meeting one of the two conditions below:
   3a) three times a week or more for commuting;
   3b) once a month or more for other purposes.

### 4. Summary of results

#### 4.1 Sample profile

A total of 1,870 respondents completed the survey questionnaire. Gender and age were uniformly distributed, as shown in Fig. 3.

Although the majority of samples were workers, housewives/househusbands, students and unemployed/retired respondents are also incorporated (Fig. 4).

These figures indicate that, while children and elderly people did not take part in the survey, a wide variety of samples with diverse characteristics and purposes were still obtained.
4.2 Passenger evaluation of transfer convenience

As noted earlier, names of places were masked in the video clips to avoid bias when familiar with one route and not the other. However, there was a concern that masking may not be sufficient. Consequently, and introductory question was designed to ask respondents if they recognized the places filmed on the clips they viewed. Out of 3,740 clips, i.e. 2 clips each to 1,870 respondents, places in 115 clips were correctly identified. Based on the answer given by the respondent, the model was controlled for “route familiarity” in order to avoid bias in modeling.

Respondents were also asked to select criteria for evaluating user-friendliness of the route selected. As summarized in Fig. 5, the most important criterion of convenience was distance between the station exit and the bus stop. This agrees with the conclusions drawn by previous studies on rail to rail transfers, which clearly demonstrated that walking distance was the inconvenience factor. In order of importance then followed safety, spaciousness and use of stairs. Provision of overhead shelter was also considered important. On the other hand, availability of shops along the transfer route drew little attention. When carrying a trunk, negotiation of stairs was a greater concern. Surface roughness of the route was also key, since it directly affected the ease with which suitcases could be transported.

In sum, transfer convenience criteria can be grouped into six broad groups:
- Horizontal movement, i.e. walk distance;
- Vertical movement, i.e. escalators and stairs;
- Safety around road crossings and provision of sidewalks;
- Ease of walking,
- Ease of finding bus stops, and;
- Bus stop structure.

In modeling the effect of the physical characteristics of transfer routes on convenience evaluation, the character-
istics of each route should be quantified in consideration of these aspects.

5. Modeling transfer convenience

5.1 Model structure

The next step was to develop transfer convenience evaluation models to quantify the effect of physical characteristics of the transfer route on respondent evaluation of convenience.

The logistic regression model was applied here. As shown in (1), physical characteristics of two routes form explanatory variables, a list of which is given in the next section. "Route A" in (1) should be interpreted as the route on the first video clip given to each respondent, and "route B" as the route on the second clip.

Convenience evaluated by the survey respondents was substituted for the response variable. To comply with the logistical structure, the convenience evaluation results obtained on a scale of 1 to 10 were shrunk to a 0-to-1 scale. With this given, if \( EC_B > 0.5 \), then the route on the second clip was better than the route on the first clip, and vice versa. Parameters were estimated utilizing a maximum likelihood estimation.

\[
EC_B = \frac{1}{1 + \exp[-(V_B - V_A)]} \quad V_K = \sum_{i=1}^{n} a_i x_{K_i} \tag{1}
\]

where \( EC_B \) : evaluated convenience of route B \((0 \leq EC_B \leq 1)\), \( a_i \) : parameters, \( i \in \mathbb{N} \), \( n \) : number of explanatory variables, and \( x_{K_i} \) : physical characteristics of route K.

5.2 Explanatory variables

Explanatory variables consist of the quantified characteristics of each transfer route utilized in the survey, in relation to the six broad groups introduced in the previous chapter, and shown in Table 1. Note that the length of transfer was measured in seconds, not in meters. The use of elevators was not included in the explanatory variable, since the proportion of passengers using elevators is generally small [12], and therefore may not be a primary path for transfer. However, elevators and slopes should be considered in a future study to take into account elderly passengers or passengers with reduced mobility.

Control variables were also incorporated in order to remove possible bias in parameter estimation. The latter included the brightness of clips, since brighter clips may lead to a more favorable evaluation, regardless of the physical characteristics of the route. Route familiarity, which was discussed earlier, was also treated as a control variable since it may sway the evaluation.

5.3 Estimation results

Estimated parameters are shown in Table 2. Two separate models were developed to consider the difference in size of hand luggage. Explanatory variables were narrowed down with the stepwise method, in an effort to obtain better AIC (Akaike’s Information Criterion) and to omit variables with poor significance levels.

Negative coefficients that were found both in horizontal and vertical movement indicate that longer periods of movement fundamentally have a negative effect on convenience. Positive parameters of escalators suggest that, when the length of vertical movement remains unchanged,

<table>
<thead>
<tr>
<th>Table 1 EXPLANATORY VARIABLES</th>
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<tbody>
<tr>
<td>Aspects</td>
</tr>
<tr>
<td>Horizontal movement</td>
</tr>
<tr>
<td>Vertical movement</td>
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<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Safety</td>
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</tr>
<tr>
<td>Ease of walking</td>
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<td></td>
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<tr>
<td>Ease of finding bus stop</td>
</tr>
<tr>
<td>Bus stop structure</td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Control variables</td>
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</table>
transfer convenience will be improved if escalators are provided. Escalators going up were more beneficial than those going down, judging from the magnitude of the parameters.

Safety was also a significant issue. Road crossings had a significantly negative effect on convenience. Parameters for road crossings with signals were larger in absolute values than those without, presumably because waiting time for signals may further discourage transfers. Walking on carriageways had an even greater impact. These results strongly suggest that routes which avoided interaction between passengers and vehicle traffic could be more convenient.

A considerable number of respondents answered that overhead shelter from the elements was an important factor for convenience. However, estimated results indicated that this was in fact insignificant. One reason to explain this is the fact that overhead shelter was not sufficiently visible in the video clips. Observation of the clips suggest that underpasses encouraged transfers for passengers with trunks, since underpasses generally have well-paved floors.

Ease of finding bus stops had neither a positive nor a negative effect on convenience evaluation, possibly because this survey utilized video clips: respondents were automatically guided to the destination bus stop without having to make any effort to find it.

Routes received a more positive assessment when the bus stops provided benches and shelter. More specifically, while shelter is important for passengers with small bags, those with larger luggage tended to appreciate the provision of benches, presumably because the larger the bag, the larger the physical effort.

For control variables, while minimum brightness of clips played an insignificant role in evaluations, route familiarity indicated a significantly positive effect in the small bag model.

Adjusted likelihood ratios for both models indicated their good performance. Standard deviations of the correlation coefficient in 10-fold cross validation also suggested that both models had fair stability in predicting transfer convenience.

6. A sample estimation of convenience

This section demonstrates how transfer convenience can be evaluated with the developed models. Supposing there is an existing transfer route, namely the "existing route" in Fig. 6, passengers first go downstairs to the ground level, then walk on the sidewalk, cross the road, continue along a narrow thoroughfare with no sidewalk and then reach the bus stop. The walk takes 90 seconds from the station exit to the bus stop. The problem with this route was that passengers had to negotiate a signaled road crossing, the thoroughfare beyond the signal had no sidewalk, and the bus stop had neither a roof nor any benches due to the lack of space.

To overcome these drawbacks, two plans were proposed. The first new route offered a means to avoid crossing the road by providing a long pedestrian overpass directly from the station exit. Still, this solution did not resolve the issue of no sidewalks and did not provide any improvement to the bus stop. Therefore, the second new route included a proposals to move the bus stop to another location with a sidewalk. This approach also made it possible to provide the bus stop with a roof and a bench. However, due to the difficulty in finding a suitable space to place this

<table>
<thead>
<tr>
<th>Case</th>
<th>Small bag</th>
<th>Trunk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal movement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level walk</td>
<td>-0.011</td>
<td>-0.006</td>
</tr>
<tr>
<td>Vertical movement</td>
<td>-0.016</td>
<td>-0.040</td>
</tr>
<tr>
<td>Escalators up</td>
<td>0.489</td>
<td>0.988</td>
</tr>
<tr>
<td>Escalators down</td>
<td>0.279</td>
<td>0.678</td>
</tr>
<tr>
<td>Vertical movement</td>
<td>-0.016</td>
<td>-0.204</td>
</tr>
<tr>
<td>Road crossings w/o signals</td>
<td>-0.195</td>
<td>-0.016</td>
</tr>
<tr>
<td>Road crossings w/ signals</td>
<td>-0.332</td>
<td>-0.662</td>
</tr>
<tr>
<td>Walking on carriageways (dummy)</td>
<td></td>
<td>-0.914</td>
</tr>
<tr>
<td>Walking on carriageways (prop)</td>
<td>-0.676</td>
<td>0.002</td>
</tr>
<tr>
<td>Safety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road crossings w/o signals</td>
<td></td>
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<tr>
<td>Road crossings w/ signals</td>
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<tr>
<td>Walking on carriageways (dummy)</td>
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<tr>
<td>Walking on carriageways (prop)</td>
<td></td>
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</tr>
<tr>
<td>Ease of walking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roofs</td>
<td>0.267</td>
<td>0.237</td>
</tr>
<tr>
<td>Underpass</td>
<td>0.714</td>
<td>0.002</td>
</tr>
<tr>
<td>Ease of finding bus stop</td>
<td></td>
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<tr>
<td>Ease of finding bus stop</td>
<td></td>
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</tr>
<tr>
<td>Bus stop structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roofs at bus stop</td>
<td>0.267</td>
<td>0.237</td>
</tr>
<tr>
<td>Benches at bus stop</td>
<td>0.053*</td>
<td>0.021*</td>
</tr>
<tr>
<td>Designated waiting area</td>
<td>0.074</td>
<td>0.063</td>
</tr>
<tr>
<td>Control variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum brightness</td>
<td>0.267</td>
<td>0.237</td>
</tr>
<tr>
<td>Route familiarity</td>
<td>0.420</td>
<td>0.047**</td>
</tr>
</tbody>
</table>

Observations 1,870 1,870
AIC 2,074.8 1,995.7
Adjusted likelihood ratio 0.267 0.237
Correlation coefficient 0.053 0.021
SD of correlation coefficient in 10-fold cross validation 0.035 0.063

Coef: coefficient. p: significance probability. ***: p<0.01, **: p<0.05, *: p<0.1.
Correlation coefficient denotes the relationship between observed evaluation and estimated evaluation.
stop, the second new route required a longer walk.

All these quantities were put into models to estimate the relative convenience of both the new routes to the existing route.

The estimated convenience is summarized in Fig. 7. The original 0-to-1 scale was converted into a new -1 to 1 scale for more intuitive understanding. The new scoring system means that when the scale is positive, the route is better, and vice versa.

Results indicate that both new routes were better in terms of convenience than the existing route. The second new route offered the advantage of no road crossings, which was a significant barrier to transfer. Estimated results differ between transfer directions for the second new route, given the difference in escalator direction which influenced the convenience evaluation.

Convenience evaluation can be thus implemented. In practice, it can be employed to evaluate planned routes for rail to bus transfers when a new station is proposed or an existing station is to be refurbished. Further study on assessing transfer convenience in monetary terms may make it possible to apply convenience evaluation models to cost-benefit analyses.

7. Conclusion and further research

This research studied how passengers evaluate rail to bus transfer convenience, focusing on the physical characteristics of the transfer routes, and with extensive support from an online survey. Convenience evaluation models suggest that longer walks and vertical movement have a negative impact on convenience, while provision of escalators, and roofs and benches to bus stops are beneficial. Intersections where passengers have to negotiate traffic junctions or road crossings are dissuasive; this implies that avoiding road crossings and installing sidewalks would encourage transfer. A sample convenience estimation demonstrated how the developed models can be put into practical use.

Further study should take into account factors related to the actual bus service, such as frequency of operation and rail to bus schedule coordination. Appropriate guidance for transfer will also contribute to convenience. This includes information on where you are, where you can find the bus stop, and when the bus leaves. Considering these aspects will further offer an even more sophisticated method for assessing transfer convenience.

In applying this technique in practice, station-specific characteristics should also be considered. For example, a station near a shopping mall tends to have a larger proportion of shopping passengers. In other cases, the elderly and passengers with reduced mobility or a handicap should be considered for stations near a hospital. Further in-depth analysis and modeling is necessary to take these character-

<table>
<thead>
<tr>
<th>Route</th>
<th>Description</th>
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<tbody>
<tr>
<td>New route 1</td>
<td>Station exit on the second floor 45 seconds on pedestrian overpass 20 seconds' walk downstairs 10 seconds' walk with no sidewalk Reach bus stop, with no roof, no bench</td>
</tr>
<tr>
<td>(Case 1)</td>
<td></td>
</tr>
<tr>
<td>New route 2</td>
<td>Station exit on the second floor 20 seconds on the downward escalator 80 seconds' walk on the sidewalk Reach bus stop, with roof, bench</td>
</tr>
<tr>
<td>(Case 2)</td>
<td></td>
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</table>

**Fig. 6** Sample transfer routes for convenience evaluation

**Fig. 7** Estimated convenience evaluation
istics into account.

References


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