Public transport travel time perception: effects of socioeconomic characteristics, trip characteristics and facility usage

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Abstract: Perceived travel time in public transport trip directly affects passengers' satisfaction and therefore is an essential consideration when planning and operating the public transport system. However, beyond the prevalent analysis on the waiting time perception, there are few articles that have concerned the travel time perception along the entire multimodal trip. In this context, this paper presents an empirical investigation of actual and perceived travel time at each stage in a bus-rail transport trip, where first mile, in-vehicle stage, transfer stage and last mile are all considered. Data on actual and perceived travel time, socioeconomic characteristics, trip characteristics and facility usage are collected by accompany survey undertaken from passengers' originations to destinations. The results from a series of paired T-tests show that passenger do perceive travel time to be greater than the actual amount at each stage. Three linear regression models are developed for estimation of perceived walking, waiting and in-vehicle time. Results indicate that socioeconomic characteristics, trip characteristics and facility usage seem to have an impact on passengers' travel time perception, while the travel time spent on the previous stage does not affect the perception too much.

Key words: Public transport; travel time perception; socioeconomic characteristics; trip characteristics; facility usage

1. Introduction

Travel time is one of the core elements that heavily affect the passengers' opinions on the quality of public transport service (Krygsman et al., 2004). Nowadays, passengers often use more than one traffic mode or service to complete the trip. Accordingly, the total travel time includes all supplementary travel times between the origin and destination such as wait time, walking time etc. An example is shown in Figure 1, where passenger first walks from his/her home to the bus station, then takes one bus to a Massive Rapid Transit (MRT) station, after that walks to the office at last. This trip contains three traffic modes, walk, bus and MRT, with five trip stages, first mile, first main haul (bus), transfer stage, second main haul (MRT), and last mile. Correspondingly, the travel time in this trip includes out-of-vehicle time and in-vehicle time, where out-of-vehicle time contains walking time and waiting time.

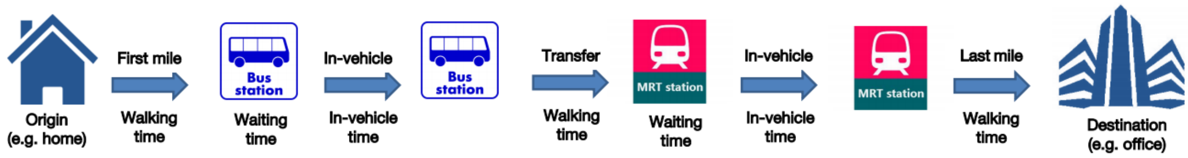


Figure 1 Trip stages and travel time in a multimodal public transport trip

Studies have found that passengers may not perceive the travel time accurately due to various factors (Hess et al. 2004; Psarros et al. 2011; Dewulf et al., 2012). Take waiting time at public transport station as an example, passengers generally expect to get on the bus as soon as possible. Being exposed to lack of comfort, crowding, and poor weather condition, passengers often perceived waiting longer than they actually spend (Beirão and Cabral, 2007). Therefore, it is more reasonable to use passengers' perceived travel time instead of actual travel time in traffic planning and operation. Currently, to our best of knowledge, existing studies on the travel time perception issue all focus on one particular trip stage and none of them has investigated the travel time perception on the basis of a complete trip (Diab et al., 2015; Meng et al., 2016). Meanwhile, most of studies put the attention on the influence of passengers' socioeconomic characteristics and trip characteristics on the travel time perception, while the influence of facility usage and the effect from the previous trip stage have not been explored clearly.

Based on the afore-mentioned concerns, the objective of this paper is to check the differences between perceived and actual travel time in a multimodal trip, and then model and quantify the perceived travel time through linear regression model. To achieve these objectives, three questions need to be discussed through the analysis from filed survey, which are: firstly, are there always perception differences for all travel time components; secondly, what factors influence the perception; thirdly, how to quantify the perceived travel time. Having established the study's motivation, the rest of the paper is structured as followed: the next section provides a brief background of past works on travel time perception. Then, a description of our methodology and presumption is given, followed by the models and results. Findings are summarised at last. The outcomes of this paper could provide foundation for other modellers and traffic plannersespecially when considering multi-modal mode choice situation in public transport system.

2. Literature Review

Travel time perception has been a hot topic of interest in public transport field as the rising importance of passenger satisfaction. Actual travel time is the clock time difference between the departure and arrival. Perceived travel time is the duration that the passenger felt that he/she was spending between the departure and arrival. Generally, the perceived travel time could be either greater or lesser than the actual travel time due to various reasons. One of the classical findings on time perception by Vierordt (1868) was that short activities were usually overestimated while long activities were usually underestimated. Many similar studies were conducted on the topic of time perception (Yarmey, 2000; Block and Gruber, 2014), in which the studies on travel time perception have made extraordinary progress. Table 1 listed most of the represented studies on travel time perception in recent years.

Table 1 Summary of studies on passengers' travel time perception

Author & year	Study item	City	Sample size	Survey method	Results	Influence factors
Yarmey, 2000	Waiting time	Guelph, Canada	1015	Laboratory experiments	Repeated experience could help traveller to correctly estimate the waiting time.	Travel experience
Hall, 2001	Waiting time	Los Angeles, USA	1199	Field survey	Passengers who have the knowledge of the schedule perceived waiting 3.57 min less than passengers who don't have the knowledge.	Age, language groups and trip types
Hess et al. 2004	Waiting time	Los Angeles, USA	N.A.	Field survey	Passengers perceived that they spend 5.3 min more than the actual waiting time, and the standard deviation of additional wait time was 3.3 min.	N.A.
Walle and Steenberghen, 2006	Walking time, waiting time	Belgium	About 7,000	Nation-wide mobility survey	Perceived waiting and walking time will affect the public transport usage.	N.A
Mishalani et al., 2006	Waiting time	Columbus, USA	83	Field survey	The average overestimation of waiting time is 0.84 min.	Actual waiting time, walking time before waiting
Beirão and Cabral, 2007	Waiting time	Porto, Portugal	24	Qualitative method	Waiting time is perceived as too long, which is a barrier to public transport use	N.A.
Daskalakis and Stathopoulos,	Waiting time	Athens, Greece	300	Field survey	Passengers perceive waiting time differently from the actual time	N.A.

2008					for reasons such as being exposed to adverse weather conditions, the surrounding environment, and the experience of being stressed by waiting anxiety	
Fan and Machemehl, 2009	Waiting time	Texas, USA	6-month period	Direct observation	An 11-min vehicle headway was identified to mark the transition from practically random to less random passenger arrivals.	Bus line headway
Psarros et al. 2011	Waiting time	Athens, Greece	Over 1,000	Field survey	The ratio of average perceived to average actual waiting time is in a range varies from 1.35 to 2.03 according to time period, gender, age groups and trip purposes.	Actual waiting time, age, trip purpose, trip time period.
Watkins et al., 2011	Waiting time	Washington D.C., USA	655	Field survey	Passengers using traditional arrival information perceive that they are waiting 0.83 min (15%) longer .than they are, while passengers using real-time arrival information perceive more accurate.	Availability of real-time information, peak period, buses per hour, aggravation level.
Yoh et al., 2011	Waiting time	California, USA	2,247	Field survey	Waiting time was paramount to passengers through more than 2000 passenger surveys. Influence factors varied for different waiting time.	Lighting, cleanliness, information, shelter, and the presence of guards.
Dewulf et al., 2012	Walking time	Ghent, Belgium	1,164	Field survey	Low-level walkers tended to overestimate walking time	Physical activity, neighbourhood walkability, and socio-demographic characteristics.

Millonig and Sleszynski, 2012	Waiting time	Innsbruck, Wiener Neustadt and Linz, Austria	1,215	Field survey	With increasing time spent on the station, people generally tend to stronger underestimate the waiting time.	Station characteristics and user characteristics
Parthasarathi et al., 2013	Waiting time	The Twin Cities, USA	273	Field survey	Network design influences passengers' perceptions, more specifically the perceptions of distance/travel time.	Network design, like relative discontinuity, P2A (Perimeter to Area), Street density, Intersection density.
Cheng and Tsai, 2014	Waiting time	Taiwan	992	Field survey	Certain scenarios can reduce certain passengers' perceived waiting time in the case of a train delay.	Age, gender, educational level, monthly income, and train-riding frequency.
Cascetta and Carteni, 2014	Transit services quality	Campania, Italy	908	Field survey	Passengers with different occupation have different waiting time perception.	Occupation
Varotto et al., 2015	Total travel time	Trieste	3,967	Field survey	The means of perceived and actual travel time do not match for any modes. Perceived travel time is overestimated compared to the actual for all modes except walk.	N.A.
Lagune-Reutler et al., 2016	Waiting time	The Twin Cities, USA	800	Field survey	Passengers tend to overestimate their waiting times by 18%, with a mean perceived wait time of 6.4473 min and a mean actual wait time of 5.4809 min.	Air pollution, traffic awareness, presence of mature trees
Fan et al., 2016	Waiting time	Minneapolis and St. Paul, USA	822	Field survey	Perceived waiting time is about 1.21 times longer than the actual waiting time on average.	Basic amenities (bench and sehlter), gender

Nesheli et al., 2016	Tolerated/ waiting time	Auckland, New Zealand, and Lyon, France	611	Field survey	Operational tactics will affect the passengers' tolerate/waiting time perception	Operational tactics including holding, skipping, and boarding limits
Ji et al., 2017	Waiting time	Nanjing, China	1,031	Field survey	Waiting time at stops with no amenities could be perceived over twice as long as passengers really spend.	Stop amenities, including bench, shelter, and real-time information sign device

It can be seen from Table 1 that perceived waiting time has been deeply discussed. A general conclusion has been concluded that passengers are easy to perceive more than the actual time when waiting for a public transport service, especially no real-time traffic information is provided (Cheng and Tsai, 2014). The influence factors that affect the waiting time perception vary city by city, where the most common factors are age and peak period. Several studies also found that perceived walking time was often an overestimation of the actual walking time. Influence factors that affect this overestimation may include physical aspects of transfer facilities, such as signage, lighting, circulation lines and characteristics of the surrounding environment (Hall, 2001). Moreover, transfer walking time has shown to be more onerous than first and last mile walking time.

Compared with the burdensome out-of-vehicle time, passengers tend to consider in-vehicle time more acceptable (Chapman et al., 2006). As in-vehicle time is mostly determined by scheduled journey time and vehicle speeds, researchers generally quantity and quality of the value of in-vehicle time in generalised cost equations and the evaluation of stop delay. Little studies have been conduct to check whether there is difference between perceived and actual in-vehicle time.

Overall, these estimations only focused on the single stage analysis (e.g. transfer stage), which doesn't consider the possible causation from other stages. Moreover, some studies used the data from the surveys that conducted sometime later (few hours or one day) after the trip, which is not reliable. This research contributes to the existing literature by examining the relationship between actual and perceived travel time in a multimodal public transport trip, including walking time, waiting time and in-vehicle time with considering the connection of different stages in the whole trip.

3. Field Survey

Data were collected by accompany survey through following the respondent from origin to destination. Respondents were selected by the surveyors from either their relatives/friends or the random persons around public transport stations. Surveyor firstly asked the respondent's willingness to participate in this survey, and then made an agreement on the survey time and location. During the trip, the surveyor followed the respondent all the way to the destination. The trip is required to be the respondent's frequent trip, which ensures that the respondent is familiar with all the trip segments. Some rules have been made to ensure the trip to be as natural as possible, such as minimise chatting with the respondent except questioning, follow the respondent behind and not side by side, try to measure the actual time without the respondent knowing.

Detailed information were recorded including trip start and end time, date, weather, location, trip purpose and facility usage in the trip, as well as socioeconomic attributes like age, gender, occupation. Actual travel time at each stage was measured by stopwatch, while perceived travel time at each stage was recorded by asking the respondent right after each action performed. Below are the variables and the corresponding data input codes that are used in the survey:

1. Perceived walking time, actual waiting time and actual in-vehicle time at each stage (continuous variable);
2. Actual walking time, actual waiting time and actual in-vehicle time at each stage (continuous variable);
3. Travel distance (continuous variable);
4. Travel Date (Travel Date =0:weekdays, and Travel Date =1:weekend);
5. Weather (Weather =0: poor weather, like cloudy, drizzle, and rainy, Weather =1: sunny);
6. Purpose (Purpose =0: non-commuter trip, to home/recreation/personal business, to work/school, Purpose =1: commuter trip);
7. Age (Age =0: <20, Age =1: 21-30, Age =2: 31-40, Age =3: 41-50, Age =4: >51);
8. Gender (Gender =0: male and Gender =1: female);
9. Occupation (Occupation =0: employment, Occupation =1: non-employment, like student, housewife, and retired);
10. Number of transfer (Number of transfer =0: one transfer, Number of transfer =1: two transfer);
11. Travel mode (Travel mode =0: MRT-based trip, Travel mode =1: bus-based trip);
12. Travel period (Travel period =0: peak hour, 6:30 to 9:00 and 17:00 to 19:30, and Travel period =1: off peak);
13. Facilities usage related with walking;
    a. Covered shelter or coved facility (Covered shelter =0: yes, and Covered shelter =1: no);

b. Elevator or escalator (Elevator =0: yes, and Elevator =1: no);

c. Stairs (Stairs =0: yes, and Stairs =1: no);

d. ATM or stores (ATM =0: yes, and ATM =1: no);

14. Facilities usage related with waiting;

a. Arrival time panel or other information system (Information =0: yes, and Information =1: no);

b. Seat (Seat =0: yes, and Seat =1: no);

c. Aircon environment (Aircon =0: yes, and Aircon =1:no).

The survey was undertaken from December 2015 to February 2016. In total, 437 available trips (316 trips with 1 time transfer only, 109 trips with 2 times transfer, and 12 trips with 3 times transfer) were collected. Considering the small portion of 3 times transfer trips, 425 data of 1 time and 2 times transport trips were used in the analysis and modelling.

Preliminary statistical analysis revealed a relative balance between male and female passengers 46% versus 54% according to the national proportion 49% versus 51%. Travellers' age and distribution are also in line with the national household travel survey results, where the youth, adult and elderly account for 24%, 59% and 17% respectively, and the employed traveller accounts for 52% in all travellers. 50% of the trips were for commute purpose, which is not slight less than the results from national household travel survey (73%). It is not surprisingly as the passengers prefer to be followed during non-peak period.

Considering the total travel time, as shown in Figure 2, the average actual and perceived travel time are 66.2 and 69.6 min, respectively. The out-of-vehicle time accounts for 40.3% and 41.8% in average actual and perceived travel time. Breaking the perceived out-of-vehicle time down even further, traveller usually perceived that he/she walks 5.4 min (7.7%) and waits 6.0 min (8.6%) in first mile, walks 4.1 min (6.0%) and waits 6.8 min (9.8%) during transfer and walks 6.8 min (9.8%) in last mile. The significant amount of transfer travel time with a proportion of 18.4% of total travel time clearly shows the importance of transfer in total travel time, which has been also reported in other studies (Anderson et al., 2014; Debrezion et al., 2009).

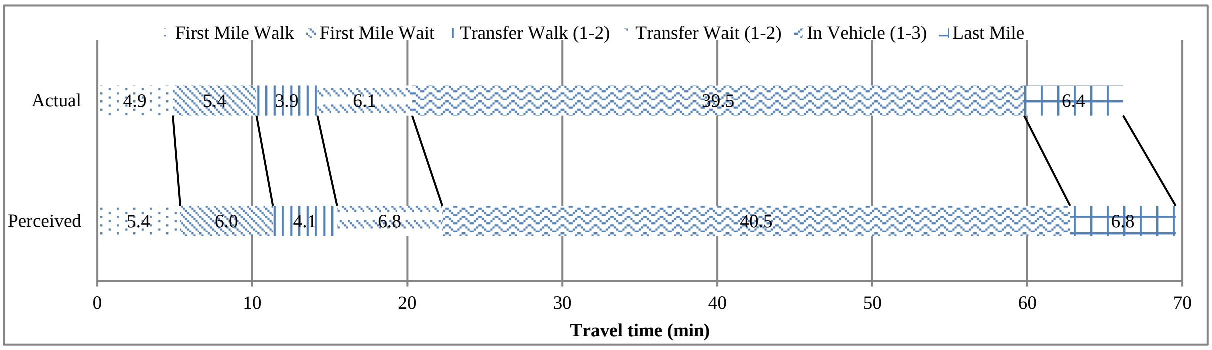


Figure 2 Actual and perceived travel Time at each trip segment

Table 2 summarises the perceived and actual average travel time at each stage for different sociological attributes and trip characteristics. By inspecting Table 2 results, in general, perceived travel time is greater than the actual travel time at each stage. Passengers have more accurate perception while in-vehicle compared with out-of-vehicle. Specifically, passengers usually perceive more during waiting than walking (1.11 and 1.11 versus 1.10, 1.05 and 1.07). The overall analysis could provide qualitatively understanding of the perceptions by specific groups. Such as, women tend to overestimate their walking time, waiting time and in-vehicle time than men.

Table 2 Perceived and actual average travel time (in min) for different sociological attribute and trip characteristics

	AFMK	PFMK	**PFMK/ AFMK**	AFMT	PFMT	**PFMT/ AFMT**	AIV	PIV	**PIV/ AIV**
Age									
<20	5.05	5.60	**1.11**	5.54	5.92	**1.07**	38.45	38.98	**1.01**
20-30	4.95	5.35	**1.08**	5.54	6.11	**1.10**	42.32	43.55	**1.03**
31-40	5.10	5.81	**1.14**	4.93	5.52	**1.12**	37.59	37.80	**1.01**
41-50	5.01	5.34	**1.07**	6.20	6.70	**1.08**	40.39	41.23	**1.02**
>51	3.68	4.31	**1.17**	4.26	5.29	**1.24**	28.47	30.51	**1.07**
Gender									
Men	4.98	5.35	**1.07**	5.61	6.16	**1.10**	42.10	43.18	**1.03**
Women	4.77	5.35	**1.12**	5.22	5.83	**1.12**	37.35	38.31	**1.03**
Purpose									
To work/ school	4.83	5.17	**1.07**	6.00	6.85	**1.14**	43.85	44.73	**1.02**
Other	4.88	5.40	**1.11**	5.23	5.75	**1.10**	38.34	39.39	**1.03**
Occupation									
Employed	5.06	5.66	**1.12**	5.09	5.77	**1.13**	37.27	38.43	**1.03**
Others	4.71	5.11	**1.08**	5.63	6.14	**1.09**	41.23	42.13	**1.02**

Peak									
Peak hour	4.83	5.28	**1.09**	5.28	5.93	**1.12**	40.31	41.80	**1.04**
Off-peak hour	4.89	5.40	**1.10**	5.47	6.01	**1.10**	38.95	39.66	**1.02**
Date									
Weekend	4.77	5.27	**1.10**	5.42	6.05	**1.12**	40.00	41.24	**1.03**
Weekdays	5.11	5.54	**1.08**	5.33	5.80	**1.09**	38.20	38.67	**1.01**
Total	4.87	5.35	**1.10**	5.40	5.98	**1.11**	39.48	40.50	**1.03**

	ATRK	PTRK	**PTRK/ ATRK**	ATRT	PTRT	**PTRT/ ATRT**	ALMK	PLMK	**PLMK/ ALMK**
Age									
<20	3.38	3.75	**1.11**	6.21	6.47	**1.05**	6.51	6.72	**1.03**
20-30	3.78	3.90	**1.03**	6.60	7.45	**1.12**	6.50	6.90	**1.06**
31-40	4.04	4.18	**1.03**	5.11	5.45	**1.09**	6.37	7.02	**1.10**
41-50	4.24	4.38	**1.03**	6.43	7.38	**1.12**	6.35	6.88	**1.08**
>51	4.95	5.62	**1.14**	4.62	5.26	**1.19**	5.74	6.04	**1.05**
Gender									
Men	3.86	4.09	**1.06**	5.94	6.47	**1.09**	6.27	6.53	**1.04**
Women	3.98	4.19	**1.05**	6.32	7.18	**1.14**	6.48	7.03	**1.08**
Purpose									
To work/ school	4.23	4.57	**1.08**	6.45	7.25	**1.12**	6.95	6.99	**1.01**
Other	3.85	4.03	**1.05**	6.02	6.67	**1.11**	6.24	6.76	**1.08**
Occupation									
Employed	4.12	4.42	**1.07**	5.57	6.28	**1.13**	6.26	6.85	**1.09**
Others	3.77	3.92	**1.04**	6.53	7.19	**1.10**	6.49	6.77	**1.04**
Peak									
Peak hour	4.16	4.33	**1.04**	6.24	6.98	**1.12**	6.69	7.08	**1.06**
Off-peak hour	3.78	4.02	**1.06**	6.02	6.66	**1.11**	6.20	6.63	**1.07**
Date									
Weekend	3.93	4.16	**1.06**	6.05	6.73	**1.11**	6.47	6.73	**1.04**
Weekdays	3.92	4.10	**1.05**	6.25	6.92	**1.11**	6.19	6.98	**1.13**
Total	3.93	4.14	**1.05**	6.11	6.79	**1.11**	6.39	6.81	**1.07**

AFMK: Actual first mile walking time; PFMK: Perceived first mile walking time; AIV: Actual in-vehicle travel time; PIV: Perceived in-vehicle travel time; ATRK: Actual transfer walking time; PTRK: Perceived transfer walking time; ALMK: Actual last mile walking time; PLMK: Perceived last mile walking time.

To check if there is difference between the actual and perceived travel time for walking, waiting and in-vehicle time, a series of paired T-test is used. The hypothesis is that there is no difference between the actual travel time and perceived travel time for all travel time components in the public transit trip:

$$H_0:\ \mu_{\text{percieved time}} - \mu_{\text{actual time}} = 0 \quad (1)$$

From the results of the series of T-test in Table 3, the hypotheses that the perceived travel time at each stage is equal to the corresponding actual travel time are rejected. Taking the first mile walking time analysis as an example, as the p-value is less than 0.05 (< 0.0001), it can be concluded that there is a statistically significant difference between the perceived first mile walking time and the actual first mile walking time. In other words, the difference between the perceived first mile walking time and the actual first mile walking time is not equal to zero. There is a mean 0.48 min difference between the perceived first mile walking time and the actual first mile walking time with a standard deviation of 1.42 min and 95% confidence intervals of 0.35 to 0.62.

Table 3 Results of T-test for each trip stage

Variable	Mean	Std. Dev	95% CL Mean
First mile walking time			
Actual	4.87	3.38	4.55-5.19
Perceived	5.35	3.97	4.97-5.73
Difference	0.48	1.42	0.35-0.62
No. observations = 425, t=7.01, Pr(T>t) < 0.0001			
First mile waiting time			
Perceived	5.39	3.76	5.03-5.75
Actual	5.98	4.26	5.57-6.38
Difference	0.59	1.50	0.44-0.73
No. observations = 425, t=8.05, Pr(T>t) < 0.0001			
First transfer walking time			
Actual	2.96	2.44	2.73-3.19
Perceived	3.12	2.66	2.87-3.37
Difference	0.16	1.01	0.06-0.26
No. observations = 425, t=3.25, Pr(T>t) =0.0012			
First transfer waiting time			
Actual	4.99	3.92	4.62-5.36
Perceived	5.55	4.56	5.12-5.99
Difference	0.56	1.57	0.41-0.71
No. observations = 425, t=7.40, Pr(T>t) < 0.0001			

Second transfer walking time			
Actual	3.77	1.83	3.42-4.12
Perceived	3.99	2.07	3.59-4.38
Difference	0.22	0.95	0.04-0.40
No. observations = 109, t=2.38, Pr(T>t) =0.019			
Second transfer waiting time			
Actual	4.36	3.55	3.68-5.03
Perceived	4.82	3.87	4.08-5.55
Difference	0.46	1.18	0.24-0.69
No. observations = 109, t=4.07, Pr(T>t) < 0.0001			
First in-vehicle time			
Actual	16.48	13.31	15.21-17.75
Perceived	17.03	13.92	15.70-18.36
Difference	0.55	2.54	0.30-0.79
No. observations = 425, t=4.43, Pr(T>t) < 0.0001			
Second in-vehicle time			
Actual	20.40	14.66	19.00-21.80
Perceived	20.93	15.09	19.49-22.37
Difference	0.53	2.88	0.26-0.81
No. observations = 425, t=3.81, Pr(T>t) =0.0002			
Third in-vehicle time			
Actual	10.13	8.77	8.46-11.79
Perceived	10.64	8.57	9.01-12.27
Difference	0.25	1.71	0.07-0.58
No. observations = 109, t=3.41, Pr(T>t) =0.0009			
Last mile walking time			
Actual	6.39	4.89	5.92-6.85
Perceived	6.81	5.63	6.27-7.34
Difference	0.42	2.03	0.22-0.61
No. observations = 425, t=4.23, Pr(T>t) < 0.0001			

Then we analyse the total walking, waiting and in-vehicle time by considering it at all relevant stages. As shown in Table 4, the hypothesis that the perceived total walking time is equal to the actual total walking time is rejected, same for total waiting time and total in-vehicle time. On average, passenger perceives that he/she is walking 1.12 min and waiting 1.27 min longer and spending in-vehicle 1.02 min longer than he/she actually is. From this, we can answer the first research question that there are always perception differences for all travel time components.

Table 4 Results of T-test for all relevant stages

Total walking time			
Actual	15.18	7.06	14.51-15.86
Perceived	16.30	8.13	15.52-17.07
Difference	1.12	3.04	0.83-1.41
No. observations = 425, t=7.56, Pr(T>t) < 0.0001			
Total waiting time			
Actual	11.50	6.69	10.86-12.14
Perceived	12.77	7.66	12.04-13.50
Difference	1.27	2.48	1.03-1.50
No. observations = 425, t=10.54, Pr(T>t) < 0.0001			
Total in-vehicle time			
Actual	39.48	18.24	37.74-41.22
Perceived	40.50	18.69	38.71-42.28
Difference	1.02	4.25	0.74-1.54
No. observations = 425, t=4.92, Pr(T>t) < 0.0001			

4. Linear Regression Model

Modelling the travel time component on each trip stage is not instructive to planners. For example, traveller A's first transfer stage might be the second transfer stage for traveller B. To quantify the perceived travel time, it is reasonable to model the same travel time component by considering it at different stages. An issue arises naturally, that is, whether or not the travel time experienced before the trip stage will affect the travel time perception on this stage. For example, will the actual first transfer walking time affect the first transfer waiting time perception? A set of correlation analysis is applied, in which the dependent variables include all the perceived travel time at each stage. As shown in Table 5, the perceived travel time is only highly correlated to the actual travel time at the current stage (Pearson correlation coefficient >0.9 and p-value < 0.0001). Hence, we can conclude that the travel time perception at the current stage is very little (or hardly) affected by the travel time experienced in previous stage. Therefore, we can model the same travel time component perception by adding it from all relevant trip stages, e.g. waiting time at each stage.

Table 5 Results of correlation analysis

Variable	Pearson Correlation Coefficient	p-value
Perceived first mile walking time		
Actual first mile walking time	**0.93756**	**<0.0001**
Perceived first mile waiting time		
Actual first mile walking time	0.03366	0.4889
Actual first mile waiting time	**0.93745**	**< 0.0001**
Perceived first in-vehicle time		
Actual first mile walking time	0.11132	0.0217
Actual first mile waiting time	0.26693	< 0.0001
Actual first in-vehicle time	**0.98355**	**< 0.0001**
Perceived first transfer walking time		
Actual first mile walking time	-0.05968	0.2195
Actual first mile waiting time	-0.21079	< 0.0001
Actual first in-vehicle time	-0.17983	0.0002
Actual first transfer walking time	**0.92523**	**< 0.0001**
Perceived first transfer waiting time		
Actual first mile walking time	0.14043	0.0037
Actual first mile waiting time	0.37727	< 0.0001
Actual first in-vehicle time	0.29774	< 0.0001
Actual first transfer walking time	0.26189	< 0.0001
Actual first transfer waiting time	**0.94290**	**< 0.0001**
Perceived second in-vehicle time		
Actual first mile walking time	-0.04974	0.3063
Actual first mile waiting time	0.16569	0.0006
Actual first in-vehicle time	-0.17834	0.0002
Actual second transfer walking time	-0.11357	0.2396
Actual second transfer waiting time	0.05461	0.5727
Actual second in-vehicle time	**0.98170**	**< 0.0001**
Perceived second transfer walking time		
Actual first mile walking time	0.08520	0.3784
Actual first mile waiting time	0.11447	0.2359
Actual first in-vehicle time	-0.02417	0.8030
Actual first transfer walking time	0.26252	0.0058
Actual first transfer waiting time	-0.04005	0.6792
Actual second in-vehicle time	-0.15403	0.1098
Actual second transfer walking time	**0.91877**	**< 0.0001**
Perceived second transfer waiting time		
Actual first mile walking time	0.13770	0.1533
Actual first mile waiting time	0.12569	0.1928
Actual first in-vehicle time	-0.01072	0.9119
Actual first transfer walking time	0.11415	0.2372

Actual first transfer waiting time	0.26168	0.0060
Actual second in-vehicle time	0.00632	0.9480
Actual second transfer walking time	0.02574	0.7905
Actual second transfer waiting time	**0.95280**	**< 0.0001**
Perceived third in-vehicle time		
Actual first mile walking time	0.01298	0.8934
Actual first mile waiting time	0.02812	0.7716
Actual first in-vehicle time	0.03470	0.7201
Actual first transfer walking time	-0.08174	0.3981
Actual first transfer waiting time	-0.03075	0.7509
Actual second in-vehicle time	-0.08988	0.3526
Actual second transfer walking time	-0.08958	0.3543
Actual second transfer waiting time	0.16131	0.0938
Actual third in-vehicle time	**0.98081**	**< 0.0001**
Perceived last mile walking time		
Actual first mile walking time	0.19081	< 0.0001
Actual first mile waiting time	0.14573	0.0026
Actual first in-vehicle time	0.06524	0.1795
Actual first transfer walking time	0.05324	0.2735
Actual first transfer waiting time	0.07161	0.1405
Actual second in-vehicle time	0.02769	0.5691
Actual second transfer walking time	0.20837	0.0297
Actual second transfer waiting time	-0.02058	0.8318
Actual third in-vehicle time	-0.11593	0.2300
Actual last mile walking time	**0.93486**	**< 0.0001**

A set of scatter plot diagrams is given in Figure 3 to show the general relationship between the perceived travel time and actual travel time. It could be found that there is a strong linear relationship between the perceived travel time and actual travel time for all travel time component. Therefore, to find out which factor could affect the travel time perception, and how to quantify the perception, three linear regression models can be developed to quantify the perceived walking, waiting and in-vehicle time based on the actual walking, waiting and in-vehicle time, as well as other potential influence factors. Stepwise selection method in SAS® (a statistical analysis system) is used to determine the final models:

$$y_k = \beta_{1\mathrm{k}} x_{1\mathrm{k}} + \beta_{2\mathrm{k}} x_{2\mathrm{k}} + \beta_{3\mathrm{k}} x_{3\mathrm{k}} + \cdots \beta_{nk} x_{nk} + \varepsilon_k \tag{2}$$

$$y_t = \beta_{1\mathrm{t}} x_{1\mathrm{t}} + \beta_{2\mathrm{t}} x_{2\mathrm{t}} + \beta_{3\mathrm{t}} x_{3\mathrm{t}} + \cdots \beta_{nt} x_{nt} + \varepsilon_t \tag{3}$$

$$y_i = \beta_{1\mathrm{i}} x_{1\mathrm{i}} + \beta_{2\mathrm{i}} x_{2\mathrm{i}} + \beta_{3\mathrm{i}} x_{3\mathrm{i}} + \cdots \beta_{ni} x_{ni} + \varepsilon_i \tag{4}$$

where y_k, y_t and y_i are the dependent variables and represent perceived walking, waiting and in-vehicle time respectively. $\beta_{1k} \dots \beta_{nk}$, $\beta_{1t} \dots \beta_{nt}$, $\beta_{1i} \dots \beta_{ni}$ are the coefficients of independent variables, ε_k, ε_t, ε_i are the error terms, $x_{1k} \dots x_{nk}$, $x_{1t} \dots x_{nt}$, $x_{1i} \dots x_{ni}$ are the independent variables which are the variables 2-14 as listed in section 3.

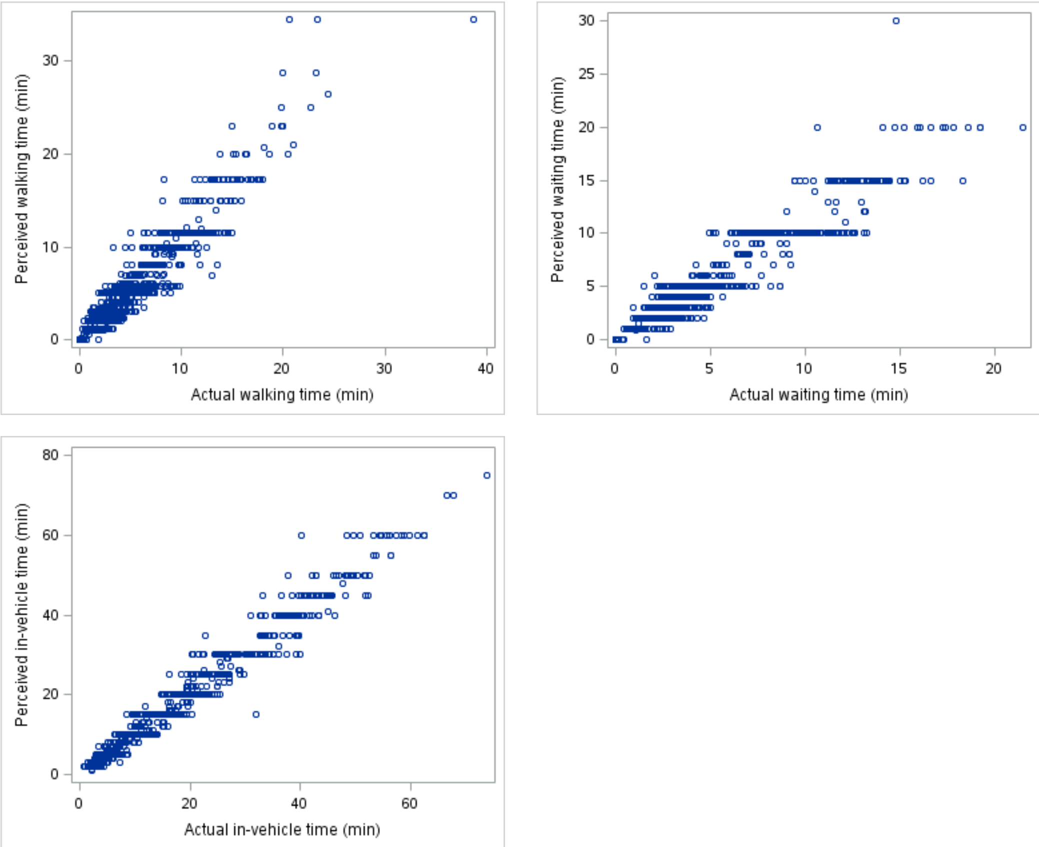


Figure 3 A set of scatter plot diagrams

4.1 Perceived Walking Time Modelling

The influencing variables related with the walking stage are included in the modelling by stepwise selection method. A stepwise method is a proper method for this analysis because of finding the best combination of the attributes by adding and removing the attributes until the selection model achieved based on the predefined requirements. It automatically selects the variable to be added to or removed from the model of regression analysis. Selection stopped when the candidate for entry has SLE (significance level for entry into the model) > 0.05 and the candidate for removal has SLS (Significance Level for Staying in the model) < 0.05. Apart from automatic selection option in SAS, the variables are also put into the model one by one together with the variable Distance to check the impact on time perception in short and long trips. Possible interaction terms (based on statistical and practical considerations) such as Distance*Age and Distance*Gender also were checked. The steps were repeated until there were no other variables that could improve the adjusted R^2 of the model. The final results in Table 6 show that actual walking time, travel distance, occupation, elevator usage, weather, trip purpose and covered shelter usage will affect the perception of walking time. The estimated model is listed in Table 7 with an overall adjusted R^2 0.9512. The model performs well on the diagnostic tests. On average, passenger perceives he/she is walking 1.0743 min for every minute he/she actually walks. Long distance trip decreases the walking perception. Moreover, passenger perceives that he/she is walking 0.2069 min more if the weather is poor, 0.2632 min less if the trip is for non-commuter purpose, 0.1962 min less if he/she uses elevator and 0.1760 less if he/she uses covered sheltered. Employment group perceives walking 0.2232 min more than non-employment group. According to the results, it is necessary to provide elevator at MRT stations to minimise passengers' walking time perception.

Table 6 Stepwise selection results

Variable	Adjusted R^2	*t*- Statistic	*p*-value
Actual walking time	0.9501	26350.3	<.0001
Distance	0.9502	4.18	0.0412
Occupation	0.9506	6.96	0.0010
Elevator	0.9508	4.47	0.0346
Weather	0.9509	4.29	0.0385
Purpose	0.9511	6.05	0.0140
Covered shelter	0.9512*	4.06	0.0442

* Optimal Value of Criterion

Table 7 Estimation results for perceived walking time

Variable	Coefficient	Std. Err	*t*- Statistic	*p*-value
Actual walking time	1.0743	0.0103	103.87	<.0001
Distance	-0.0192	0.0060	-3.20	0.0014
Occupation 0 (ref Occupation =1)	0.2232	0.0817	2.73	0.0064
Elevator 0 (ref Elevator =1)	-0.1962	0.0812	-2.42	0.0159
Weather 0 (ref Weather =1)	0.2069	0.0809	2.56	0.0107
Purpose 0 (ref Purpose =1)	-0.2632	0.1022	-2.57	0.0101
Covered shelter 0 (ref Covered shelter =1)	-0.1760	0.0874	-2.01	0.0442
No. observations = 1384, Adj R^2 = 0.9514, F value =3370.58, Pr(T>t) <0.0001				

4.2 Perceived Waiting Time Modelling

Similarly, the results in Table 8 show that actual waiting time, age, trip distance and arrival time panel usage will affect the perception of waiting time. The estimated model is listed in Table 9 with an overall adjusted R^2 0.9586. On average, passenger perceives he/she is waiting 1.0738 min for every minute he/she actually waits. Long distance trip decreases the waiting time perception. Youth generation tends to perceive waiting less than the elderly. If passenger has the access to the arrival information, he/she perceives waiting 0.2678 min less. From the insignificant variables, it could be found that the number of transfer times will not affect the waiting time perception. It means that the perception difference may not relevant to the standing location in the trip. Meanwhile, unlike some other research outcomes, the results indicate that gender and trip purpose do not affect the waiting time perception. For operators, arrival information board with real time traffic information is needed to facilitate passengers waiting at the public transport stations.

Table 8 Stepwise selection results

Variable	Adjusted R^2	*t*- Statistic	*p*-value
Actual waiting time	0.9576	21637.7	<.0001
Age	0.9580	2.85	0.0146
Distance	0.9581	4.26	0.0393
Information	0.9583*	4.44	0.0354

* Optimal Value of Criterion

Table 9 Estimation results for perceived waiting time

Variable	Coefficient	Std. Err	*t*- Statistic	*p*-value
Distance	-0.0170	0.0072	-2.36	0.0186
Actual waiting time	1.0738	0.0128	83.63	<.0001
Age 0 (ref Age=4)	-0.5972	0.2015	-2.96	0.0031
Age 1 (ref Age=4)	-0.2049	0.1701	-1.20	0.2289
Age 2 (ref Age=4)	-0.3618	0.1947	-1.86	0.0635
Age 3 (ref Age=4)	-0.2330	0.2072	-1.12	0.2612
Information 0 (ref Information =1)	-0.2678	0.1271	-2.11	0.0354
No. observations = 959, Adj R^2 = 0.9586, F value=2752.93, Pr(T>t) <0.0001				

4.3 Perceived In-vehicle Time Modelling

The results in Table 10 show that only actual in-vehicle time and peak hour will affect the perception of in-vehicle time. The estimated model is listed in Table 11 with an overall adjusted R^2

0.9669. On average, passenger perceives he/she is spending 1.019 min for every minute he/she actually spends in vehicle. Passenger perceives spending 0.3410 min more if the trip is conducted in peak hours. From the insignificant variables, it could be found that socioeconomic characteristics factors and facility usage factors do not affect the in-vehicle travel time perception.

Table 10 Stepwise selection results

Variable	Adjusted R^2	*t*- Statistic	*p*-value
Actual in-vehicle time	0.9668	27912.6	<.0001
Travel period	0.9669*	3.89	0.0490

* Optimal Value of Criterion

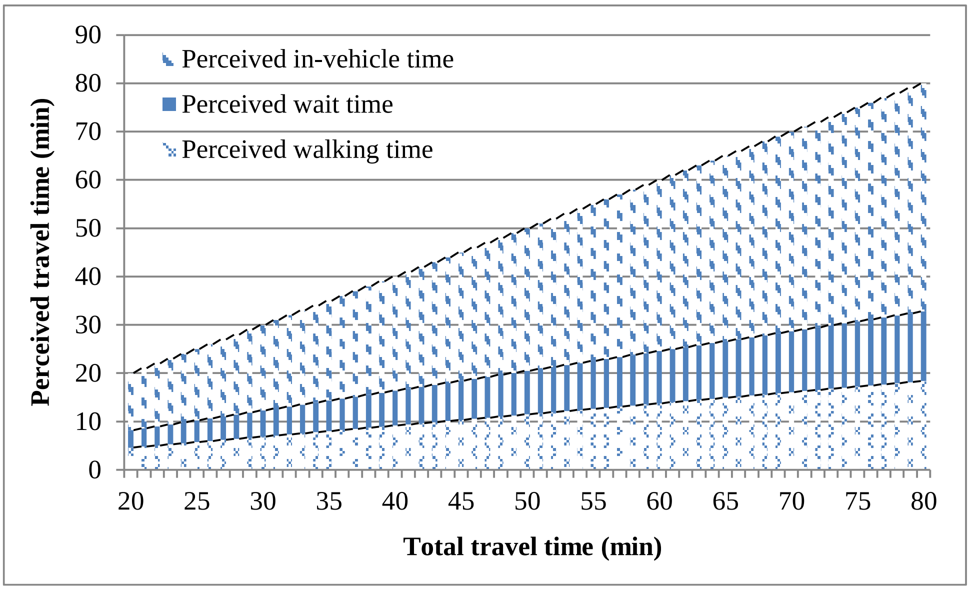
Table 11 Estimation results for perceived in-vehicle time

Variable	Coefficient	Std. Err	*t*- Statistic	*p*-value
Actual in-vehicle time	1.019	0.0061	167.26	<.0001
Travel period 0 (ref Travel period =1)	0.3410	0.1730	1.97	0.0490
No. observations = 959, Adj R^2 = 0.9669, F value=1400.3, Pr(T>t) <0.0001				

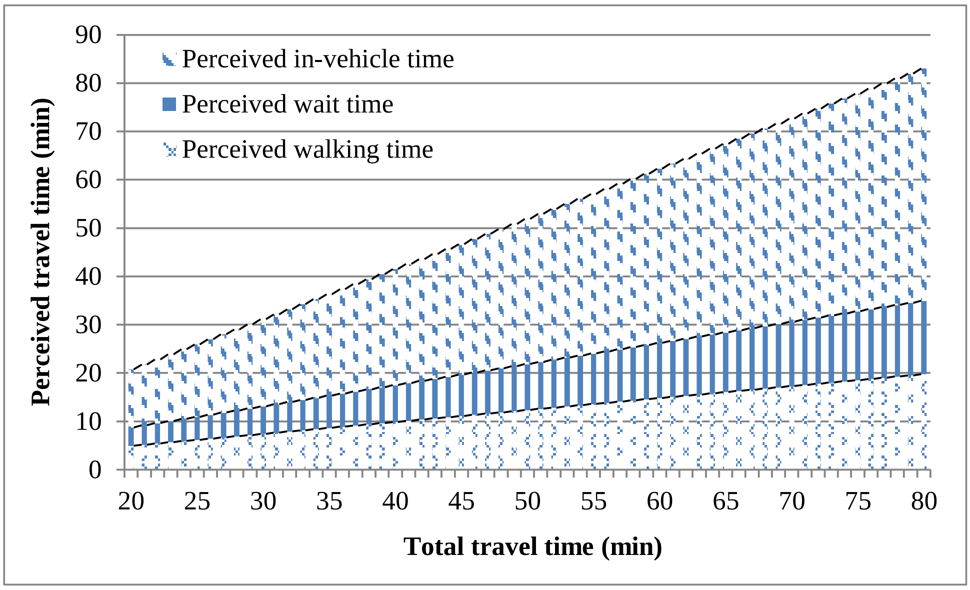
4.4 Model Prediction

The above analysis has answered our proposed three research questions. To use the models in the planning phase, we first calculate the average proportion of each travel time component in total travel time based on figures from Figure 2. The average proportion of walking time, waiting time and in-vehicle time are 23%, 17% and 60% of average total travel time. Therefore, we can estimate the average perceived travel time at each stage if the average total travel time is given. For example, if the average total travel time is observed around 45 min, then the average actual walking, waiting and in-vehicle time are 10.35 min, 8.10 min, and 26.55 min, respectively. Based on Tables 5, 7 and 9, the corresponding perceived walking, waiting and in-vehicle time could be estimated. Figure 3 clearly illustrates the prediction of average perceived walking time, perceived waiting time and perceived in-vehicle time based on the total travel time, in which the total travel time ranges from 20 min to 80 min. The actual travel time distribution is given in Figure 3(a). The basic scenario in Figure 3(b) only considers the influence of actual travel time at each trip stage while the scenario in Figure 3(c) takes the maximum effect from socioeconomic characteristics, trip characteristics and facility usage into account. For the 45 min trip, if the influences from socioeconomic characteristics, trip characteristics and facility usage are not considered, perceived walking, waiting and in-vehicle time will be 11.12

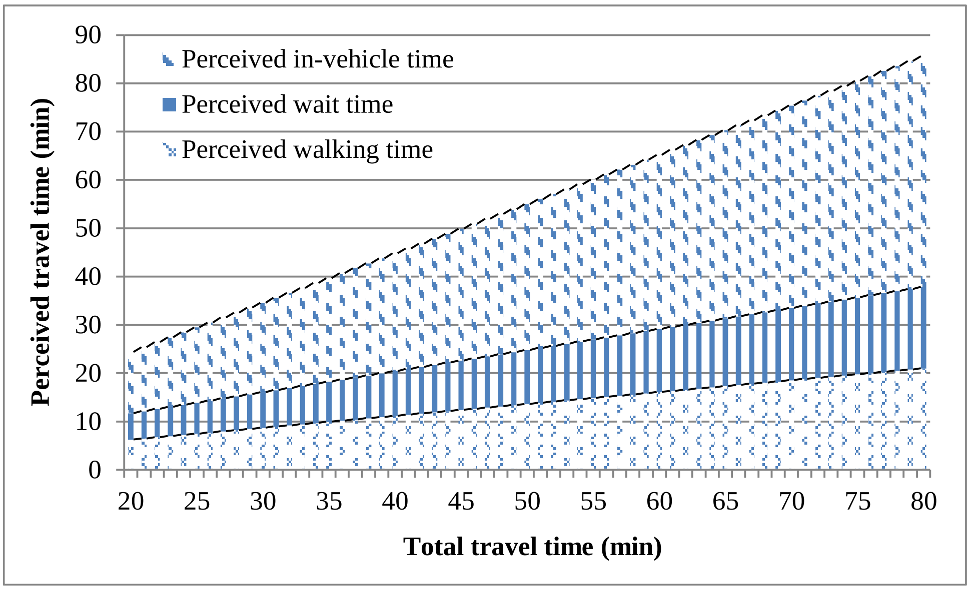
min, 8.55, and 27.05min. If the influences from these factors are taken into account, the corresponding maximum travel time perceptions will be 11.55min, 8.70min, and 27.40min. The comparison also proves that: the out-of-vehicle travel time is a significant amount in a multimodal public transport trip. The effect of socioeconomic characteristics, trip characteristics and facility usage may increase about 5% of the overestimation on the perceived travel time. Planner could take effective actions within the system to improve the level of service by reducing the travel time perception.



(a) Actual travel time distribution according to the total travel time



(b) Travel time perception while only the effect from actual travel time is considered



(c) Maximum travel time perception with consideration the effects from socioeconomic characteristics, trip characteristics and facility usage

Figure 4 Actual and perceived travel time based on the total travel time

5. Conclusion

The underlying goal of this research is to help transit agencies improve the passengers' stratification on the level of service by investigating the perception travel time in different stages in a bus-rail public transport trip. Based on the data from accompany survey, perception and actual travel time, as well as socioeconomic characteristics and travel characteristics were collected in this study to investigate the influence variables on passengers' perception. A stepwise linear regression method was used to determine the significant variables for the prediction of walking time perception and waiting time perception.

From the results, it could be concluded that passengers do perceive travel time greater than they actually spend at each stage. Actual walking time, travel distance, weather, occupation, trip purpose, covered shelter usage and elevator usage will affect the perception of walking time. Actual waiting time, age and arrival time panel usage will influence the perception of waiting time. Walking time experienced before the current stage will not affect the waiting time perception in the current stage. Actual in-vehicle time and peak hour will affect the perception of in-vehicle travel time.

Compared with the results from previous studies as listed in Table 1, our numbers are much smaller. The reasons may include: (1) Because of the small city-state of Singapore, the average travel distance is relatively shorter than other cities. The high frequency transit service also guarantees the passengers to get the service within a short time period. Therefore, the perception differences of all travel time components could be less than other cities. (2) The survey method used in this study is to ask the travel time perception immediately after the each action performed, which may cause the passengers' attention to care the travel time in a subconscious state. Then the reported perceived travel is closer to the actual travel time. From the perspective of impact factors, our results are in line with other studies that socioeconomic characteristics, trip characteristics and facility usage do affect the travel time perception at each trip stage in varying degrees. The insignificance of gender and trip purpose on the perceived waiting time goes against the results from previous studies (Psarros et al. 2011; Cheng and Tsai, 2014; Fan et al., 2016). This may due to different local features and transportation system characteristics. We also find that travel time spent on the previous stage does not affect the perception too much. Further research shall consider the results into public transport values of time studies, mode choice studies, and the influence from other possible factors such as the on-board inspection of tickets.

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