Public Transport Crowding Valuation: Evidence from College Students in Guangzhou

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Abstract

Overcrowding has grown to be an increasingly important issue for public transit in Guangzhou, China. To capture traveler benefits of reduced crowding from improved public transport, it is necessary to identify the relevant importance of crowding to travelers. This paper analyzes the disutility of crowding in metro car and bus transit with discrete choice models. Based on the stated preference survey data from college students in Guangzhou, the results show that there is non-negligible impact of crowding on passenger travel. The relationship between the disutility of crowding and standee density is not linear; that is, the disutility increases at a modest rate as the standee density increases when it is easy to move around in cars and increases rapidly when it is difficult to move around in cars. Also, there is only a slight difference between the effects of crowding on metro and bus transit.

Keywords: *Crowding; discrete choice; public transit; stated preference*

Introduction

Traditionally, researchers have considered travel time and cost as main attributes that influencing peoples' travel choice behaviors. However, as Tirachini et al. (2013) and Hensher et al. (2013) point out, with the improvement of the understanding of the modal choice problem, there is solid evidence that travelers not only take into account of quantitative attributes such as travel time and cost, but also qualitative aspects that may influence the experience of traveling, such as crowding, reliability, etc. Because of the high density of passengers in carriages of public transit, there may be many effects on passenger well-being, such as anxiety, stress, feelings of exhaustion, reduction of perceived security, and so on.

Because there are so many effects of crowding on traveler well-being, it is necessary to determine how much travelers are willing to pay to reduce the crowding in carriages of public transit. Therefore, this paper attempts to determine the influences of crowding in carriages of public transit and if there is difference between passenger viewpoints on crowding in metro cars and buses.

As pointed by Zhan (2016), in Chinese high-education regions, the university campus is a special community in which the high student density generates a large and significant trip demand. Therefore, exploring and understanding college students' evaluation of the impact of public transit are the basic supports for transportation development strategies policies and planning.

Literature Review

Crowding on public transit reduces the probability that passengers will find a seat in carriages and prevents individuals from using travel time for other activities effectively (reading, rest, etc.). Congestion in public transit also may induce security fears, increase noise levels, and reduce hygiene. All of these effect increase personal stress and dissatisfaction (O'Regan and Buckley 2003; Evans and Wener 2007; Mahudin et al. 2011; Mahudin et al. 2012; Li and Hensher 2013). Theyf also may affect traveler path choice of public transportation (Kim et al. 2016).

Noting widespread dissatisfaction with crowding in bus or metro cars, a considerable number of studies have been carried out to determine the effects of crowding. Most analyzed the valuation of crowding in public transportation with discrete choice models. Generally, there are two discrete choice models, the constant value per trip model and the multiplier value model. The constant value per trip model assumes that the crowding effect is irrespective of the duration of travel; the travel time multiplier value model assumes that the crowding effect is proportional to travel time. In addition to discrete choice models, there are other methods used to analyze the value of crowding.

Constant Value per Trip Model

Cantwell et al. (2009) divided the crowding conditions on trains and buses into five segments—very crowded, somewhat crowded, neither crowded nor uncrowded, somewhat uncrowded, and very uncrowded. It was found that the ratio between the valuation of train crowding and bus crowding was 1.4, which indicates that users would derive a greater benefit from a reduction in crowding. Basu and Hunt (2012) defined five levels of in-vehicle crowding in a qualitative manner and found the in-vehicle valuations (in Indian Rupees) to be 0.32 for light, 0.46 for moderate, 0.54 for heavy, and 0.59 for very heavy, adopting very light crowding as the benchmark.

Multiplier Value Model

Accent (2006) provided multi-level qualitative descriptions to crudely specify in-vehicle crowding, that is, seat flip uncrowded, seat flip crowded, seat perch uncrowded, seat perch crowded, stand uncrowded, stand lean, and stand crowded. The multipliers of these conditions varied from 1.0–2.14. Douglas and Karpouzis (2006) estimated the passenger cost of on-train crowding with Stated Preference (SP) data, in which eight levels of crowding were provided (uncrowded seat, crowded seat, stand up to 10 minutes, stand 15 minutes, stand 20 minutes or longer, crush stand up to 10 minutes, crush stand 15 minutes, crush stand 20 minutes or longer). The relative valuation compared to uncrowded seating varied from 1.17–2.52. Furthermore, gender was found to be an influence; females had a higher cost associated with standing in crushing conditions than males.

The written descriptions of in-vehicle crowding in Mott (2007) were plenty of seats, a few seats available, no seats available and a few standees, and no seats and densely-packed. Also, the paper divided travelers into seven groups—traders only, commuters, non-commuters, car available, non-car available, up to 40 minutes, and over 40 minutes. The multipliers varied from 1.00–3.01 for commuters, and the others were similar.

MVA Consultancy (2008) specified in-vehicle crowding with standee density (standees per square meter) and analyzed seating multipliers and standing multipliers. The seating multipliers and standing multipliers for business travelers varied from 1.00–1.81 and 1.91–2.16, respectively, when the standee density increased from 0 to 6 passengers per square meter (m^2). Non-business travelers tended to have somewhat low multipliers.

Lu et al. (2008) conducted an SP experiment in Greater Manchester in 2005 in which crowding was shown with combinations of probability of standing and length of time (for example, 2 out of 5 times standing for an entire journey). Within the multinomial logit (MNL) model, the value of crowding was estimated at 12.05 pence per person minute, which is more than twice the value of in-vehicle time. Whelan and Crockett (2009) estimated of the value of overcrowding in trains with an SP survey. To describe and present all attributes in an objective and quantifiable way with a minimal scope for differences in interpretation, they developed a combination of verbal and graphical stimulus material for use in the SP study. The results showed that there is a linear relationship between time multipliers and standee density and found that journey purpose, distance, and income had a significant impacts on time multipliers.

Hensher et al. (2011) described crowding attribute levels by mode with seats occupied and number of standees and showed that with the rise in the number of standees, the crowding utility increases with a quadratic function and the crowding valuation of metro is slightly higher than that of bus. Wang and Legaspi (2012) described in-vehicle crowding with a load factor, in which the multipliers were functions of load factor and standing time. For example, the cost of in-vehicle crowding per minute for standing 10–20 minutes was smaller than that for standing 20 minutes or more.

Haywood and Koning (2013, 2015) specified in-vehicle crowding with passenger density, which is different from standee density. The multipliers ranged from 1.00–1.57, and

standee density ranged from 0–6 pass/m². Kroes et al. (2013) presented in-vehicle crowding levels by mode with load factor, which ranged from 25–250%. Tirachini et al. (2013) studied the relationship between multipliers and load factor and between multipliers and standee density. It was found that there was a linear relationship between multipliers and standee density, and the multipliers reached approximately 3 when the standee density was 4 standees/m².

Vovsha et al. (2014) quantified in-vehicle crowding with seven categories associated with the probability of having a seat and the inability to board when crowding reaches an extreme level. Data in that paper shows that trip purpose, age, travel mode, income, and trip length had influence on multipliers, although all these effects were not striking. Batarce et al. (2015) evaluated time multipliers with SP data and RP data; results shows that the time multipliers at 5–6 standees/m² is 2.1 times the multipliers at 1–2 standees/m².

Other Methods

Cantwell et al. (2009) analyzed the relationship between crowding in public transport and commute satisfaction with a linear regression analysis. Haywood and Koning (2011) investigated the impact of travel comfort on the utility of subway users with an ordered logit model and found that metro passengers were prepared to travel, on average, eight minutes longer per trip to reduce the high peak-hour level of crowding to the substantially lower level of crowding experienced outside the peaks. This is roughly equivalent to a value of about 1.5 euros per trip, which is clearly non-negligible. Also, it was found that certain individual characteristics (age, socioeconomic status, etc.) significantly influence willingness to pay. Prud'homme et al. (2012) estimated the disutility of crowding with the ordered logit model.

Two papers review the literature about crowding on public transit. Li and Hensher (2011) reviewed public transport crowding valuation research using studies conducted in the UK, the U.S., Australia, and Israel and identified three measures to value crowding—a travel time multiplier, a monetary value per time unit, and a monetary value per trip—but they did not provide a comparison between their performances. They also described associated ways to represent crowding in SP experiments and implied that SP research is the preferred way of conducting valuation research for crowding. Despite the highly-different characteristics of the studies reviewed, they noted that all reported that crowding would increase the value of travel time savings, which, according to them, “can be viewed as an additional component of generalized time.”

Wardman and Whelan (2011) reviewed evidence from British experience of the valuation of rail crowding obtained over 20 years from 17 studies in a meta-analysis project and found that the seating multiplier averages 1.19 and the standing multiplier averages 2.32, which implies that the disutility of travel in a very crowded situation for standees is more than twice as much as compared with a situation when seats are available.

Although many studies on crowding have been conducted, most have been in developed countries or areas. There is still little research on crowding in China, especially based on passenger perception. Li and Hensher (2013) argued that the benchmarks that define the unacceptable crowding levels vary across different countries or regions. For example, four standees per m^2 is the benchmark for Australia (Diec et al. 2010), a number that increases to five standees per m^2 for the U.S. (Furth et al. 2006).

Furthermore, as Das and Pandit (2013) pointed out, “Since the service delivery environment differs between developed and developing nations, the user perception of service quality varies between these economic regions”; as a result, research results from developed countries or areas not suitable for China.

Experiment Design and Data Collection

In this study, we analyzed the valuation of in-vehicle crowding with multinomial logit model.

Although Turner et al. (2004), Cox et al. (2006), and Li and Hensher. (2013) argued that there is a disconnection or gap between objective and subjective measures of crowding, there are still many debates on the subjective measures of crowding. The objective measures, such as the number of standing passengers per square meter, are still an appropriate representation of passenger subjective measure of crowding.

To estimate the economic value passengers place on crowding in a metro car or bus, this study conducted an SP choice experiment in which a sample of passengers was offered a series of choices between two (or more) hypothetical alternative public transport services. These services differed in some key characteristics.

To ensure that the interviewees could easily understand the scenarios presented to them and to ensure that the key attributes of the scenarios were presented in a quantifiable manner, the experiment was designed with a two-stage process—a pilot survey and a formal survey. In the pilot survey stage, several choice attributes were considered for inclusion within the SP exercises: (1) level of crowding in metro car, (2) waiting time on subway platform, (3) fare, (4) journey time in metro car, (5) walking time from origination to subway platform and from platform to destination, and (6) interchange.

As mentioned, there are many ways to represent in-vehicle crowding, such as load factor, standee density, combinations of probability of standing and length of standing time, and so on. Because the average commuting time in Guangzhou exceeds 45 minutes during rush hour, public transportation can be so overcrowded that the door is blocked by passengers, sometimes making boarding and alighting difficult; thus, it is entirely possible for passengers to stand at the same level of overcrowding for the entire trip. Therefore, in this study, we did not represent in-vehicle crowding with the probability of standing. Since the same load factor may have different levels of crowding across different types of trains with varying amounts of seating and standing space, this

study describes crowding with the objective standard measure of number of standing passengers per square meter.

It is difficult for respondents to identify in-vehicle crowdedness when presented only with standee density, e.g., 6 standees/m². Therefore, to enable respondents to have a clear and consistent understanding of the levels of crowding, in-vehicle crowding (or standee density) was described using the linguistic notion method. Based on related research achievements by Jiang et al. (2012) and Qin and Jia (2012, 2014), crowding levels were described as shown in Table 1.

TABLE 1.
Standee Density and
Crowding Description in
Metro Cars and Bus Carriages

Crowding Conditions	Standee Density	Crowding Description
Crowding1	0 person/m ²	No person standing inside car
Crowding2	1 person/m ²	No seat, but can circulate freely
Crowding3	4 persons/m ²	Some restrictions in movement, high probability of physical contact
Crowding4	7 persons/m ²	Impossible movement, difficult to get on/off car

An example of the layout of the SP question is shown in Figure 1. A focus group of 4 people was asked to evaluate the interpretability of the question. All noted that there were too many attributes and that it was easy to get confused. Therefore, after discussion, the number of attributes was decreased. The attributes and level of each attribute are shown in Table 2.

Since the average commuting time in Guangzhou is around 50 minutes, four levels were set for this attribute—30 minutes, 40 minutes, 45 minutes, and 60 minutes. For standee density, four levels were used based on reality, three levels for fare, and three levels for waiting time on platform.

FIGURE 1.
Example SP question of
pilot survey

Situation 1	
Metro A	Metro B
Some restriction in movement, high probability of physical contact	No seat, but can circulate freely
Waiting time is 5 minutes	Waiting time is 10 minutes
Journey time is 35 minutes	Journey time is 40 minutes
Walking time is 8 minutes	Walking time is 6 minutes
Fare is ¥2	Fare is ¥3
Don't need to transfer	Have to transfer for a time
Q: Which metro do you prefer?	
☐ Prefer A ☐ Prefer B	

TABLE 2.
Levels of Attributes in
Formal Investigation

Attribute	Level of Attribute
Journey time in metro car	i) 30 min, ii) 40 min, iii) 45 min, iv) 60min
Standee density	i) 0 person/m ² , ii) 1 person/m ² , iii) 4 persons/m ² , iv) 7 persons/m ²
Fare	i) ¥3, ii) ¥4, iii) ¥5
Waiting time on platform	i) 5 min, ii) 10 min, iii) 15 min

With attributes and levels mentioned in Table 2, a total of 144 ($4 \times 4 \times 3 \times 3$) profiles (or a virtual transit system) could be formed, but it was unrealistic and unnecessary to ask the respondents to evaluate all the profiles, and orthogonal design was not used because it would produce too many profiles, especially when the goal is to induce interactions between crowding and travel time.

To gain the separate effects and interactions of attributes, the DOE platform in the software JMP was used to create a choice design. To create an effective design, information about all the attributes and their levels was needed. Therefore, a sample survey was created for a pilot study, and prior information was obtained with JMP. The core of the survey was a set of SP questions in which respondents were asked to sort three hypothetical journeys that differed in terms of on-train travel time, waiting time, on-train crowding, and ticket fare according to their preferences. Respondents were asked to make their choice in the context of the trip they were making. Each respondent undertook one comparison. A total of 16 choice sets similar to Appendix II were developed. Times and crowding were varied systematically so that the effect of travel time and crowding could be established statistically. The choice sets were used for metro and bus.

College students were selected as the focus of the study. Because the demographic characteristics of college students is somewhat different from working people, except for the SP choice investigation, some demographic characteristics were also investigated, as shown in Figure 2.

FIGURE 2.

College student characteristic survey

Gender	Woman		Do you have a car?	Yes	
	Man			No	
Average monthly consumption	≤ ¥1000		Frequency of travel by metro	Very often ≥ 3 times/week]	
	¥1000–¥1500			Often 1–4 times/week	
	¥1500–¥2000			Occasional 1–3 times/month	
	≥ ¥2000			Circumstantial	

Data Analysis

Sample Size and Descriptive Analysis

The surveys were undertaken between April and May 2015 for metro and between July and August 2015 for bus on the main campus of South China University of Technology in downtown Guangzhou. Each respondent was asked to evaluate only one choice set in Appendix II, and each choice set was evaluated 23 times for metro and 13 times

for bus, resulting in 368 valid surveys for metro and 208 for bus. Table 3 shows the socioeconomic characteristics of the college students from the data obtained in the SP survey.

TABLE 3.
Distribution of Sample into
Different Socio-Economic
Groups

Category	Sub-category	Percentages (%)	
		Metro	Bus
Gender	Woman	48.90%	40.10%
	Man	51.10%	59.90%
Do you have a car?	Yes	0.00%	0.00%
	No	100.00%	100.00%
Average monthly consumption	≤ ¥1000	18.80%	22.77%
	¥1000–¥1500	32.60%	38.12%
	¥1500–¥2000	39.10%	33.66%
	≥ ¥2000	9.50%	5.45%
Frequency of travel by metro	Very often (≥ 3 times/week)	51.60%	43.56%
	Often (1–4 times/week)	36.70%	48.02%
	Occasional (1–3 times/month)	11.70%	8.42%
	Circumstantial	0.00%	0.00%

In total, 48.90% of metro respondents and 40.10% of bus respondents were women. A total of 88.30% traveled by metro more than once a week, and 91.58% traveled by bus more than once a week. All respondents were familiar with metro and bus.

Modeling and Discussion of Results

The collected SP data were analyzed with the multinomial logit model in which decision-makers are assumed to make choices based on the concept of utility maximization.

Model 1 – Single Constant Value Model

The analysis began with the estimation of the single constant value per trip model, as specified in Equation 1:

$$U_i = \alpha_0 IVT + \alpha_1 Fare + \alpha_2 Wait + \sum_{i=1}^4 \beta_i D_i + \varepsilon_i \quad (1)$$

Where U_i is the utility of alternative i , Fare is the journey ticket price, IVT is the journey time in car (minutes), Wait is the waiting time on the platform, D_i is a vector of four dummy variables representing the four different levels of crowding shown in Table 1, and ε_i is the unobserved part of utility. $\alpha_0, \alpha_1, \alpha_2, \beta_1, \beta_2, \beta_3, \beta_4$ are the coefficients to be estimated.

The choice probability that alternative i over alternative j can be expressed with $P_i = \text{Pr ob}(U_i > U_j, \forall j \neq i)$. Since the choice probability that alternative i is selected

depends only on the difference in utility, but not its absolute level, we normalized β_1 to zero, and $\beta_2, \beta_3, \beta_4$ can be interpreted as being to β_1 .

The results of the single constant value per trip model runs are shown in Table 4.

TABLE 4.
Results of Single Constant
Value per Trip Model

	Parameters	β_2	β_3	β_4	α_0	α_1	α_2
Metro	Coefficient	-1.53515*	-1.89828*	-3.99241*	-0.09653*	-0.23946*	-0.11975*
	Standard Error	0.16314	0.18559	0.27845	0.00982	0.06581	0.01715
	z	-9.41	-10.23	-14.34	-9.83	-3.64	-6.98
	Prob. $ z > Z^{***}$	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000
Bus	Coefficient	-1.34293*	-1.64462*	-3.12547*	-0.07165*	-0.17247**	-0.05972*
	Standard Error	0.20071	0.21929	0.29068	0.01114	0.08094	0.01943
	z	-6.69	-7.50	-10.75	-6.43	-2.13	-3.07
	Prob. $ z > Z^{***}$	0.0000	0.0000	0.0000	.0000	0.0331	0.0021

*Significant at 10% level

** Significant at 5% level

***Significant at 1% level

Fit statistics for bus: $R^2 = 0.3208$, $F = 268.3921$

Fit statistics for metro: $R^2 = 0.3417$, $F = 419.4775$

As shown in Table 4, all the coefficients were significant at the 95% confidence level ($\text{Prob.}|z| > Z^* < 0.05$). The estimated coefficients in Table 4 provide information on the value of crowding levels.

Dividing the coefficients in Table 4 except for α_1 by α_1 , we obtained the coefficients' value expressed by ticket price (RMB Yuan), as shown in Figure 3, which indicates that the values of crowding in bus are slightly larger than those in metro.

FIGURE 3.
Monetary values of different
levels of crowding (RMB Yuan)

Crowding's value in metro increases to ¥6.41 if passengers have to stand, even though the standee is free to circulate. But the value increases slowly as the standee density increases when it is less than 4 persons/m² (no high probability of physical contact). The disutility of crowding increases rapidly as the standee density increases when it

is more than 4 persons/m²—that is, the slope of the line between 4 persons/m² and 7 persons/m² (7.13) is much larger than that between 1 person/m² and 4 persons/m² (0.97). Crowding's value for bus is almost the same as that for metro.

Dividing the coefficients in Table 4 except for α_0 by α_0 , we obtained the coefficients' value expressed by journey time (in minutes), as shown in Figure 4.

FIGURE 4.
Values of different levels of
crowding expressed by IVT
(min)

Also as shown in Figure 4, the characteristic of crowding's value (expressed by journey time) in a bus is almost the same as that in a metro, except that crowding's values in a bus are slightly larger than that in a metro. Crowding's value in a metro car increases to 15.90 minutes if passengers have to stand and to 41.36 minutes when standee density increases to 7 standees/m². Crowding's value in a bus increases to 18.74 minutes if passengers have to stand and to 43.62 minutes when standee density increases to 7 standees/m².

Therefore, we can conclude that passengers dislike crowding strongly, especially when there is a high probability of physical contact.

Model 2. Travel Time Multiplier Model

The single constant value model assumes that the crowding effect is irrespective of the duration of travel. Kroes et al. (2013) argued that the longer the journey, the more important it is to travel comfortably, so the travel time multiplier value model, which assumes that the crowding effect is proportional to the travel time, seems intuitively more appealing. Therefore, we analyzed the effect of crowding in a metro car with the travel time multiplier model. The equation can be expressed as:

$$U_i = \alpha_1 \text{Fare} + \alpha_2 \text{Wait} + \sum_{i=1}^4 \gamma_i D_i \cdot \text{IVT} + \varepsilon_i \quad (2)$$

Where the meanings of the parameters (U_i , Fare, Wait, IVT, D_i , ε_i) are the same as in Equation 1. α_1 , α_2 , γ_1 , γ_2 , γ_3 , γ_4 are the coefficients to be estimated. The results of the travel time multiplier value model runs are shown in Table 5.

TABLE 5.
Results of Travel Time
Multiplier Value Model

	Parameters	γ_1	γ_2	γ_3	γ_4	α_1	α_2
Metro	Coefficient	-0.05682A*	-0.08501*	-0.09200*	-0.14836*	-0.20441*	-0.10619*
	Standard Error	0.00812	0.00923	0.00997	0.01220	0.06483	0.01620
	z	-7.00	-9.21	-9.23	-12.16	-3.15	-6.56
	Prob. $ z > Z^{***}$	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000
Bus	Coefficient	-0.03823*	-0.06344*	-0.07051*	-0.10925*	-0.14882***	-0.05493*
	Standard Error	0.00970	0.01081	0.01163	0.01303	0.08080	0.01880
	z	-3.94	-5.87	-6.06	-8.38	-1.84	-2.92
	Prob. $ z > Z^{***}$	0.0001	0.0000	0.0000	0.0000	0.0655	0.0035

*Significant at 10% level

***Significant at 1% level

Fit statistics for bus: $R^2 = 0.3192$, $F = 270.0541$

Fit statistics for metro: $R^2 = 0.2913$, $F = 428.0019$

As shown in Table 5, all the coefficients are significant at the 95% confidence level ($\text{Prob.}|z| > Z^* < 0.05$), except α_1 of bus, which is significant at the 90% confidence level. Dividing the coefficients in Table 5 except for α_1 by α_1 , we obtained the coefficients' value expressed by monetary value (RMB Yuan), as shown in Figure 5.

FIGURE 5.
Relationship between value
of time multiplier and standee
density in metro car

It can be easily determined from Figure 5 that the difference between the bus multiplier and the metro multiplier is extremely small.

To evaluate the effect of crowding more clearly, it was necessary to use relative multipliers. Therefore, we chose a multiplier of bus when the standee density was 0 standees/ m^2 as the reference value and divided all multipliers of bus by the reference value to obtain the relative multipliers of bus, and did the same for multipliers of metro. The relative multipliers are shown in Figure 6.

FIGURE 6.
Relative multipliers compared
with reference values

The relative multipliers value increases slowly as the standee density increases when it is less than 4 persons/m² (no high probability of physical contact) and increases rapidly when the standee density is larger than 4 persons/m². The relative multiplier of metro when the standee density is 7 persons/m² is 2.858 times that when the standee density is 0 persons/m² and is 2.611 for bus.

Conclusions

Using data from a survey of college students in Guangzhou, we proposed individual trade-offs among travel time, cost, waiting time, and passenger density and found that crowding is a non-negligible factor that affecting a traveler's utility and mode choice. For example, crowding's value in a metro car increases to 15.90 minutes if passengers have to stand and to 41.36 minutes when standee density increases to 7 persons/m². Since the average one-way commuting time in Guangzhou is about 45 minutes, crowding's value is obviously non-ignorable. Furthermore, there is non-linear relationship between the disutility of crowding and standee density. This disutility increases at a modest rate as the standee density increases when it is no more than 4 persons/m² and increases rapidly when standee density is more than 4 persons/m². Therefore, 4 persons/m² (where there is a high probability of physical contact) is a critical point of disutility. Furthermore, there is only small difference between values of crowding in bus carriages and metro cars.

This conclusion is different from that of other published papers. The ratio that compares the train crowding coefficient with the bus crowding coefficient equals to 1.4 in Cantwell et al. (2009), and the ratios are larger than 1 in Vovsha et al. (2014). However, the ratio in this study fluctuated around 1. In fact, the ratios vary from 1.09 to 1.21 for the single constant value model and 0.92 to 1.05 for the travel time multiplier model. Since the travel time multiplier model seems intuitively more appealing, we can conclude from the data in this study that there is a negligible difference between crowding's valuation in metro and bus in the same crowded situations.

MVA Consultancy (2008), Tirachini et al. (2013), and Whelan and Crockett (2009) concluded that there is a linear relationship between the cost of crowding in a carriage

and standee density. However, the results in this study show a high cost for standing relative to sitting (time is valued 1.5–1.65 times higher) but little extra cost for standing in moderately-crowded conditions. Crush standing, however, nearly doubles the time multiplier. The results in this study are quite different from previous studies. When the carriage is not extremely crowded (standee density less than 4 standees/m²), there is little difference among the multipliers in this study and the multipliers in previous studies, but there are great differences among the multipliers in this study and the multipliers in previous studies. For example, the time multiplier for metro is 2.858 in a crush standing condition, and the time multipliers in MVA Consultancy (2008) and Whelan and Crockett (2009) are only around 2.

Traditional planning practices usually focus on quantitative factors (travel time, cost, etc.). Although some planners in China have recognized the existence of crowding in cars of public transit, they have overlooked and undervalued its impact. The conclusion in this study is particularly important for transit planning because metro's service quality varies greatly and because nearly all transit service quality decisions are made in a formal planning process. Our results can be used during the planning and appraisal stages of public transport projects. For example, in the design of a bus or metro network, planners should focus not only on traditional factors such as traveling time, walking time, ticket price, etc., but also on the impact of crowding in cars. In the analysis of network equilibrium, researchers should also take into account the impact of crowding in public transit.

In this study, survey data were obtained only from college students, and results perhaps can be generalized to others, such as commuters and older adults. However, since demographic characteristics may affect the evaluation of crowding in public transit, it is necessary to obtain more survey data from other groups to analyze the impact of crowding in carriages and determine the differences between the cost of crowding in bus and metro cars.

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APPENDIX I: Summary of Reviewed Crowding Valuation Studies

Author	Methods	Mode	Way of Representing Crowding	Measurement	Value	Classification
Accent (2006)	Discrete choice model	Rail	Qualitative description	Multiplier	When crowding varied from “seat uncrowded” to “stand crowded,” multipliers increased from 1 to 2.14.	None
Basu and Hunt (2012)	Discrete choice model	Train	Qualitative description	Constant value	Valuations of in-vehicle were 0.32, 0.46, 0.46, 0.54, 0.59 Indian Rupees for light crowding, moderate crowding, heavy crowding, and very heavy crowding, respectively, adopting very light crowding as benchmark.	None
Batarce et al. (2015)	Discrete choice model	Bus, train	Qualitative description	Multiplier	Value of in-vehicle travel time varied from \$4.60 to \$10.40 when standee density varied from 1–2 standees/m ² to 5–6 standees/m ² .	None
Cantwell et al. (2009)	Discrete choice model, linear regression	Train, bus	Qualitative description	Constant value	Ratio between valuation of train crowding and bus crowding is 1.4.	Train, Bus
Douglas and Karpouzis (2006)	Discrete choice model	train	Combinations of seating time, standing time, degree of crowdedness on train	Multiplier	When crowding on train varied from “crowded seat” to “crush stand 20 minutes or longer,” time multiplier varied from 1.17 to 2.52.	Gender, Age, Trip Purpose
Faber and MacDonald (2007)	Discrete choice model	Rail	Qualitative description	Multiplier	When in-vehicle crowding varied from “plenty of seats” to “standees packed,” multipliers increased from 1 to 3.01 for commuters, 2.73 for commuters.	Commuter or Not, Car Availability, Over 40 Min or Not
Haywood and Koning (2011)	Ordered logit Model	Subway	Additional minutes Willingness to wait for more comfortable subway	Constant value	Travelers in Paris willing to increase trip durations by 5.7–8.1 minutes to enjoy off-peaks comfort conditions during rush hours.	Age, Socioeconomic Status
Haywood and Koning (2013)	Discrete choice model	Metro	Standee density	Multiplier	Multiplier ranged from 1.00 to 1.57 when standee density ranged from 0 to 6 pass/m ² .	None
Hensher et al. (2011)	Discrete choice model	Metro, bus	Seats occupied, number of standees	Multiplier	With rise of number of standees, crowding utility increased with a quadratic function.	None
Kroes et al. (2013)	Discrete choice model	Metro, bus, train	Load factor	Multiplier	When load factor were 25–250%, multipliers were 1–1.363 for seated train passengers, 1.261–1.553 for standing train passengers, 1–1.511 for seated bus passengers, 1.342–1.718 for standing passengers.	None

APPENDIX I (cont'd): Summary of Reviewed Crowding Valuation Studies

Author	Methods	Mode	Way of Representing Crowding	Measurement	Value	Classification
Lu et al. (2008)	Discrete choice model	Rolling stock	Combinations of probability of standing and length of time	Multiplier	Value of crowding estimated at 12.05 pence per person minute, more than twice value of in-vehicle time.	Complex Design, Cheap Talk
MVA Consultancy (2008)	Discrete choice model	Rail	Standee density	Multiplier	When standees density varied from 0–6 pass/m ² , 1–1.81 (business, seating), 1.91–2.16 (business, standing), 1–1.62 (non-business, seating), 1–2.06 (non-business, standing).	Business, Non-Business, Sit, Stand, Regional, Interurban
Prud'homme et al. (2012)	Linear regression	Subway	Standee density	Constant	WTP (€/trip) equals to standee density $\times$ 0.68.	None
Tirachini et al. (2013)	Discrete choice model	Metro	Load factor, standee density	Multiplier	Linear relationship between multipliers and standee density.	None
Vovsha et al. (2014)	Discrete choice model	Bus, LRT, rail	Qualitative descriptions	Multiplier	Non-linear relationship between multipliers and standees density.	Trip Purpose, Age, Travel Mode, Income, Trip Length
Wang and Legaspi (2012)	Discrete choice model	Train	Load factor	Multiplier	Multiplier was function of load factor and standing time.	None
Whelan and Crockett (2009)	Discrete choice model	Train	Load factor, standee density	Multiplier	When standee densities increases from 0 to 6 pass/m ² , time multipliers of seated passengers and standees increase from 1 to 1.63 and 1.53 to 2.04, respectively.	Trip Purpose, Trip Length, Income

APPENDIX II. Survey for Bus and Metro

Choice Set	Choice ID	Journey Time	In-vehicle Crowding	Fare	Waiting Time
1	1	40 min	Some restrictions in movement, high probability of physical contact	¥5	10 min
	2	60 min	No seat, but can circulate freely	¥3	5 min
	3	45 min	No person standing inside car	¥4	15 min
2	1	40 min	No person standing inside car	¥4	15 min
	2	30 min	No seat, but can circulate freely	¥3	10 min
	3	45 min	Impossible movement, difficult to get on/off metro car	¥5	5 min
3	1	40 min	Impossible movement, difficult to get on/off metro car	¥4	10 min
	2	45 min	No person standing inside car	¥5	15 min
	3	30 min	Some restrictions in movement, high probability of physical contact	¥3	5 min
4	1	45 min	Some restrictions in movement, high probability of physical contact	¥4	5 min
	2	40 min	No seat, but can circulate freely	¥5	15 min
	3	30 min	Impossible movement, difficult to get on/off metro car	¥3	10 min
5	1	45 min	Impossible movement, difficult to get on/off metro car	¥4	10 min
	2	60 min	No person standing inside car	¥5	5 min
	3	40 min	Some restrictions in movement, high probability of physical contact	¥3	15 min
6	1	45 min	Some restrictions in movement, high probability of physical contact	¥5	10 min
	2	60 min	No person standing inside car	¥3	5 min
	3	60 min	No seat, but can circulate freely	¥4	5 min
7	1	30 min	Some restrictions in movement, high probability of physical contact	¥4	15 min
	2	45 min	No seat, but can circulate freely	¥3	10 min
	3	60 min	Impossible movement, difficult to get on/off metro car	¥5	10 min
8	1	30 min	No seat, but can circulate freely	¥4	5 min
	2	40 min	No person standing inside car	¥3	10 min
	3	45 min	Some restrictions in movement, high probability of physical contact	¥5	15 min
9	1	60 min	Impossible movement, difficult to get on/off metro car	¥3	5 min
	2	30 min	No seat, but can circulate freely	¥5	15 min
	3	40 min	Some restrictions in movement, high probability of physical contact	¥4	10 min
10	1	45 min	Some restrictions in movement, high probability of physical contact	¥5	5 min
	2	40 min	No seat, but can circulate freely	¥3	10 min
	3	30 min	Impossible movement, difficult to get on/off metro car	¥4	15 min
11	1	45 min	No seat, but can circulate freely	¥4	15 min
	2	40 min	No person standing inside car	¥5	5 min
	3	30 min	Some restrictions in movement, high probability of physical contact	¥3	10 min
12	1	45 min	No person standing inside car	¥3	10 min
	2	40 min	No seat, but can circulate freely	¥4	5 min
	3	30 min	Impossible movement, difficult to get on/off metro car	¥5	15 min

APPENDIX II (cont'd). Survey for Bus and Metro

Choice Set	Choice ID	Journey Time	In-vehicle Crowding	Fare	Waiting Time
13	1	45 min	No seat, but can circulate freely	¥3	15 min
	2	60 min	Some restrictions in movement, high probability of physical contact	¥4	5 min
	3	60 min	No person standing inside car	¥5	10 min
14	1	45 min	Some restrictions in movement, high probability of physical contact	¥3	15 min
	2	40 min	No seat, but can circulate freely	¥5	10 min
	3	60 min	No person standing inside car	¥4	10 min
15	1	30 min	No person standing inside car	¥4	10 min
	2	40 min	Impossible movement, difficult to get on/off metro car	¥3	15 min
	3	45 min	Some restrictions in movement, high probability of physical contact	¥3	5 min
16	1	45 min	No seat, but can circulate freely	¥4	10 min
	2	30 min	Some restrictions in movement, high probability of physical contact	¥5	10 min
	3	40 min	Impossible movement, difficult to get on/off metro car	¥3	5 min