Passenger Evaluation on Rail-Bus Transfer Convenience in Railway Station

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Abstract: This research aims to establish a method to evaluate convenience of rail-bus transfer routes regarding their physical and structural characteristics. An online survey is conducted to obtain passengers' evaluation on rail-bus transfer convenience. With data obtained through the survey, transfer convenience evaluation models are developed to quantify the effect of each physical characteristic of transfer routes on convenience evaluation. Besides horizontal and vertical walk distances, which are already taken into account in preceding studies, features outside stations, including safety concerns and bus stop structures, are also considered. Developed models are applied to a sample case to demonstrate how transfer convenience can be evaluated in practice.

Keywords: Station, Bus, Transfer, Convenience, Evaluation

1. INTRODUCTION

1.1 Background

Railway is one of the most important transport modes in the Tokyo Metropolitan region, accounting for 30% of as many as 85 million trips within the region with 35 million residents in 2008 (MLIT, 2009). With concerns regarding aging society, energy security and environmental issues, railway is to be further enhanced to provide residents and businesses with convenient and efficient transport services.

Railway needs to be accessed by other modes. In other words, using railway needs transfers. In 2010, two-thirds of residents in the region accessed to the railway station from their home on foot, followed by bikes, which comprises nearly one-fifth of the total access (MLIT, 2012). This implies that most railway passengers live within the *walkable* radius from a station.

On the other hand, the share of bus, the most common motorized access mode to the station, is continuingly decreasing from 14% in 2000 to 10% in 2010 (MLIT, 2012). A survey data also indicates that the majority of stations with low bus use (less than 1% of total access) have bus stops distant to/from the station, which implies that the transfer inconvenience may be a factor of discouraging bus access (MLIT, 2007). It is important for railway to improve the rail-bus transfer convenience to be more attractive for passengers using buses to the station, and to provide further opportunity to make the most of transit use.

A number of preceding researches studied *rail-to-rail* transfer convenience *within the station*. They paid attention to relative physical burden of transfer passengers on each structural element of the station, including walking, stairs, escalators and elevators.

Instinctively, larger physical load can be found in vertical movements than in horizontal movements. Iida *et al.* (1996) calculated the physical burden of going upstairs to be more than twice as large as that of walking horizontally, and passengers feel 1.6 times larger burden than level walk just to wait for elevators. Kang *et al.* (2010) also found the passenger preference on escalators in changing levels in transfer facilities.

Questionnaires carried out in Doi *et al.* (1999), which targeted passengers using major railway station in Tokyo Metropolitan region, revealed that the passengers' demand toward better rail-to-rail transfer environment includes wider passages and stairs, reduced walking distances, optimal allocation of washrooms and benches, and the improved accessibility to information on train schedules and delays. Another research (Guo *et al*., 2011), which employed the London Underground system as a case study, calculated the perceived cost of transfers in terms of in-vehicle minutes. They found that the systemwide average of the cost of one transfer equals to 4.9 minutes of in-vehicle time, and it varies depending on the size, complexity and transfer convenience of stations. Based on their estimation of the total annual transfer cost to be more than $573 million, they suggest the importance of the investments to provide passengers with the better transfer circumstances.

These findings are also incorporated in the cost-benefit analysis to justify investments in transfer convenience improvements. Oshima *et al.* (1996) simulated the cost and benefit of installing escalators to 16 stations in the Tokyo Metropolitan region. Benefit is calculated with total physical energy savings by using escalators and the value of energy. Kato *et al.* (2000) and Sato *et al.* (2002) also quantified benefits in easing physical burden.

The majority of preceding studies on transfer convenience focus on that among trains in the station, lacking the attention to access-egress modes. One of the few researches (Yanagawa *et al.*, 2004) considered rail-bus transfer; however, it does not evaluate the convenience of transfer route.

1.2 Objectives

This research analyses how a passenger evaluates rail-bus transfer convenience. Evaluation criteria may vary widely, including ease of walking, abundance of the direction signs to the bus stop, provision of facilities such as post offices, shops, police stations and washrooms, and connectivity of rail and bus schedules. This research, however, focuses on the physical and structural characteristics of transfer routes regarding easiness of walking between stations and bus stops.

This paper first attempts to reveal how and to what extent each physical characteristic of transfer routes affect the convenience of using the transfer routes, and then aims to provide convenience evaluation scores of transfer routes as a whole. This score may be utilized for convenience evaluation when stations are to be constructed or repaired, and new transfer routes are to be installed.

This study is unique in taking physical structures outside the railway station, such as road crossings, traffic signals and roofs over the sidewalks, into account. In addition, this study focuses much on evaluating the transfer route as a whole, rather than on comparing the effect of each physical characteristic of transfer routes on convenience.

2. METHODOLOGY

As noted in the previous section, the first step of this paper is to discover the relationship between physical characteristics of transfer routes and the convenience evaluation. This step can be interpreted as to model the relationship between them.

In obtaining data for modeling through surveys, it may be costly in terms of time and budget if a considerable number of subjects were asked to walk on the actual transfer routes. Therefore, to obtain ample samples sufficient for modeling, an online survey on rail-bus transfer convenience is conducted. Each survey respondent is provided with 2 out of 30 short video clips, each showing different rail-bus transfer routes, and they are asked to answer which route is more desirable for them to use, and the criteria for it. Physical characteristics of each route are also quantified by carefully scanning each video clip. Characteristics that cannot be comprehended from clips, such as temperature and noise, are ignored. Route length is measured in seconds, not in meters, since distance cannot be felt from video clips. Details of the survey are provided in the following section. A minimum number of 435 respondents is necessary to be provided with every possible combination of 2 out of 30 clips.

Transfer convenience evaluation models are created in the next step to quantify the effect of each physical characteristics of transfer route on respondents' convenience evaluation. Explanatory variables represent physical characteristics of transfer routes, while respondents' evaluation on transfer convenience is placed to the model as the response variable. Estimation results and discussions on the model are then provided.

A sample calculation of transfer convenience is also carried out to demonstrate how this model can be put into practice. Finally, conclusions and possible further studies are stated.

Framework of this research can be summarized as shown in Figure 1.

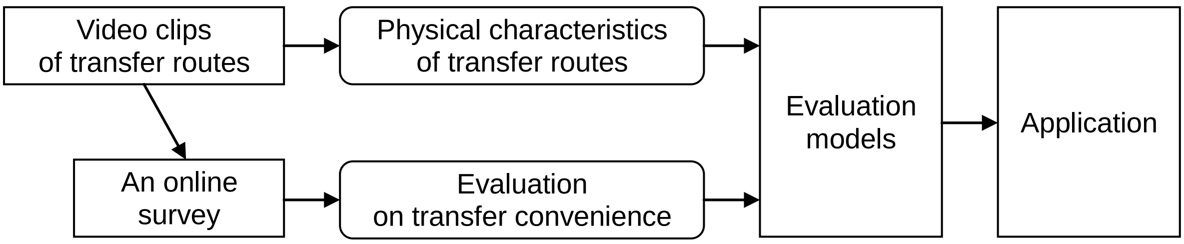


Figure 1. Research framework

3. SURVEY

3.1 Outline

A survey is conducted online in December 2011 to obtain how passengers evaluate rail-bus transfer convenience. Persons who comply with the following criteria responded to the survey:

1) Residents of either cities in Tokyo Prefecture or Government Ordinance Cities;
2) Age between 20 and 59, and;
3) Frequently using rail-bus transfers, either:
   3a) Using rail-bus transfers three times a week or more for commuting, or;
   3b) Using rail-bus transfers once a month or more for other purposes.

Criteria 3a and 3b are set in order to incorporate the views of transfer convenience of both commuters and non-commuters. A total of 1,870 observations are collected through the survey. Out of them, 941 observations meet the criteria 1/2/3a, while remaining 929 are collected under the criteria 1/2/3b. Hereafter, the former observations are called "commuter samples," while the latter are referred to as “general samples.” Commuter samples also include students using rail-bus transfers three times a week or more for going to school.

3.2 Questionnaire

The questionnaire in the survey is based on short video clips, which will be introduced in detail in the next subsection. Each respondent is first provided with 2 out of 30 randomly selected short video clips showing the circumstances of rail-bus transfer from a station exit to a bus stop. They are then asked to compare the transfer convenience of two routes, and to answer which route is more convenient for them. Convenience is evaluated on a scale of 1 to 10, “1” being “the route on the *first* clip is definitely convenient,” and “10” being “the route on the *second* clip is definitely convenient.”

For the same route pair, each respondent is asked to evaluate the convenience assuming two cases, namely they having a small bag, and having a large trunk.

Additional questions ask them criteria for evaluating transfer convenience. Twenty-three options are provided, some of which include:

- Because the route is shorter;
- Because the route has escalators;
- Because the route has roofs, and;
- Because the route has no road crossing.

The complete list of criteria will be shown in the next section. Multiple answers are allowed to reflect every possible aspect of convenience evaluation.

3.3 Preparing Video Clips

Video clips utilized in the survey are filmed in actual stations in service. In order to select the filming location, a station transfer database is first developed. It comprises information on station structure, physical characteristics of rail-bus transfer routes and structure of bus terminals of stations with public bus services in the Tokyo Metropolitan region. Out of them, 30 transfer routes in 27 stations are chosen for filming video clips. They are chosen to maximize differences in physical characteristics and variety in geographical locations.

Video clips are filmed in October and November 2011. Daylight time in sunny or cloudy days is chosen for filming to avoid effects of time and weather on evaluation. From the exit of the station to a bus stop, video clips are shot with an effort to replicate the sight of transferring passengers, just as if each survey respondent is actually walking on the transfer routes.

Filmed clips are then modulated to reduce camera shake. Further, subtitles are added to help respondents recognize what can be found on each route, some of which include:

- Going upstairs/downstairs;
- Waiting for the green light, and;
- Crossing the road.

Place names, which can be easily found in shop names and intersection names, are concealed to avoid each respondent being biased. Faces of pedestrians are also masked.

The 30 video clips, screenshots of which are shown in Figure 2, are thus finalized. The shortest clip only has 22 seconds, while the longest one lasts 135 seconds. These clips are then loaded to online survey system to be offered to respondents.

Figure 2. Screenshots of video clips showing transfer routes

4. SUMMARIZED RESULTS

4.1 Sample Profile

As noted in the previous section, the total of 1,870 respondents completed the survey questionnaire. Out of them, 941 are the commuter samples and the rest are the general samples. Gender and age are uniformly distributed, as shown in Figure 3.

Regardless of the sample groups, the majority of samples are workers (Figure 4). As many as 82% of commuter samples are full- or part-time workers. General samples incorporate larger proportion of housewives/househusbands and unemployed/retired respondents. These samples may have different trip purposes to commuter samples, for example shopping, leisure and social activities.

These figures indicate that, while children and elderly are absent, a wide variety of samples with diverse characteristics and purposes are obtained.

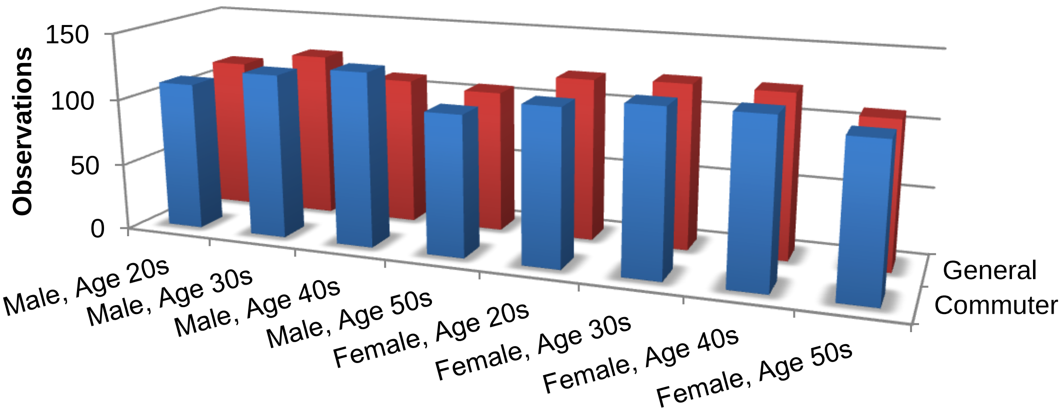


Figure 3. Gender and age distribution of samples

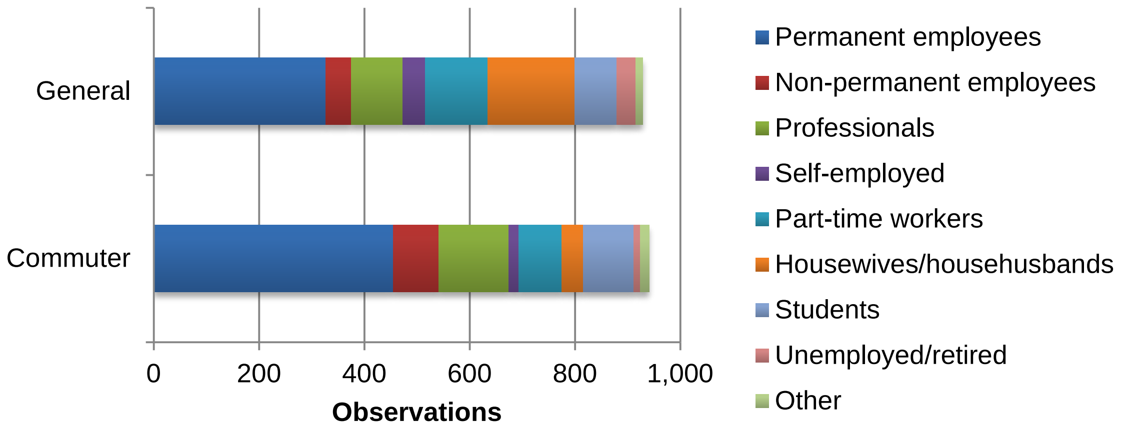


Figure 4. Occupation of samples

4.2 Passenger Evaluation on Transfer Convenience

As noted earlier, places names are masked in the video clips because answers may be biased if a respondent knows one route on the clip and doesn't know the other. However, masking may not be sufficient. Therefore, the first question is designed to ask whether each respondent knows where two provided video clips were filmed.

Out of 3,740 answers, namely two (clips) times 1,870 (samples), 115 answers, or 3.1%, correctly identified where the station on the video clip is. Judged from this fact, the model should be controlled for the factor whether a respondent knows where the station on the clip is (hereafter "route familiarity") in order to avoid bias in modeling.

Respondents are then asked to deliver their evaluation on two transfer routes on a scale of 1 to 10. Average ratings for the clip pairs for the corresponding respondents are shown in Figures 5 and 6. The former assumes the case that each respondent has a small bag, while the latter assumes that each of them has a trunk. Results are shown in color codes instead of numeric expressions for the sake of easier comprehension. Reds indicate that the route on the first clip (on the left) is more convenient than that on the second one (on the top), while greens mean the opposite.

These figures indicate that convenience evaluation differs route by route, which suggests that differences in physical structures of transfer routes, which can be recognized through video clips, may explain different evaluations on convenience. In addition, differences in convenience evaluation is found according to the difference in bag size, which suggests the preferability of developing different models assuming different luggage size.

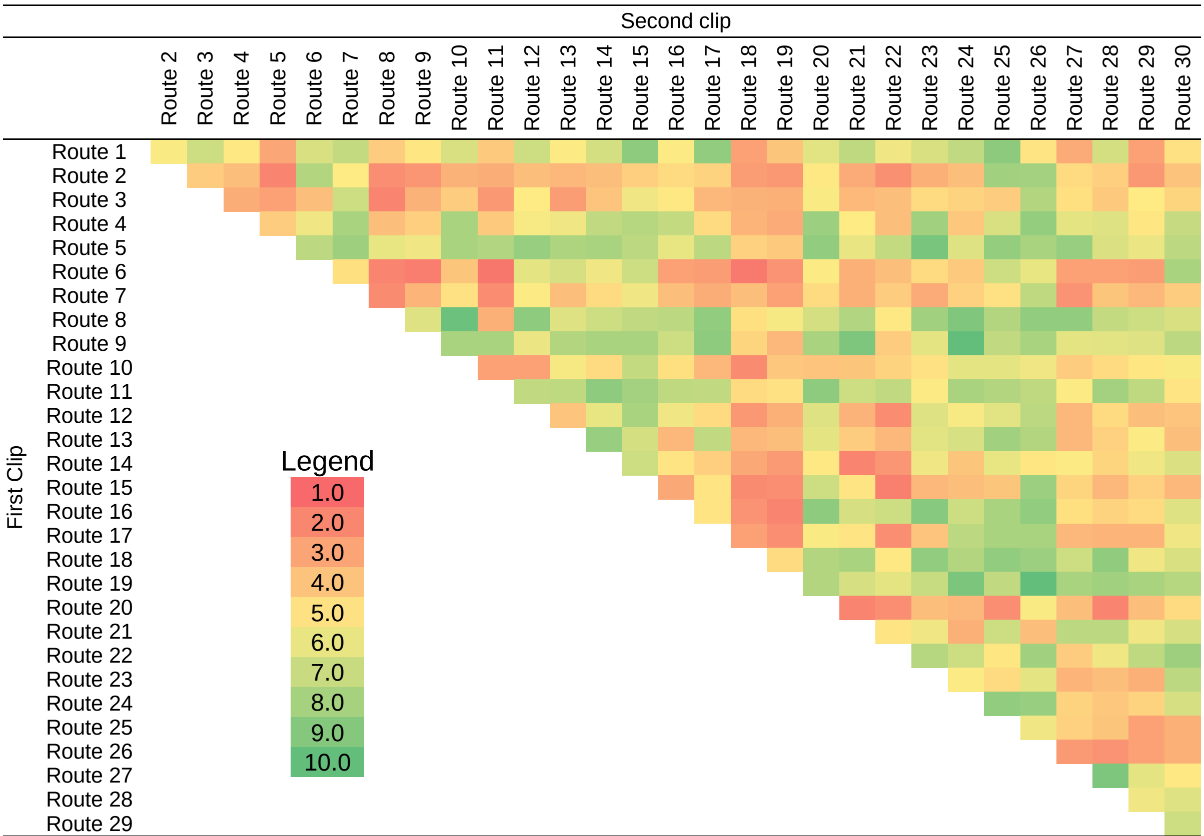


Figure 5. Average convenience evaluation assuming having a small bag

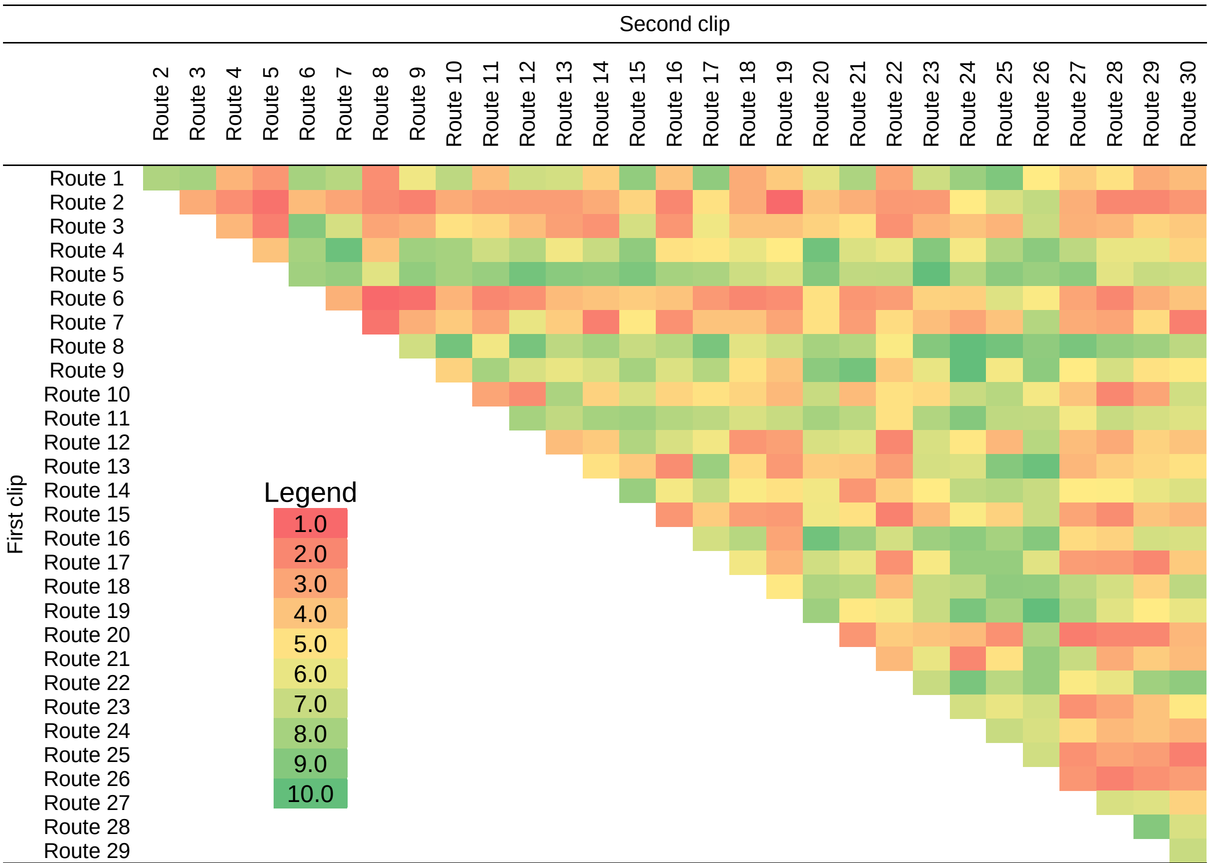


Figure 6. Average convenience evaluation assuming having a trunk

Criteria of evaluating the chosen transfer route to be more convenient are also asked. Answers are summarized in Figure 7. The most important criterion of convenience is the distance between the station exit and the bus stop. This agrees with conclusions made by studies on rail-rail transfer, which insist that the walking distance is the major source of transfer inconvenience. This is followed by safety, spaciousness and vertical movements. Provision of roofs is also a factor. On the other hand, shops along the transfer route drew little attention.

When having a trunk, vertical movement is of a larger concern. Surface roughness of the route is also important, since it directly affects the easiness of dragging trunks and suitcases.

Summarizing these results, criteria of transfer convenience can be grouped into six broad aspects:

- Horizontal movement, i.e. walk distance;
- Vertical movement, i.e. escalators and stairs;
- Safety, concerning road crossings and provision of sidewalks;
- Ease of walking,
- Ease of finding bus stops, and;
- Bus stop structure.

In modeling the effect of physical characteristics of transfer routes on convenience evaluation, characteristics of each route should be quantified regarding these aspects.

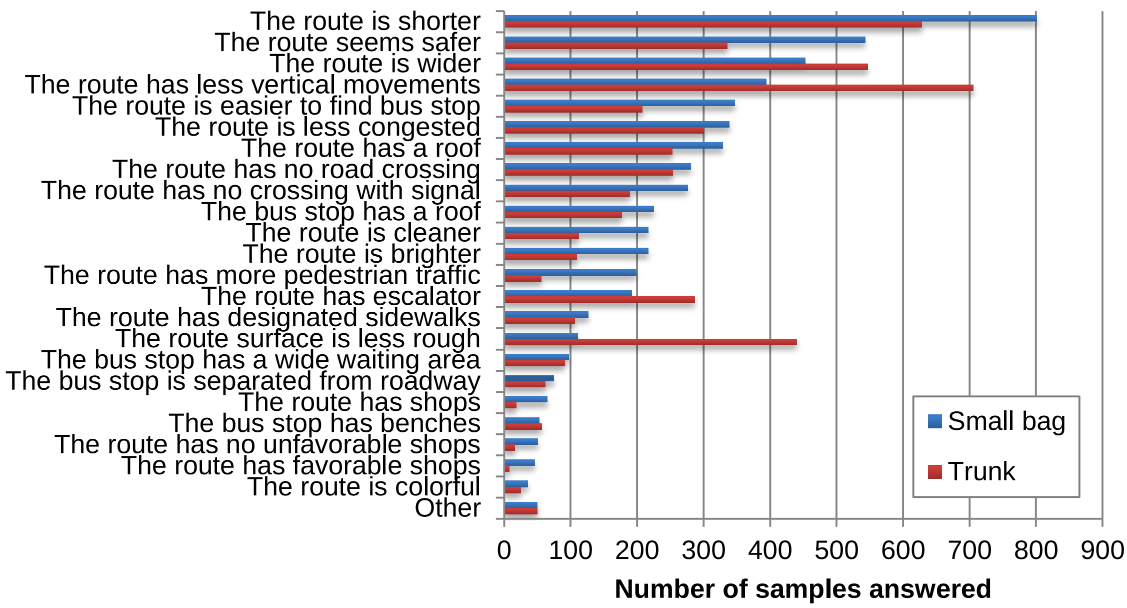


Figure 7. Evaluation criteria for transfer convenience

5. MODELLING TRANSFER CONVENIENCE

5.1 Model Structure

The next step is to develop transfer convenience evaluation models to quantify the effect of physical characteristics of transfer route on respondents' evaluation of convenience.

The logit model is applied here. This model, shown in Equation (1), compares the physical characteristics of two routes ("route A" and "route B") and calculates the relative convenience of one route to the other. Physical characteristics of two routes form utility function for each route in this model. A list of physical characteristics employed in the model will be given in the next subsection. Convenience evaluation is assigned to the response variable. Since the logit model is utilized, the convenience of a transfer route will be calculated within the range of 0 to 1.

$$EC_B = \frac{\exp(\sum_{i=1}^{n} a_i\, x_{Bi})}{\exp(\sum_{i=1}^{n} a_i\, x_{Ai}) + \exp(\sum_{i=1}^{n} a_i\, x_{Bi})} \tag{1}$$

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,
x_{Ai} : physical characteristics of route A, and
x_{Bi} : physical characteristics of route B.

Model parameters are estimated using survey data. "Route A" in Equation (1) is interpreted as the route on the first video clip given to each respondent, and "route B" as the route on the second clip. Physical characteristics of transfer routes employed in the survey are quantified and substituted for x_{Ai} and x_{Bi} in Equation (1).

Convenience evaluated by the survey respondents is substituted for the response variable. To comply with the logit model structure, the convenience evaluation results obtained in the scale of 1 to 10 are shrunk to 0-to-1 scale. It can be interpreted that if EC_2 exceeds 0.5, then the route on the second clip is better than the route on the first clip, otherwise the opposite.

Parameters are estimated utilizing maximum likelihood estimation.

5.2 Setting Explanatory Variables

Explanatory variables consist of quantified characteristics of each transfer route utilized in the survey, regarding six broad aspects introduced in the previous section, as shown in Table 1. Note that the length of transfer is measured in seconds, not in meters. The use of elevators is not included in the explanatory variable. This is because the proportion of passengers using elevators seems to be small, as Isobe (2005) suggests, and therefore it may not be a primary path for transfer. However, elevators and slopes should be considered in further study to incorporate the existence of mobility impaired persons.

Control variables are also taken into account in order to remove possible biases in parameter estimation. Brightness of clips is considered since brighter clip may result in better evaluation, regardless of the physical characteristics of routes. Route familiarity, which is discussed in the earlier section, is also treated as a control variable since evaluation may be biased if a respondent already knows the route.

Table 1. Explanatory variables

Aspects	Variables	Units/Measures
Horizontal movement	Level walk	Duration in seconds
Vertical movement	Vertical movement	Duration in seconds
	Escalators up	Number counts
	Escalators down	Number counts
Safety	Road crossings without signals	Number counts
	Road crossings with signals	Number counts
	Walking on carriageways (dummy)	Dummy variable (yes/no)
	Walking on carriageways (proportion)	Proportion of walking on carriageways to the whole walking duration
Ease of walking	Roofs	Proportion of walking under roof to the whole walking duration
	Underpass	1 if more than a half of the route is underpass, 0 otherwise
Ease of finding bus stop	Ease of finding bus stop	Proportion of duration from the last corner of the route to bus stop to the whole walking duration
Bus stop structure	Roofs at bus stop	Dummy variable (yes/no)
	Benches at bus stop	Dummy variable (yes/no)
	Designated waiting area	Dummy variable (yes/no)
Control variables	Video clip brightness	Minimum brightness of each clip
	Route familiarity	1 if survey respondent knows where the clip is filmed, 0 otherwise

5.3 Estimation Results

Estimated parameters are shown in Table 2. Two separate models are developed to consider the size difference in hand luggage. Explanatory variables are narrowed down with the stepwise method, in an effort to obtain better AIC. Variables with poor significance level are also omitted.

Negative coefficients that are found both in horizontal and vertical movements all indicate that the longer movement fundamentally has the negative effect on convenience. Positive parameters for escalators suggest that, when the length of vertical movement remains unchanged, transfer convenience will be improved if escalators are provided. Escalators going up are more beneficial than those going down, which is instinctively correct, judged from the magnitude of the parameters.

Safety is also a significant issue. Road crossings have significantly negative effects on convenience. Parameters for road crossings with signals are larger in absolute term than that for those without signals, presumably because waiting time for signals may further discourage transfers. Walking on carriageways even has a greater impact. These strongly suggest that avoiding conflicts between transferring passengers and vehicle traffic can realize further convenient transfer circumstances.

A considerable number of respondents answered that the roof on the route is an important factor for it to be convenient. However, estimation results indicate that they are insignificant. A reason can be found at the fact that video clips fails to show the existence of roofs sufficiently. It can be understood from the observations in the clip that underpasses encourage transfers when passengers have trunks, since common underpasses boast well-paved floors.

Routes are evaluated to be more convenient when bus stops are provided with benches and roofs. Though minimum brightness of clips played insignificant role in evaluation, route familiarity indicated a significantly positive effect in the small bag model.

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

Table 2. Estimation results

Case		Small bag		Trunk	
		Coef	p	Coef	p
Horizontal movement	Level walk	-0.011	0.000***	-0.006	0.004***
Vertical movement	Vertical movement	-0.016	0.000***	-0.040	0.000***
	Escalators up	0.489	0.012**	0.988	0.000***
	Escalators down	0.279	0.031**	0.678	0.000***
Safety	Road crossings w/o signals	-0.195	0.016**	-0.204	0.016**
	Road crossings w/ signals	-0.332	0.005***	-0.662	0.000***
	Walking on carriageways (dummy)			-0.914	0.000***
	Walking on carriageways (prop)	-0.676	0.002***		
Ease of walking	Roofs				
	Underpass			0.714	0.002***
Ease of finding bus stop	Ease of finding bus stop				
Bus stop structure	Roofs at bus stop	0.267	0.053*		
	Benches at bus stop			0.237	0.021**
	Designated waiting area				
Control variables	Minimum brightness				
	Route familiarity	0.420	0.047**		
	Observations	1,870		1,870	
	AIC	2,074.8		1,995.7	
	Adjusted likelihood ratio	0.199		0.230	
	Correlation coefficient	0.584		0.619	
	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.

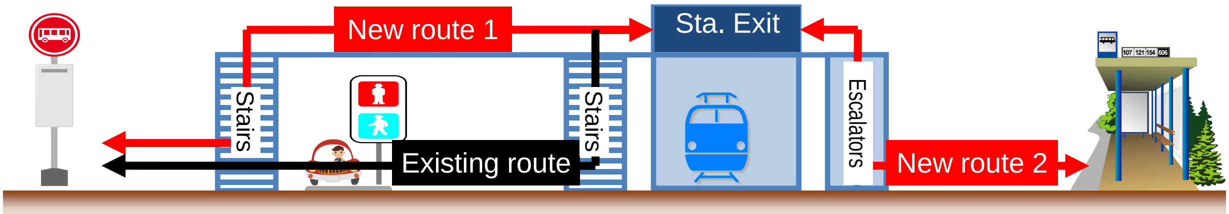
6. A SAMPLE ESTIMATION OF CONVENIENCE

This section demonstrates how transfer convenience can be evaluated with developed models.

Suppose that there is an existing transfer route as shown in the “existing route” row of Figure 8. Passengers first go downstairs onto the ground, then walk on the sidewalk, cross the road, go through a narrow road with no sidewalk and then reach the bus stop. A total duration of 90 seconds is necessary to get to the bus stop from the station exit. Problems on this route are that passengers have to go through a signaled road crossing, the road beyond the signal has no sidewalk, and bus stop has no roof and bench due to the lack of enough space.

To overcome these weaknesses, two plans are proposed. New route 1 attempts to avoid road crossing by providing a long pedestrian overpass directly from the station exit. Still, provision of sidewalks and bus stop improvement are yet to be done. Therefore, new route 2 proposes to replace the bus stop to another location with a sidewalk. This also realizes to provide the bus stop with a roof and a bench. However, due to the difficulty in finding a suitable space to place a bus stop, new route 2 demands a longer walk.

All these quantities are put into the model to estimate the relative convenience of both new route 1 and new route 2 to the existing route.



Existing route	Station exit on the second floor 20 seconds' walk downstairs 30 seconds' walk on the sidewalk A signaled road crossing (20 seconds to cross) 20 seconds' walk with no sidewalk Reach bus stop, with no roof, no bench
New route 1 (Case 1)	Station exit on the second floor 45 seconds' walk on pedestrian overpass 20 seconds' walk downstairs 10 seconds' walk with no sidewalk Reach bus stop, with no roof, no bench
New route 2 (Case 2)	Station exit on the second floor 20 seconds on the downward escalator 80 seconds' walk on the sidewalk Reach bus stop, with roof, bench

Figure 8. Sample transfer routes for convenience evaluation

Estimated convenience is summarized in Figure 9. As the model utilizes logistic regression, raw estimation ranges from 0 to 1. For more instinctive understanding of the estimation, the 0-to-1 scale can be converted into a new -1-to-1 scale. First, the 0.5 is subtracted from the raw estimation value to set the center of the range to 0. Next, the value is multiplied by 2 to obtain the converted value of convenience which ranges from -1 to 1. The new route can be judged better when the new scale is positive, and the new route is worse when the new scale is negative. This figure utilizes the new evaluation scale.

Results indicate that both new routes are better in convenience than the existing route. An advantage in adopting new route 2 is that it has no road crossings, which is a large barrier for the transfer. In case 2, estimated results differ between transfer directions since difference in directions of escalators has difference in the effect on the convenience evaluation.

Convenience evaluation is thus made. As a practical use, it can be employed to evaluate planned routes for rail-bus transfers when a new station is proposed or an existing station is to be refurbished. Further study on valuing transfer convenience in terms of money may realize utilizing convenience evaluation models in the cost-benefit analyses.

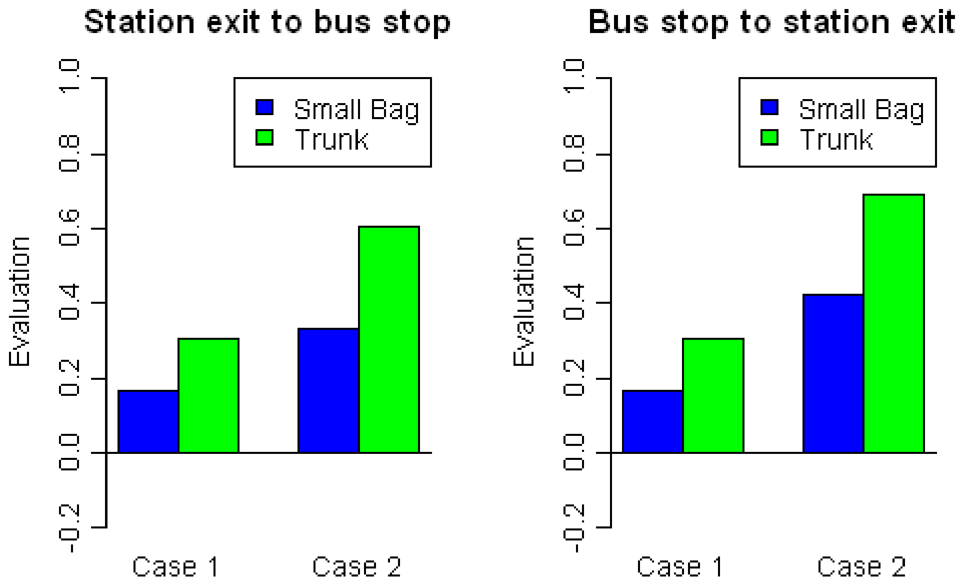


Figure 9. Estimated convenience evaluation

7. CONCLUSION AND FURTHER RESEARCH

This research studied how passengers evaluate rail-bus transfer convenience, focusing on the physical characteristics of routes, with an extensive support of the online survey. Convenience evaluation models suggest that longer walks and vertical movements have the negative impact on convenience, while provision of escalators to the route, roofs and benches to bus stops are beneficial. Traffic conflicts between pedestrians and vehicles strongly discourage transfers; this implies that avoiding road crossings and installing sidewalks are preferable for better transfer circumstances. A sample convenience estimation demonstrated how developed models can be put into practical use.

Further study should take level of bus services such as number of runs and rail-bus schedule coordination into account. 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 sophisticate the approach to evaluate transfer convenience.

In applying this technique to practice, station-specific characteristics should also be considered. For example, a station near a shopping mall tends to have a large proportion of shopping passengers. In another case, the elderly and handicapped passengers should be considered in a station near a hospital. A further in-depth analysis and modeling is necessary to take these characteristics into account. Different attributes of sample groups in the survey, namely commuter and general samples, will be considered in this stage of research.

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