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Service quality evaluation for urban rail transfer facilities with Rasch analysis

Junghwa Kim[a,*], Jan-Dirk Schmöcker[a,*], Jeong Whon Yu[b], Jung Yoon Choi[b]

[a] Department of Urban Management, Kyoto University, Japan
[b] Department of Engineering, Ajou University, Republic of Korea

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ABSTRACT

This paper evaluates the service level of urban rail transfer facilities based on Rasch analysis, taking into account transit users' subjective perceptions. A total of 3970 respondents who usually transfer between different urban rail lines at least 3 times a week and who are between 15 and 75 years old were randomly surveyed. We evaluate the transfer station service quality by capturing satisfaction with a range of service items. The items are grouped into five criteria: information, mobility, comfort, convenience and safety. The satisfaction with the five criteria is further distinguished based on trip purpose. From the results, it was concluded that service items related to transfer time (train arrival information, walking distance) are important to users during commute, educational, business and leisure trips. Instead important service items for transfer convenience when on shopping or leisure trips are walking amenity, waiting space, parking lot usability or specific facilities such as the presence of baby-care rooms. Considering also the characteristics of Seoul's transit network we discuss which transfer facilities are likely to be a key for encouraging people to use urban rail and suggest that Rasch analysis is a suitable tool for this type of evaluation that is not frequently used in transport planning.

1. Introduction

Demand for transportation refers to the amount and type of travel that people will choose under certain conditions and factors such as prices and service quality. There has been increased attention as to how to measure the impacts of service quality on travel demand and how to predict the impacts of specific service quality changes toward transport elasticities (Litman, 2013). In particular, public transportation has been becoming increasingly important for environmental goals. With growing competition, it is expected that service quality will have an increasing impact on the public transport demand. Improvements of service quality can help smoothen the operation and make transit a more attractive travel option (Iseki et al., 2007). More specifically, a range of academic and consultancy studies have shown that transfer inconvenience discourages potential users from taking mass transit and reduces the satisfaction of existing users (Hine and Scott, 2000; CTPS, 1997; Steer Davies and Gleave, 1998; Wardman, 2001; Guo and Wilson, 2011). Hence, improving transit facilities may play an important role in raising public transport satisfaction and positively affect ridership in the long term.

Several aspects of transfer service quality and their respective importance are difficult to quantify for many travelers. We therefore utilize in this paper Rasch analysis. The approach was developed to increase objectivity and invariant comparisons between items and persons (Engelhard, 2013). In other words, the goal is better comparability of different persons answering several questions. Some persons might be very familiar with a question's content whereas others might find it very difficult to answer the same question, as they have never been exposed to the problem. To provide one example where Rasch analysis is frequently used, we refer to Hawthorne et al. (2008) who establish the utility score for the Assessment the Quality of Life (AQoL)[1] instrument. In transport planning it has been less used. An exception is Cheng (2011) who evaluates public transport web site service quality by adopting Rasch analysis. Following examples might show why we believe that using Rasch analysis is also appropriate for the problem addressed in this paper:

Questions regarding satisfaction with parking facilities at a station will be easy to answer for travelers familiar with park-and-ride. In contrast, passengers who make only or mostly transfers between two public transport lines at the same station will have much more difficulty answering the same question. Similarly, questions regarding satisfaction with children facilities will only be answerable for a subgroup of

* Corresponding authors.
E-mail address: schmoecker@trans.kuciv.kyoto-u.ac.jp (J.-D. Schmöcker).

[1] Assessment the Quality of Life (AQoL) instruments measure health-related Quality of Life. The four instruments differ in sensitivity and length in different domains of health.

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the travelers. Instead other questions regarding, for example, waiting time experiences could be answered fairly well by all public transport travelers. We therefore suggest that Rash analysis can contribute to control for the bias in usage and/or knowledge about certain transfer facilities.

2. Literature review for transit service

Several studies evaluating transit performance have emphasized efficiency, effectiveness, productivity and service quality (Eboli and Mazzulla, 2011). Litman (2008) investigated the value transit users place on qualitative factors and explored how service quality factors affect travel time values and transit ridership. He indicated that service quality improvements can be converted into travel time units and provide benefits comparable to speed improvement that reduce total travel time. Nathanail (2008) developed a framework for monitoring and controlling the quality of services provided to their passengers based on the estimation of 22 indicators, grouped under six criteria. These are itinerary accuracy, system safety, cleanliness, passenger comfort, service and passenger information. In addition, several other studies have focused on the measurement of transit service quality by customers as monitoring of passenger satisfaction with simple descriptive statistical analysis is already ongoing in several cities around the Hensher et al. (2003) established a methodology to measure and calculate an overall service quality level which includes 13 attributes, such as bus travel time, bus fare, walking time to the bus stop, seat availability, information, driver attitude, etc. Based on focus group analysis Hu and Jen (2006) developed an evaluation scale that contains 20 items and group them into four dimensions. These are comprised of direct passenger facilities, tangible service equipment, convenience of service and operating management support. Eboli and Mazzulla (2011) propose a methodology to evaluate transportation service quality considering both subjective and objective measures of service performance. They considered the judgment of passengers' perception as a subjective measure of service quality, while the performance measures provided by transit operators are taken as objective service quality measures. Liou et al. (2014) proposed a novel information fusion model that addresses the relationships among the various criteria for a method of non-additive weighted gap analysis aimed at evaluating and improving the service quality of bus systems in Taipei.

In contrast, there are few studies focusing specifically on service quality of transfer facilities. Kim et al. (2008) established service evaluation indicators for transit facilities in the high-speed railway station in Korea. They noted that the most important element for transfer facility evaluation is the connectivity from the departure to the arriving stations. Their proposed indicators comprise of a general level of service indicator, the propriety of allocation and the quality of information throughout the transfer facilities. Iseki et al. (2007) developed an evaluation instrument for transit agencies which can be used to assess the quality of service at transit transfer facilities and eventually to improve travel connectivity for increasing ridership. They argued that transit users' main requirements for transfer facilities can be classified into three groups. These are minimal transfer time and distance, convenience and comfort, as well as safety and security. Furthermore, they identified physical attributes of transfer facilities as one area where transit agencies can reduce wait, walk and transfer penalties for facility passengers. Other literature instead classified attributes determining transfer satisfaction into following five factor categories: 1) access, 2) connection and reliability, 3) information, 4) amenities, and 5) security and safety (Land and Foreman, 2001; Horowitz and Thompson, 1995; Metropolitan Transportation Commission, 2006; Iseki et al., 2007).

There are further a number of other studies focusing on pedestrian movements during transfers. Fruin (1971) is an early study that developed an algorithm for calculating the service level in pedestrian facilities, including footways, stairs and queuing areas. The assessment is based on pedestrian velocity, space and conflict probability. Yao et al. (2012) investigated the design scale, layout form, and operating status of typical transfer subway stations in Beijing. They furthermore evaluated the transfer facility service level with a pedestrian behavior model focusing on stairs, corridors and platforms. They argue that the service level can be evaluated based on the quantitative observation of pedestrian parameters, such as velocity, density and flow. Yun and Lee (2010) proposed an evaluation method for pedestrian level of service in transfer facilities by using queuing theory in order to consider that walking speeds and pedestrian density are not sufficient for evaluating the service level. Jang et al. (2010) instead discuss the quality of specific facilities in transfer stations. They obtain the time spent at ticket booths and ticket vending machines through queuing theory and determine pedestrians' service level. The importance of different facilities is obtained by applying AHP (Analytic Hierarchy Process) and is discussed for five urban railroad transfer stations in Seoul.

Closer to our study, Lois et al. (2016) explored the predictive capacity of attitudes towards several service factors on general satisfaction with transport interchange. By estimating a path model, they demonstrated that safety perception and a good evaluation of information provided at the travel interchange are important predictors of general transfer facility satisfaction. Our study continues the analysis conducted by Kang et al. (2015) by using the same data set but utilizing different survey items. Kang et al. evaluated the individual level-of-service of urban railway transfer facilities in Seoul metropolitan area. Their analysis shows that there are correlations between the quantitative factors of facility characteristics and qualitative factors representing users stated perceived service level. Neither Kang et al. (2015) nor Lois et al. (2016) look into the importance of trip purpose nor do they control for response difficulty.

In conclusion, we suggest that most studies have evaluated the service quality of transfer facilities focusing on the measurement of design aspects. However, this does not answer the question as to how transit users perceive the importance of walking speed, queuing as well as factors such as safety and comfort. The aforementioned study of Liou et al. (2014) also identified this as a research gap. We propose that Rasch analysis can overcome this problem. In the following we evaluate the level of service according to five criteria that appear to cover the range of issues involved when transferring; these are: information, mobility, comfort, convenience and safety. We hypothesize that user satisfaction level would show different tendencies depending on trip purpose i.e. whether travelers are on a business, commuting, educational, leisure or shopping trip.

3. Data

3.1. Data collection

The survey was implemented in form of personal interviews conducted in 43 metro transfer stations in Seoul's metropolitan area between 17th December 2013 to 22th January 2014. A total of 3970 respondents were surveyed with roughly the same number of samples for each station (around 90). We targeted urban rail users who transfer to a subway line more than three times a week. The frequency of using the station was one of the first questions and if the respondent does not fulfill this criteria, the survey was not continued. Besides this restriction, the data was collected by randomly approaching respondents at the platforms or in the stations. We acknowledge though that we can not exclude the possibility for some biases. For example, the rate of busy, time conscious travelers refusing to answer the survey might be higher.

Respondents are aged between 15 and 75 with an average age of 37.8. 50.4% were men, 47% hold a university degree, whereas the highest education of 44.2% was high school graduation. Approximately half of the respondents ($n = 1846$) answered that their monthly household income is between 3000 and 4500 US$ (assuming an exchange rate of 1000 Won to 1 US$). More detailed information is

Table 1
Descriptive statistic of data.

Variables	Total	Trip purpose				
		Commute	School	Business	Shopping	Leisure
Gender (% of Male)	50.4	54.1	52.1	71.7	22.4	40.3
Averaged Age (std)	37.8 (16.5)	41.8 (11.6)	20.1 (3.9)	43.0 (11.2)	40.1 (13.8)	45.0 (18.9)
Education (%)						
Middle school	4.3	1.6	3.7	1.2	3.5	9.1
High school	44.2	50.2	31.4	39.3	53.9	49.6
University or College	47.0	44.0	62.2	50.9	40.2	37.5
Graduate school	2.9	2,8	1.9	6.2	1.3	1.9
No answer	1.6	1.3	0.8	2.4	1.1	2.0
Monthly Household Income (%)						
Less than 1500 dollars	6.1	2.3	1,8	1.2	5.2	15.2
1,500–3000 dollars	26.5	28.2	26.1	24.1	27.4	28.4
3000–4500 dollars	47.7	50.9	52.1	54.3	52.0	38.9
4500–6000 dollars	16.2	16.2	16.2	16.7	13.8	14.2
Over 6000 dollars	1.4	1.2	0.9	1.8	0.5	1.6
No answer	2.1	1.3	2.9	1.9	1.1	1.7
Driving License (%)	58.0	71.5	29.8	86.8	53.9	52.8
Smart Phone Use for Transfer Information (%)						
Never use	27.2	30.4	14.2	18.8	36.4	38.0
Seldom use	23.3	26.7	18.6	28.0	35.8	25.1
Often use	228	22.6	27.5	24.9	18.3	16.0
Usually use	26.8	20.3	39.7	28.4	9.4	20.9
Number of transfers per week	6.17	7.50	6.90	6.01	5.66	4.90
Sample number	3870	1065	783	676	371	1081

provided in Table 1. For the question on trip purpose, respondents were allowed to give multiple responses. Of the 3970 participants, 1065 were on a commuting trips, 783 on a school (including university) trip, 676 on a business trip, 371 on a shopping trip and 1081 travelled for leisure reasons. Noteworthy are expected correlations in Korean society. 71.7% of the business trips but only 22.4% of shopping trips were performed by men. The survey showed that 26.8% of the respondents usually use a transfer information service through their smart phone whereas 27.2% answered they never have any experiences to use it. That ratio was particularly higher for school trips and low for shopping trips. Regarding number of transfers, those on commute trips have the highest transfer frequencies with on average 7.5 times/week, while leisure trip travelers answered their weekly average transfer frequency including multimodal transfers is less than 5 times.

3.2. Questionnaire content

As shown in Table 2, a total of 17 items classified into 5 groups were included in the survey. The items were selected after a range of focus group meetings had been conducted. The first group contains questions to measure the quality of transfer *information provision*. The second criteria consists of five questions to measure *mobility convenience*. These are items focusing on walkability to transfer. The third criteria, determinants of *comfort*, are measured by four questions about temperature, air conditions and brightness. This is followed by four items regarding the *convenience* of facilities such as availability of parking lots, toilets and baby-care rooms. Finally, respondents were asked regarding their satisfaction toward *safety and security* such as their perceived level of exposure to crime. All service quality items were answered on a 7-point Likert scale with end points “totally dissatisfied” and “fully satisfied”.

Table 2
Service items measured in the questionnaire (translated from Korean).

Criteria	No	Item Label	Measure
Information Provision (In)	1	*In_1*	Information facilities for transfer (guide map and direction indicators) are displayed well
	2	*In_2*	Facilities showing arrival information of transit to transfer, are displayed well
Mobility Convenience (Mo)	3	*Mo_1*	Corridors in transfer station are broad enough for moving
	4	*Mo_2*	Waiting spaces in the transfer station are enough wide
	5	*Mo_3*	Amenities for walking in the transfer station (elevators, escalators, moving walks, wheelchair lifts etc.) are fully installed
	6	*Mo_4*	Walking distances required for transfer are short
	7	*Mo_5*	Walking is easy because corridors have gentle grade ramps
Comfort (Cf)	8	*Cf_1*	The station temperature is controlled adequately
	9	*Cf_2*	There is a low noise level in transfer stations
	10	*Cf_3*	Air-conditioning of transfer stations is good
	11	*Cf_4*	Transfer stations are very bright (illumination and lighting)
Convenience of facilities (Cv)	12	*Cv_1*	The transfer parking lot system is convenient to use
	13	*Cv_2*	The distance from parking lots to transfer stations is short
	14	*Cv_3*	Public toilets are convenient to use
	15	*Cv_4*	Baby-care rooms are convenient to use
Safety and Security (SS)	16	*SS_1*	Transfer stations are fully fortified against accidents
	17	*SS_2*	Transfer stations are fully prepared to cope with for various crimes

7 point: fully agree – 4 point: neutral-1 point: fully disagree.

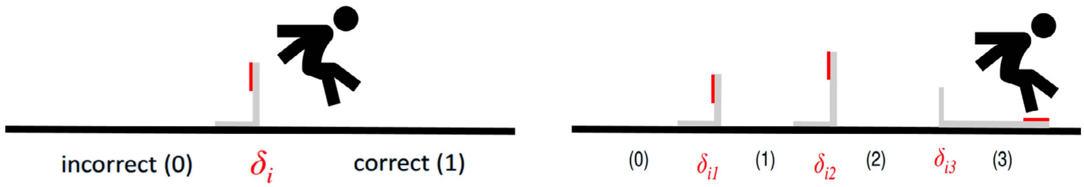

Fig. 1. Conceptual figure for item difficulty δ_i (left: dichotomous response option, right: polytomous response option, i.e. poor (0), sufficient (1), good (2), excellent (3)).

4. Methodology

4.1. Proposed methodology

Consider that individuals have been given a range of reading tasks varying from simple to complex texts and are then asked a follow-on questionnaire regarding their perception and opinions of some of the content. Their answers will depend on both their background (education, personality, attitudes towards reading) as well as the difficulty of the text. One might want to give less weight to the opinions of readers who have had difficulty understanding the text and vice versa, take frequent strong opinions to easily understandable questions very serious. The above is a similar, classic example for the application of Rasch analysis and the analogies to the example provided in the introduction regarding assessing satisfaction of transfer items (opinions on the text) and a person's ability to do so (familiarity with reading the text) should be obvious.

Rasch analysis is a special case of IRT (item response theory) applied to assessments in a wide range of disciplines, including health studies, education, psychology, marketing, economics and social sciences (Yang, 2009). The mathematical theory underlying Rasch analysis has been developed by Georg Rasch in 1960. The analysis specifies that the probability of item endorsement is a function of two different parameters, which are the underlying ability of the individuals and their expected item response (Rasch, 1960; Hawthorne et al., 2008) with dichotomous data as illustrated in the following.

Let, $X_{ni} = x \in \{0, 1\}$ and

$$\Pr\{X_{ni} = 1\} = \frac{\pi_{ni1}}{\pi_{ni0} + \pi_{ni1}} = \frac{exp(\beta_n - \delta_i)}{1 + exp(\beta_n - \delta_i)} \tag{1}$$

In (1), $\Pr\{X_{ni} = 1\}$ is the probability of success upon interaction between the relevant person and assessment item and hence π_{ni1} is the conditional probability of scoring $X_{ni} = 1$ on item i by person n. β_n denotes a respondent's position or, in Rasch analysis terms, "ability" (familiarity to answer transfer service item) of person n on the latent trait and the parameter δ_i denotes the "difficulty" of item i (satisfaction with this transfer service item). If the ability of a respondent matches the difficulty of item i then the probability for this to occur is estimated as 0.5. In other words, if respondent's ability β_n is equal to item difficulty δ_i, the probability of responding to the correct answer ($X_{ni} = 1$, see Fig. 1) is exactly 0.5. The higher β_n compared to δ_i, the higher the probability to correctly answer $X_{ni} = 1$ and vice versa.

Since in our case we obtain assessments in the range from 1 to 7, the polytomous Rasch "Partial Credit" analysis (Masters, 1982) is considered. First, let $X_{ni} = x \in \{0, 1, \cdots, m_i\}$ be an integer random variable where m_i is the maximum score for item i. This defines the probability with multiple response categories as:

$$\Pr(X_{ni} = x) = \begin{cases} \dfrac{exp\sum_{k=1}^{x}(\beta_n - \delta_{ik})}{1 + \sum_{j=1}^{m_i}\sum_{k=1}^{j}(\beta_n - \delta_{ik})} & \text{for } x > 0 \\ \dfrac{1}{1 + \sum_{j=1}^{m_i}\sum_{k=1}^{j}(\beta_n - \delta_{ik})} & \text{for } x = 0 \end{cases} \tag{2}$$

where δ_{ik} is the kth threshold location of item i on a latent continuum and β_n is the location of person n on the same continuum. Note that this equation is the same as

$$\Pr\{X_{ni} = x\} = \frac{exp\sum_{k=0}^{x}(\beta_n - \delta_{ik})}{\sum_{j=0}^{m_i} exp\sum_{k=0}^{j}(\beta_n - \delta_{ik})}; \tag{3}$$

where the value of δ_{i0} is chosen for each person n for computational convenience, that is $\sum_{j=0}^{0}(\beta_n - \delta_{ij}) = 0$. Here, the δ_{ik} parameters are interpreted as the intersection between two consecutive scores (categories) where the probabilities of responding in the adjacent categories is equal. Hence, the δ_{ik} term describe the "step difficulty" and Embreston and Reise (2000) have suggested calling this term a *category-intersection parameter*. According to Masters (1982), the equation permits the eliminations of creating two internal parameters representing the responded individual's ability and the item difficulty (Hawthorne et al., 2008).

The Rasch analysis estimates the 'goodness of fit' between item difficulty and individual's ability. Thus this is taken as a criterion for the structure of the responses, rather than a mere statistical description of the responses. Infit and outfit statistics, which are the output of Rasch analysis, are capable of reflecting the degree of agreement between observed responses and model expectations. Jackson et al. (2002) noted that infit is a weighted statistic that indicates the degree to which the observations for a specific item meet the model expectations, and outfit is an unweighted statistic that implies whether unexpected responses or outliers are found based on a person's ability (Cheng, 2011). Therefore, according to Carvalho et al. (2012), "the former is more sensitive to unexpected patterns of observations by people with responses that are close to the item's difficulty level, and the latter is more sensitive to unexpected observations by people with responses that are far from the item's difficulty level" (e.g., when people with high ability miss easy items or people with low ability get hard items). Moreover, infit and outfit are both described in terms of mean square residual values (MNSQ[2]) which shows the magnitude of the discrepancy between the observed and expected responses. The standardized MNSQ (ZSTD) is also an indicator which shows the statistical probability of the discrepancy in the model (Jackson et al., 2002; Fischl and Fisher, 2007; Cheng, 2011).

4.2. Application of Rasch analysis

Since all service items in our study were measured on a 7-point Likert scale, m_i is equal to 7 and $X_{ni} = x \in \{1, \cdots, 7\}$. Therefore, we use the above introduced Partial Credit Rasch analysis with following interpretation: There are two principal parameters, β_n denoting the overall satisfaction of individual n with the transfer facilities and the "difficulty" or (dis-)satisfaction towards service i denoted by the average of δ_{ij}, where $i = 1\ldots17$ (see Table 2) and $j = 1\ldots7$. The difficulty of service item i can be interpreted as "satisfaction level for service i". In other words, a particular item i with high difficulty can be considered as a service for which users have low satisfaction.

Fig. 2 is a further attempt to illustrate how to apply the concept into this study and to interpret the meanings of respondents' "ability" and

[2] Over 2.0: Distorts or degrades the measurement system; 1.5–2.0: Unproductive for construction of measurement, but not degrading; 1.0–1.5: Productive for measurement; Less than 1.0: Less productive for measurement, but not degrading. May produce misleadingly good reliabilities and separations

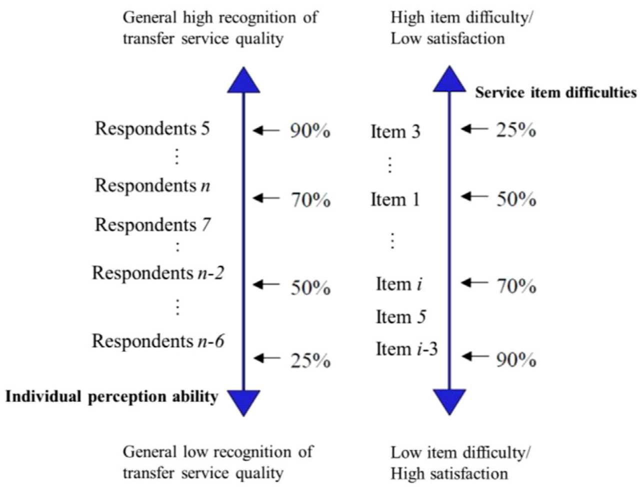

Fig. 2. Illustration for application and interpretation of Rasch analysis Left scale: Individual perception ability; Right scale: Service item difficulties.

"item difficulty". Ability is interpreted here as a general recognition of service items, i.e. whether a respondent is able to recognize and distinguish the quality of an item. The left-hand side of the figure shows the relative levels of users' recognition ability towards services to consider inter-individual variance of latent traits in attitudes towards transfer facility services, and the right-hand side is the level of satisfaction or perceived difficulty with specific service items. In other words, passengers have their own recognition ability toward different items, the more difficult they recognize the item, the less likely they are satisfied. Therefore, it is important to recognize that service items that have high or low satisfaction are both considered as important. Instead items rated in the middle of the scale tend to be items towards which travelers are indifferent. From a policy perspective, therefore items at both ends of the scale can be important. Those items with which users are satisfied and are perceived as important need to be maintained and items that users are not satisfied with require improvement.

5. Analysis result

As noted in the introduction we distinguish the satisfaction according to the five trip purposes commuting, school, business, shopping and leisure. We conducted the Polytomous Rasch model analysis with WINSTEPS 3.92.1 version. The analysis was performed by setting the mean of item difficulty estimates to 0 logits and by using the maximum likelihood estimation method.

The reliability of the measurement is defined as the ratio of the variability of the true score to the observed variability. The interpretation of person reliability and item reliability are similar to the explanations of Cronbach's coefficient testing (Wright, 1996). That is, the reliabilities range between 0 and 1, with reliabilities above 0.9 being desired but coefficients larger than 0.7 being acceptable (Bond and Fox, 2001; Duncan et al., 2003; Nilsson et al., 2005). Our reliability results for the four trip purposes are indeed over 0.9; the exception is the model for school trips with a value of 0.25. These results imply that the 17 items grouped into 5 criterias perform the function of measuring transfer facility satisfaction well for all trip purposes except for school trips.

Fig. 3 shows the person-item maps for all five trip purposes in the standard graph used to illustrate Rasch analysis results. Items and respondents are separated by a vertical line. The left side is the distribution of respondents and the right side shows the mean item logit estimated of each item. The estimates of each individual's satisfaction with each service item are shown on the same scale. By defining item difficulty and person ability on the same scale, we can obtain interpretations for a person's "ability score" to judge satisfaction with a specific item. The person ability scale on the left and the item difficulty scale on the right are linked through the mathematical function of the probability of successfully locating a person's ability (Wu and Adams, 2007). As shown in Fig. 3, we can see that respondents' recognition abilities for service quality are generally higher than that of service items' difficulties. This indicates that, overall, the respondents were familiar with the items asked for and did not perceive the questions to be overly difficult. Respondents located at a higher level on the left represent those that have in general higher satisfaction, which makes them more likely to agree with the items in the questionnaire. In contrast, items listed at a higher level on the right side are those with which respondents are less likely to be satisfied with: Fewer respondents are capable to respond to these items with ease and this indicates that the respondents feel less satisfied with these service items (Cheng, 2011; Haans, 2013). The dots and sharp signs on the left indicate the number of respondents for a specific rating; i.e. for commuting each "#" represents 7 individuals and each "." a single to 6 individuals.

We emphasize the Rasch analysis hypothesis that the average measure of all item parameters is fixed at zero logit as a comparative basis for the relative interval scale. For commuting the average value of the ability of 1065 users is 1.47 logits (School trip: n = 783, 1.27 logit; Business trip: n = 676, 1.38 logit; Shopping trip: n = 371, 1.68 logit; and Leisure trip: n = 1081, 1.39 logit). The positive values demonstrate that users are "capable" of being satisfied with service items implying that users in urban rail are generally satisfied with the transfer service items for all trip purposes. Further, comparatively those on a school trip feel less satisfied with the service facilities, while shopping trip users are most satisfied.

MNSQ and ZSTD (Z-standardized fit statistic) indicate how accurately or predictable the data fit the Rasch model. According to Smith et al. (1998), MNSQ ranges from 0.9 to 1.1 are acceptable. As shown in Table 3 therefore all infit and oufit measures are acceptable. In addition, also ZSTD[3] appears to be satisfactory.

In Tables 4, the logit estimates of item difficulty (δ_i) are presented. Since a logit is defined as the natural log of an odds ratio, an item with a higher logit indicates that users are likely to have low levels of satisfaction on this transfer service item. Table 4 shows the estimates of item difficulty for commuting trips. The top three items with which users are not satisfied are *Mo_4* ("Walking distances required for transfer are short"), *Cv_1* ("The transfer parking lot system is convenient to use") and *Cv_4* ("Baby-care rooms are convenient to use"). The most satisfied transfer service item is *In_2* ("Facilities showing arrival information of transit to transfer, are displayed well") followed by *In_1*("Information facilities for transfer (guide map and direction indicators) are displayed well") and *Mo_2* ("Waiting spaces in the transfer station are enough wide").

Users on school trips are also satisfied with *In_2*, *In_1*, and *Mo_2* similar to commuters but are unsatisfied with *Mo_4, Cf_1* ("The station temperature is controlled adequately") and *Cf_2* ("There is a low noise level in transfer stations"). For business trip, *Mo_4, Cv_1* and *Cv_2* ("The distance from parking lot to the transfer station is short") obtain the least satisfied ratings, while business travelers are most satisfied with items *In_1*, *In_2*, *SS_1*("Transfer stations are fully fortified against accidents") and again *Mo_2*. Hence, the only difference compared to school trips is *SS_1*. The importance put on safety and prevention of accidents by business travelers might be partly explainable by this group considering the possibility of travel delays due to unexpected accidents or incidents as an important factor. Table 4 also shows that the unsatisfied items for shopping travelers are *Cv_4*, *Cv_1* and *Cf_1,* indicating that

[3] ZSTD are t-tests of the hypothesis "Do the data fit the model (perfectly)?" These are reported as standardized z-scores, i.e., unit normal deviates. They show the improbability of the data, i.e., its significance, if the data actually did fit the model. The expected value is zero. Negative values indicate predictability and positive values a lack of such.

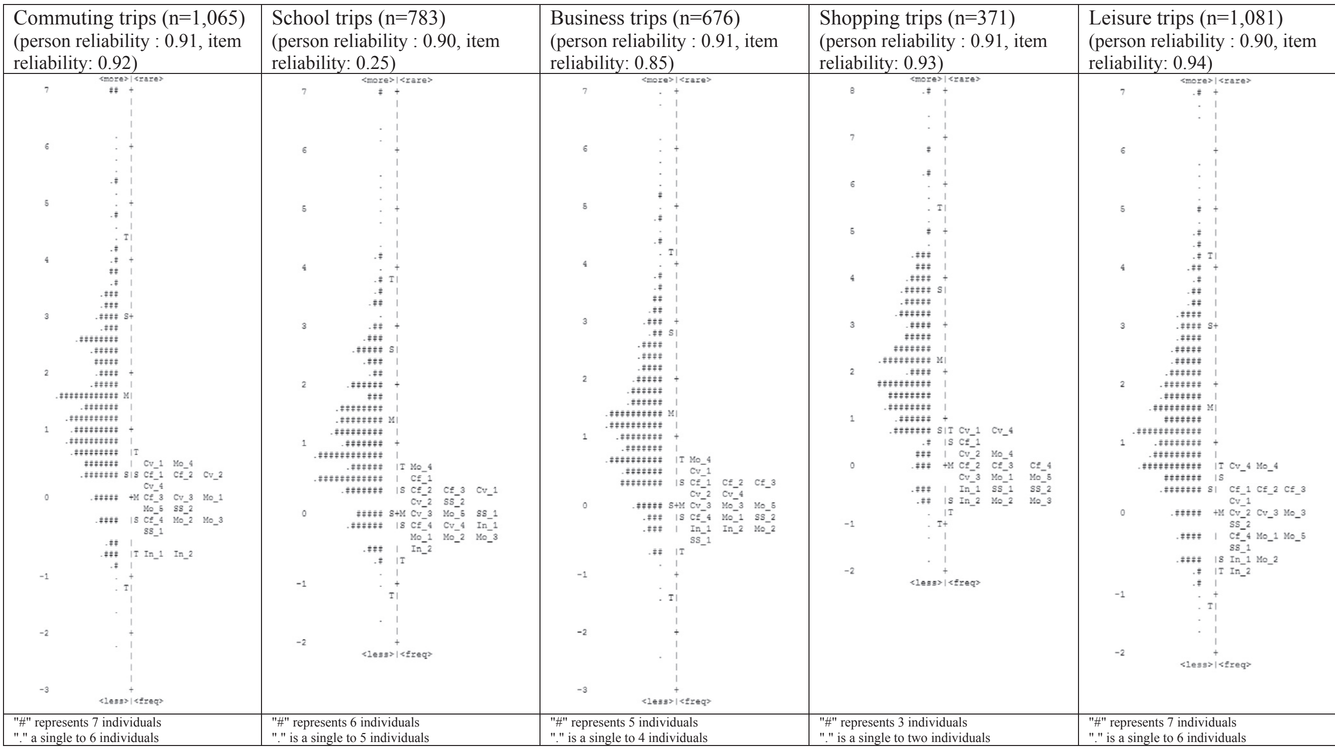

Fig. 3. Person-item maps by trip purpose. ※'M' represents the means of respondents and items. Term 'S' represents one-sample standard deviation, and 'T' is for a two-sample standard deviation. Mo, Cv, Cf, In and SS are the criteria introduced in Table 1.

Table 3
Summary of fit statistics.

Trip purpose	Infit (mean)		Outfit (mean)	
	MNSQ	Zstd	MNSQ	Zstd
Commuting trip	0.97	−0.54	0.97	−0.33
School trip	0.90	−0.68	0.93	−0.35
Business trip	0.91	−0.62	0.95	−0.18
Shopping trip	0.97	−0.12	0.97	−0.28
Leisure trip	0.93	−0.72	0.95	−0.45

some respondents feel strongly that transfer stations miss facilities such as baby care rooms. On the other hand, shoppers are satisfied with *Mo_2*, *Mo_3* ("Amenities for walking in the transfer station (elevators, escalators, moving walks, wheelchair lifts etc.) are fully installed") and *In_2*. In other words it appears that shopping travelers consider items which help them to move with ease as important which is in line with our expectation and it appears that walking amenities in Seoul's urban rail network fulfill shopping travelers' expectations. In addition, the top three satisfied and unsatisfied items for leisure are the same as for commute trips.

Table 4 also indicates that perceptions of "Waiting space" and

Table 4
Item difficulties and rank analysis for item satisfaction by trip purpose.

Criteria	No	Item label		Estimates of average item difficulty (δ_i)				
				Commute trip	School trip	Business trip	Shopping trip	Leisure trip
Information Provision	1	*In_1*	Information Display	**−0.5****	**−0.29****	−0.33	−0.31	**−0.44****
	2	*In_2*	Arrival Information	**−0.52*****	**−0.43*****	**−0.49*****	**−0.38***	**−0.5*****
Mobility Convenience	3	*Mo_1*	Corridor Width	−0.04	−0.17	−0.13	−0.04	−0.21
	4	*Mo_2*	Waiting Space	**−0.27***	**−0.28***	**−0.34***	**−0.59*****	**−0.37***
	5	*Mo_3*	Walking Amenities	−0.11	−0.12	0.03	**−0.49****	−0.03
	6	*Mo_4*	Walking Distance	*0.47****	*0.63****	*0.56****	0.28	*0.52***
	7	*Mo_5*	Corridor Slope	−0.02	−0.01	0.06	−0.12	−0.13
Comfort	8	*Cf_1*	Temperature	0.22	*0.33***	0.12	*0.45**	0.17
	9	*Cf_2*	Noise	0.13	*0.23***	0.22	−0.05	0.28
	10	*Cf_3*	Air Condition	0.08	0.13	0.2	0.1	0.21
	11	*Cf_4*	Bright	−0.24	−0.22	−0.2	−0.12	−0.17
Convenience Facilities	12	*Cv_1*	Parking Lot Usability	*0.42***	0.2	*0.32***	*0.66***	*0.28**
	13	*Cv_2*	Parking Lot Connection	0.28	0.1	*0.25**	0.27	0.06
	14	*Cv_3*	Public Toilet	−0.03	0.06	−0.05	0.02	−0.02
	15	*Cv_4*	Baby-care Room	*0.28**	−0.21	0.24	*0.81****	*0.57****
Safety and Security	16	*SS_1*	Safety to Accident	−0.13	−0.09	**−0.35****	−0.29	−0.21
	17	*SS_2*	Safety to Crime	0.00	0.12	−0.12	−0.17	0.00

Bold: High satisfaction/Low difficulty, *Italic: Low satisfaction/High difficulty,* ***: rank 1.**:rank2, *: rank3.

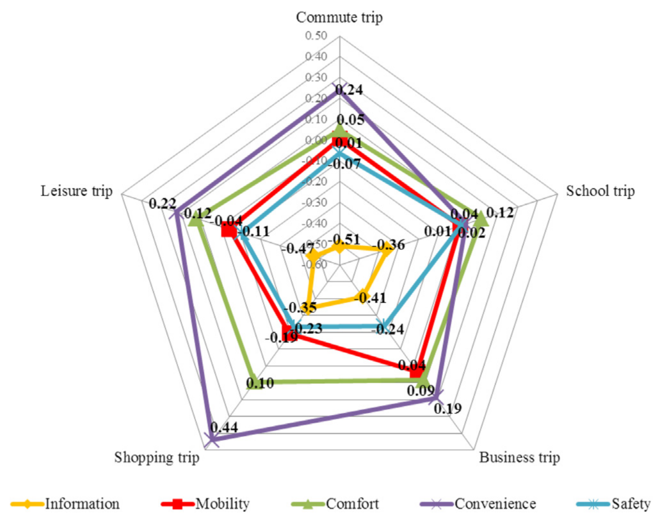

Fig. 4. Mean value of item difficulty estimates by trip purpose.

"Information service for train arrival" are likely satisfied regardless of trip purpose. Waiting spaces at Seoul's stations are in general fairly wide compared to other cities which might explain this result. Information display (*In_1*) is also an important satisfied item among commuting, school and leisure travelers. Since the public transport information system in Seoul is well established, this appears reasonable. Seoul has launched the TOPIS[4] system that provides integrated real-time transport information since 2009. Our analysis gives hence some support for arguments that such systems might indeed be important to improve public transport service perceptions. We note that for commuters and school travelers the required information will be likely different compared to the expectation and needs of leisure travelers. TOPIS provides real-time information, which will be important for time-sensitive users familiar with the network, but also basic information to find and explore routes for occasional travelers.

In contrast, *Mo_4* (walking distance) is the least satisfied service item for all except shopping travelers. This appears also reasonable given that there are indeed long pathways between many platforms in Seoul. In particular, since some lines are built deep underground often long escalators or stairs have to be taken for transfer. In line with our findings, Kim et al. (2012) verified that in Seoul transfer distance is a key indicator to measure the level of service. As one might expect, not high demand is placed on *Cv_1* (parking lot usability) for educational trips, but this is an item with low levels of satisfaction for other trip purposes. In the Seoul metropolitan area, there are 154 transfer parking systems around subway stations, 138 of which are being operated as off-street parking facilities[5]. Only 16 transfer parking facilities, less than 10%, are located inside of buildings or underground in the vicinity of the subway station. In general, off-street parking means travelers have to walk further, possibly explaining this result. Younger people instead place more importance on the station environment as we find that travelers with educational purpose are less satisfied with temperature and noise in the stations. Our findings might be in line with general trends of young people becoming less attracted to private transport but instead placing higher demand on public transport service quality where they want to use their time in a pleasant environment being online. This interpretation requires though further research.

Finally, Fig. 4 shows the mean value of difficulty estimates for the five criteria groups by trip purpose. *Convenience* and *Comfort* were derived as the least satisfied services whereas *Information* is the most satisfied service category for all trip purposes. Looking from the view point of specific trip purposes, we find those on school trips assess all criteria similarly but that the five criteria are evaluated very differently by shopping travelers. This implies that there are gaps in the satisfaction of the transfer service items for shopping travelers. Considering that about 80% of the subway users with shopping purpose are women (see Table 1), it can be seen that female travelers tend to have stronger opinions regarding (dis-)satisfaction.

6. Conclusion

In this study, we evaluated the satisfaction with transfer facilities in Seoul's urban rail system by Rasch analysis. Five measurement dimensions (information, mobility, comfort, convenience and safety) with in total 17 service items are used. Separate models were built for five trip purposes (commuting, school, business, shopping and leisure). We show that the person-item map of the Rasch analytical results are capable of demonstrating how the satisfaction among urban rail users with different service aspects differ controlling for their overall ability to recognize and distinguish the quality of items.

The users' average satisfaction with the five criteria for all trip purposes are greater than zero. This means transfer travelers in Seoul are overall satisfied with the stations regardless of their trip purpose. However, shopping trip travelers have a tendency to be less satisfied. Especially items such as parking lots and baby-care facilities obtained low ratings. These results are understandable, considering that shopping travelers, mostly female in our sample, have generally more luggage to carry and are longer out increasing the need to care for children while travelling.

Considering the top three satisfied/unsatisfied service items for each trip purpose we demonstrated that service items related to transfer time such as information systems for next train arrivals are important and rated satisfactory for users almost regardless of trip purpose. We discuss that these observations are explainable given the advanced information system available in Seoul. To obtain further evidence in how far indeed an information system can improve user satisfaction this study should be repeated though in other cities with less advanced information systems.

A further main conclusion, but in line with established literature, is the importance and dissatisfaction with regards to walking distance. In Seoul this is in parts difficult to improve given the density of the public transport network and the need to build lines deep underground. Our study suggests that, when given the possibility of service redesign, walkability should be given high priority. Guo and Wilson (2011) mention that (nowadays) station design is often the result of an "architectural competition," with the emphasis on aesthetic qualities rather than the functionality of the building. Earlier reports such as MIMIC (1999) have also highlighted this conflict. Despite our results that comfort and convenience are to some degree important we suggest that overall our results emphasize the importance of functional aspects, in particular walking, or, in other words, picturesque stations are nice but the importance of aesthetics should not be overrated.

Finally, we point out that clearly stations will host all kinds of travelers, but considering that some stations will be a main hub of commuters, whereas others will be predominantly used for shopping and leisure will help to consider which infrastructure aspects are more important. We show that understanding the main type of trip purposes of travelers transferring at a particular station should be considered during the design process, therefore implicitly showing that trip purpose specific OD patterns and route choice estimation and prediction are required before the station (re-)design. We have shown that if this, possibly circular, relationship is addressed successfully, it will improve the service satisfaction.

Besides the already mentioned further work directions, we suggest that targeted analysis to specific population groups, in particular older

[4] Transport Operation & Information Service: Seoul TOPIS refers to the general transport control center responsible for operating and managing Seoul's overall traffic. http://topis.seoul.go.kr4.

[5] Webpage of MTA (metropolitan transportation Authority) : http://www.mta.go.kr/app/line_change/line_change_list.jsp?line_no=all5.

people, will be important in aging societies. In addition, we only targeted transfers occurring within urban railways, though intermodal transfers are more complex and users are less satisfied with these. We suggest the methodology proposed in this study could also be applied to such case studies.

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Appendix

A1. Item estimates and fit statistics of services for *Commute Trip*.

No	Item label	Estimates of average item difficulty (δ_i)	Infit		Outfit	
			MNSQ	Zstd	MNSQ	Zstd
6	Mobility 4	0.47	1.40	7.4	1.50	9.2
12	Convenience 1	0.42	0.61	−6.2	0.62	−6.2
15	Convenience 4	0.28	0.97	0.0	0.81	−0.5
13	Convenience 2	0.28	0.74	−3.9	0.80	−3.0
8	Comfort 1	0.22	1.16	3.1	1.19	3.7
9	Comfort 2	0.13	1.05	0.9	1.05	1.0
10	Comfort 3	0.08	0.86	−2.9	0.92	−1.7
17	Safety 2	0.00	0.96	−0.7	0.97	−0.7
7	Mobility 5	−0.02	0.83	−3.6	0.82	−3.9
14	Convenience 3	−0.03	1.05	0.8	1.01	0.2
3	Mobility 1	−0.04	0.94	−1.2	0.90	−2.1
5	Mobility 3	−0.11	1.13	2.5	1.22	4.2
16	Safety 1	−0.13	0.91	−1.9	0.92	−1.7
11	Comfort 4	−0.24	0.73	−5.8	0.72	−6.3
4	Mobility 2	−0.27	0.98	−0.4	0.98	−0.4
1	Information 1	−0.50	1.02	0.4	1.01	0.1
2	Information 2	−0.52	1.13	2.4	1.13	2.5

A2. Item estimates and fit statistics of services for *School Trip*.

No	Item label	Estimates of average item difficulty (δ_i)	Infit		Outfit	
			MNSQ	Zstd	MNSQ	Zstd
6	Mobility 4	0.63	1.51	8.6	1.75	9.9
8	Comfort 1	0.33	1.35	5.8	1.39	6.6
9	Comfort 2	0.23	1.01	0.3	1.02	0.4
12	Convenience 1	0.20	0.45	−7.2	0.52	−6.1
10	Comfort 3	0.13	0.89	−2.1	0.93	−1.2
17	Safety 2	0.12	0.86	−2.7	0.91	−1.8
13	Convenience 2	0.10	0.57	−5.2	0.71	−3.3
14	Convenience 3	0.06	1.04	0.6	1.04	0.6
7	Mobility 5	−0.01	0.90	−1.9	0.91	−1.6
16	Safety 1	−0.09	0.92	−1.4	0.91	−1.6
5	Mobility 3	−0.12	0.96	−0.6	1.03	0.5
3	Mobility 1	−0.17	0.93	−1.2	0.87	−2.5
15	Convenience 4	−0.21	0.06	−1.2	0.06	−1.2
11	Comfort 4	−0.22	0.73	−5.2	0.72	−5.4
4	Mobility 2	−0.28	0.99	−0.2	0.98	−0.3
1	Information 1	−0.29	1.09	1.4	1.06	1.2
2	Information 2	−0.43	1.03	0.6	1.00	−0.1

A3. Item estimates and fit statistics of services for *Business Trip*.

No	Item label	Estimates of average item difficulty (δ_i)	Infit		Outfit	
			MNSQ	Zstd	MNSQ	Zstd
6	Mobility 4	0.56	1.40	6.5	1.49	7.6
12	Convenience 1	0.32	0.57	−4.4	0.70	−2.9
13	Convenience 2	0.25	0.75	−2.3	0.79	−1.9
15	Convenience 4	0.24	0.26	−2.0	0.29	−1.8
9	Comfort 2	0.22	1.08	1.4	1.12	2.0

10	Comfort 3	0.20	0.83	−3.1	0.84	−2.8
8	Comfort 1	0.12	1.13	2.1	1.28	4.3
7	Mobility 5	0.06	0.73	−4.9	0.74	−4.8
5	Mobility 3	0.03	1.11	1.8	1.17	2.7
14	Convenience 3	−0.05	1.03	0.3	1.02	0.3
17	Safety 2	−0.12	0.88	−1.9	0.94	−1.1
3	Mobility 1	−0.13	0.95	−0.8	0.94	−1.0
11	Comfort 4	−0.20	0.81	−3.3	0.80	−3.4
1	Information 1	−0.33	1.13	2.0	1.09	1.4
4	Mobility 2	−0.34	0.92	−1.3	0.94	−0.9
16	Safety 1	−0.35	0.92	−1.4	0.93	−1.1
2	Information 2	−0.49	1.04	0.7	1.02	0.4

A4. Item estimates and fit statistics of services for *Shopping Trip*.

No	Item label	Estimates of average item difficulty (δ_i)	Infit		Outfit	
			MNSQ	Zstd	MNSQ	Zstd
15	Convenience 4	0.81	0.59	−1.7	0.60	−1.7
12	Convenience 1	0.66	0.71	−3.1	0.79	−2.2
8	Comfort 1	0.45	1.10	1.2	1.14	1.7
6	Mobility 4	0.28	1.28	3.0	1.18	2.1
13	Convenience 2	0.27	0.79	−2.1	0.84	−1.7
10	Comfort 3	0.10	0.98	−0.2	0.98	−0.2
14	Convenience 3	0.02	0.98	−0.2	1.00	0.0
3	Mobility 1	−0.04	0.92	−0.9	0.85	−1.9
9	Comfort 2	−0.05	1.19	2.1	1.16	1.9
7	Mobility 5	−0.12	0.71	−3.6	0.74	−3.5
11	Comfort 4	−0.12	0.83	−2.0	0.81	−2.4
17	Safety 2	−0.17	0.95	−0.5	0.90	−1.2
16	Safety 1	−0.29	0.90	−1.2	0.86	−1.8
1	Information 1	−0.31	0.96	−0.4	0.92	−0.9
2	Information 2	−0.38	1.23	2.6	1.23	2.6
5	Mobility 3	−0.49	1.38	4.0	1.42	4.6
4	Mobility 2	−0.59	1.07	0.9	0.99	−0.1

A5. Item estimates and fit statistics of services for *Leisure Trip*.

No	Item label	Estimates of average item difficulty (δ_i)	Infit		Outfit	
			MNSQ	Zstd	MNSQ	Zstd
15	Convenience 4	0.57	0.43	−2.1	0.40	−2.3
6	Mobility 4	0.52	1.44	8.4	1.65	9.9
12	Convenience 1	0.28	0.63	−5.4	0.63	−5.5
9	Comfort 2	0.28	1.14	2.8	1.23	4.5
10	Comfort 3	0.21	0.93	−1.4	0.96	−0.8
8	Comfort 1	0.17	1.11	2.2	1.15	3.0
13	Convenience 2	0.06	0.80	−2.7	0.83	−2.3
17	Safety 2	0.00	1.01	0.3	1.00	0.0
14	Convenience 3	−0.02	0.93	−1.2	0.94	−1.1
5	Mobility 3	−0.03	1.10	1.9	1.18	3.6
7	Mobility 5	−0.13	0.75	−5.4	0.75	−5.6
11	Comfort 4	−0.17	0.76	−5.3	0.73	−6.1
16	Safety 1	−0.21	0.96	−0.8	0.94	−1.2
3	Mobility 1	−0.21	0.92	−1.5	0.90	−2.0
4	Mobility 2	−0.37	1.01	0.2	1.00	0.1
1	Information 1	−0.44	0.93	−1.5	0.90	−2.1
2	Information 2	−0.50	0.96	−0.8	1.01	0.3

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