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Valuing in-vehicle comfort and crowding reduction in public transport

UPDATED RESULTS FEB 2016

Gunilla Björklund & Jan-Erik Swärdh – VTI

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Keywords: Public transport, Comfort, Crowding, Willingness to pay, Value of travel time savings

JEL Codes: C25, R41

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Abstract

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1. INTRODUCTION

Urbanization and concentration of urban areas can be seen as a good way to increase public transport traveling, which in turn may decrease environmental externalities of the transport sector. Problems may arise, however, with crowding on board public transport as the demand for such services increases. The supply can also be increased to meet increased demand, but to find the optimal supply of public transport is a really difficult issue.

Cost benefit analysis (CBA) is an economic tool which has been important for transport planners for a long time, both to analyze the investments in the transport sector and to evaluate measures (Eliasson & Lundberg, 2012). To examine CBA we need accurate estimates of costs and benefits. Increased supply of public transport may reduce discomfort and crowding on board public transport, and the travelers may experience an increased utility from such changes. This increased utility in terms of the monetary willingness to pay (WTP) metric is to be included in the CBA of supply changes in public transport.

Non-market goods, such as comfort and crowding reduction, are mostly valued based on stated preference (SP) or revealed preference (RP) data (Swärdh & Algers, 2014). RP has its well-known advantage of being based on actual behavior, but there is often difficulty in finding relevant data and thus often difficulty in estimating unbiased preference parameters. SP, with hypothetical scenarios, has the main and powerful advantage that the analyst can design the scenario and thus estimate the preferences that are the objectives of the study, without considering the availability of real data. There are known problems with SP as well, e.g. the risk that the WTP estimates will suffer from hypothetical or strategic bias, meaning that respondents will not answer SP questions in the same way as they would make real choices in a similar context.

In the literature of comfort and crowding in public transport, WTP estimation is mainly based on SP data. Still there is some variation in the methods used, especially considering the way to present the crowding levels to the respondents. Also, the estimated WTP differs substantially across different studies around the world. The WTP may be dependent on different, e.g. cultural conditional, preferences across the world but also on the fact that the income level is very different in different countries.

This potential problem highlights the benefit transfer problem, i.e. when WTP studies are transferred from one place to another. Empirical evidence on the risks of benefit transfers are relatively common in the literature, e.g. Rozan (2004). Thus, it is important that the WTP used in CBA originates from preferences based on the study location of the analyzed supply change in public transport. In other words, the knowledge of the local travelers' WTP for comfort and crowding reductions in public transport, may be important for efficient planning of the public transport network.

The purpose of the present study is to estimate the WTP for comfort, i.e. to get a seat, and crowding reduction on board local public transport in Sweden, including the modes metro, tram, commuter train, and local bus. The WTP measure can also be calculated as multipliers of the value of travel time savings (VTTS) for a reference travel condition, which is common in the literature (e.g. Haywood & Koning, 2015; Tirachini et al., 2013; Wardman & Whelan, 2011). As an example, a VTTS multiplier of 2 for a given travel condition means that the benefit of reducing travel time given this travel condition, is twice as large as reducing travel time in the reference condition. In other words, 1 minute of travel time in the worse travel condition is equivalent to 2 minutes of travel time in the reference condition.

Because previous studies regarding crowding in the Swedish public transport mainly concentrated on Stockholm, the present study will be conducted in the three largest Swedish urban areas, i.e. in addition to Stockholm, also Gothenburg and Malmö. We will also expand the study to infrequent travelers as this travel group has not been included in the previous Swedish studies.

There is a relatively large body of literature considering the benefits of comfort and crowding reduction in public transports. For an overview, see for example Wardman and Whelan (2011) or Li and Hensher (2011).

Wardman and Whelan (2011) performed a meta-study of 17 UK studies of rail crowding valuations in different travel contexts. They interpret the seating and crowding WTP as VTTS multipliers which they argue are more transferable than monetary estimates. Their main conclusions are that the valuations increase with load factor and vary with respect to journey purpose. The estimated multipliers for load factors of 100 percent up to 200 percent ranges from 1 to some 1.8 for sitting, and from 1.5 to some 2.5 for standing.

In Mumbai city, India, suburban train travelers' valuing of crowding was investigated by Basu and Hunt (2012). To make the results comparable with Swedish conditions we have calculated multipliers based on the WTP values from mixed logit models with correlated choice sets. Compared to light crowding with maximum 2 passengers standing per square meter, moderate crowding (4 passengers standing per square meter) implies a multiplier of 1.4; heavy crowding (8 passengers standing per square meter) implies a multiplier of 1.7; and very heavy crowding (12 passengers standing per square meter) implies a multiplier of 2. To illustrate the different levels of crowding, the participants were shown photographs with different amounts of people standing in a square meter. This presentation of crowding is also used by Whelan and Crockett (2009) and suggested for future research by Wardman and Whelan (2011).

Tirachini et al. (2013) estimated the VTTS under crowding conditions, using data of a choice experiment between the existing bus service or car and a proposed metro line. The crowding level is explained by drawn figures over the travelers in the vehicle. The results are in line with the meta-study of Wardman and Whelan (2011) with a VTTS multiplier taking the highest value of 3 in the error correction model, and when the load factor is 2.5 (250 percent).

Haywood and Koning (2015) estimated the crowding cost in the public transport of Paris. They used show cards with different crowding levels to estimate VTTS multipliers for the number of standing travelers per square meter ranging from 0 to 6. The results showed a benefit of crowding reduction that was lower compared to Wardman and Whelan (2011) and Tirachini et al. (2013), which for the highest density of 6 passengers per square meter was still a VTTS multiplier below 2. According to Haywood and Koning (2015), this difference may be due to the use of a metropolitan public transport network compared to regional public transport networks in the other studies.

Swedish evidence relies mostly on a study by Transek (2006), where SP data was used to estimate habitual public transport travelers' values of delays, crowding and seat availability on board buses, metro and commuter trains in Stockholm, the capital of Sweden. Subjects were asked to choose between different options with varying travel prices and crowding levels. The results showed that the WTP for seating varied between SEK[2] 7 per hour (on board the metro with little crowding) and SEK 16 per hour (on board commuter trains with a high degree of crowding). The WTP for seating was higher, the more crowding there was in the vehicles, and the WTP seemed to be higher on commuter trains than on the metro. Given that the travelers were given a seat during the trip, it was therefore no sacrifice to travel with crowding on board the vehicle. The three different crowding levels were illustrated by photographs taken into vehicles through the open doors, on the metro and commuter trains.

[2] SEK 10 ≈ EUR 1.

In an earlier Swedish study, Olsson et al. (2001) investigated commuting trips, also in Stockholm. As a measure of crowding they used a guaranteed seat. The results of the study showed that travelers would on average be willing to pay SEK 84 more per month to get a seat on buses, and SEK 89 more per month to get a seat on the metro and on commuter trains. By assuming 40 trips per month and 25 minutes per one-way trip, WTP for a seat is some SEK 5 per travel hour.

As shown above, in-vehicle crowding has been illustrated in different ways. In the present study, we have chosen to define comfort by seating, and crowding by the number of passengers standing per square meter, the latter illustrated by pictures. Compared to illustrated crowding by different load factors, which will have different implications for the discomfort of standing across different modes, or different types of the same mode of transport, passengers per square meter is also a measure that is recommended by Wardman and Whelan (2011). The result is thus a more flexible and mode-generic valuation of comfort and crowding reductions.

2. METHOD

2.1 PARTICIPANTS AND PROCEDURE

Two different types of data collection were carried out in the three largest Swedish urban areas: Gothenburg, Malmö, and Stockholm.[3] In Gothenburg and Stockholm travelers were recruited at bus stops (both cities), station platforms for metro (Stockholm), tram stops (Gothenburg), station platforms for commuter trains (both cities), and by an existing national web panel of people which we had access to through an established market research company. In Malmö the travelers were recruited only by the national web panel. The reason why these three cities were chosen was that they fulfilled the criteria that it should be possible to travel by either metro, tram or commuter train. It should also be possible to go by local bus as an alternative to the other travel modes. Although we in this study do not investigate mode choice, we want to ensure that any differences in travelers' values between rail transport and bus obtained in the study, are due to mode specific characteristics, and not differences between the cities.

The two types of data collection were motivated by the risk of oversampling of frequent travelers when recruiting during the trip only. In also including travelers from a web panel, we get more infrequent travelers in our sample. We chose to not recruit travelers during a trip in Malmö. To recruit during a trip is resource demanding and thus we used that method only in

[3] The urban area of Gothenburg has 928,629 inhabitants, the urban area of Malmö has 656,355 inhabitants, and the urban area of Stockholm has 2,054,343 inhabitants, all dated 31st of December 2010 (Statistics Sweden, 2015a).

two urban areas in order to have a sufficiently large sample for partial analysis in a given urban area and for each recruitment method.

Before the main study was conducted, we carried out a pilot study in Gothenburg to check the procedure and the questionnaire. The pilot study included 50 participants recruited during a trip and 61 participants recruited by the web panel. After the pilot study we changed the SP design by increasing the travel time of the longer trips and by omitting the variable waiting time. The pilot study was conducted in March 2015 and the main study was conducted in April to May 2015. Only data from the main study is included in the analysis presented in this paper.

An information card about the study and a link to the online survey was distributed to travelers during a trip in Gothenburg and Stockholm. Only travelers who were 18 years and older and understood Swedish were recruited. E-mail addresses were collected and information and the link were subsequently sent to the recruited travelers. Reminders were then also sent out to those who had not completed the survey within 3-4 days. Of those who received the information, including the link, 288 travelers in Gothenburg and 287 in Stockholm chose to log in and answer the online survey. Of these questionnaires, 286 and 283 respectively, were suitable for further analyses. The participants recruited during a trip all received a digital lottery ticket, valued at SEK 30, in return after the study was conducted. In total, 600 travelers in each of Gothenburg and Stockholm received the information card. Some of the collected e-mail addresses were shown not to be correct, meaning that the e-mail information and the reminders were not distributed correctly. Thus, a response rate calculated on 600 travelers, i.e. 48 percent in both areas, is probably somewhat underestimated.

From the existing web panel, we recruited 500 people each from Gothenburg and Stockholm, and 463 people from Malmö. The criteria for being recruited from the panel were that participants should be between 18 and 74 years old and have made at least one local journey with bus, metro, commuter train, or tram during the previous month. The sample of the web panel was representative of the population in large Swedish cities, regarding proportions of males and females in each of the age categories 18-34 years, 35-49 years, and 50 years or older. The participants recruited from the web panel were reimbursed by the company who administrated the panel. Here, the web panel administrator closed the survey when our predetermined number of respondents had completed the survey, and therefore no response rate can be calculated. Also in Malmö, a group of 500 respondents was the target but the web panel members were too few in some gender and age categories to reach that target.

In total, 2,038 individuals filled in the questionnaire. Of these, 2,003 questionnaires were appropriate for further analyses. In Table 1 we present the individual characteristics of the respondents. The respondents consist of slightly more women than men, which is consistent with the true distribution in the public transport network in these areas. The average age is some 44 years. The income of the respondents follows the pattern of Sweden as a whole; the median income is in the interval SEK 20,000 to 30,000 per month, 34 percent have a lower income and 39 percent a higher income so the median monthly income is probably somewhere around SEK 24,000. This can be compared with the median monthly income for *employed* individuals in Sweden as a whole, which is around SEK 29,000 (Statistics Sweden, 2015b). It should be noted that there are students and pensioners in the sample, but also that the residents in urban areas have, on average, a higher income than the rest of Sweden. Another point we note is that over 60 percent of the respondents have a university degree compared to only 35 percent in the whole of Sweden (Statistics Sweden, 2015c). The majority of the respondents are employed and substantial numbers of respondents are students and pensioners, respectively. Other occupations make up small groups only.

Table 1. Individual characteristics of the respondents.

Variable	**Mean value/percent (standard deviation)**
Proportion women	54.9%
Age in years	43.8 (16.3)
Monthly gross income in SEK	
- 0-10,000	16.3%
- 10,001-20,000	17.5%
- 20,001-30,000	27.5%
- 30,001-40,000	23.8%
- 40,001-50,000	8.6%
- Over 50,000	6.2%
Education	
- University degree	61.1%
- High school	30.5%
- Elementary school	6.4%
- Other	2.0%
Occupation	
- Employed	56.9%
- Self-employed	4.5%
- Student	16.1%
- Unemployed	3.3%
- Pensioner	14.9%
- Parental leave	1.7%
- Other	2.7%

2.2 QUESTIONNAIRE

The questionnaire consisting of four different parts was written in Swedish and administered together with written information and instructions online.[4] The first part of the questionnaire asked questions about the travelers' last journey with their main travel mode (web panel), or the journey they were making when they were recruited (travelers recruited during a trip). The main travel mode could be bus (all cities), metro (only Stockholm), commuter train (all cities), or tram (mostly Gothenburg but also a small share in Stockholm). One of the questions was how the participants experienced the crowding condition on board the main travel mode, where the pictures (see Figure 1) show number of standing passengers per square meter.

Figure 1. Four levels of crowding, representing number of passengers standing per square meter.

The second part of the questionnaire consisted of questions regarding the subjective evaluation of the crowding on board the main travel mode. The results from these questions will not be presented here.

The third part of the questionnaire consisted of eight SP questions where the travelers were asked to choose between two journeys. One example of these questions is presented in Figure 2 and the attributes and levels used are summarized in Table 2. As can be seen, the two journeys differed according to travel time within the main travel mode, the one-way price of the entire trip, sitting or standing in the main travel mode, and the level of crowding represented by one of the four pictures shown in Figure 1. The participants also had the possibility to choose *equivalent alternatives* or *none of the alternative trips*. Depending on the participants' actual travel time with the main travel mode, the attributed levels for travel time in the stated

[4] A copy of the questionnaire is available from the authors upon request.

preference situations were 5, 9, or 14 minutes for actual trips that were 15 minutes and shorter, and 18, 25, or 34 minutes for actual trips that were longer than 15 minutes. The price per one-way trip was 20, 36, or 44 SEK. The comfort attribute had two levels: sitting the whole trip within the main travel mode, or standing the whole trip within the main travel mode. The levels of crowding were four, as mentioned earlier illustrated by the pictures in Figure 1. In the scenario, the pictures were presented to illustrate the crowding level around the respondent. This means that we can combine standing with Picture 1 and in this particular scenario the respondent is the only one who is standing in the vehicle. Furthermore, the scenario always stated that all seats were occupied to avoid problems with voluntary standing although there are seats available.

Alternative A	**Alternative B**
The travel time within your main mode is **5 minutes**	The travel time within your main mode is **9 minutes**
The price of the one-way trip is **44 kronor**	The price of the one-way trip is **44 kronor**
You are **standing** during the whole trip within your main mode	You are **sitting** during the whole trip within your main mode
The picture illustrates the view around you in the vehicle 	The picture illustrates the view around you in the vehicle 

☐ I choose alternative A ☐ I choose alternative B

☐ I choose neither of the alternatives

☐ The alternatives are equivalent

Figure 2. Example of an SP question used in the survey.

We used a fractional factorial design (Kocur et al., 1982) with, in total, 16 SP choices. These were combined together in a way that avoided dominant choices. Subsequently, the 16 SP questions were randomly split into two blocks with 8 questions each. The respondents were assigned randomly to one of the SP blocks regardless of urban area, long or short trip, and web panel or recruited during a trip.

Finally, the questionnaire consisted of a part with socio-economic questions, i.e. gender, age, driving license or not, occupation, number of persons in the household, number of children younger than twelve years in the household, income, education, and type of accommodation.

Table 2. SP attributes and levels used in the survey.

Attribute	**Description**	**Levels**
Price	Price per one-way trip including other public transport modes. Given in SEK.	20, 36, 44
Travel Time	In-vehicle travel time of the main mode. Given in minutes.	5, 9, 14 (if reference trip ≤ 15 minutes) 18, 25, 34 (if reference trip > 15 minutes)
Comfort	Sitting or standing during the whole trip of the main mode.	Sitting, Standing
Crowding	Crowding level of standing passengers per square meter in the vehicle, illustrated by pictures of the view around the participants inside the vehicle.	0, 1, 4, 8

In Table 3 we present frequencies of different travel modes and recruitment methods by urban area. Note that metro is by far the most common mode in Stockholm, but is not available in the other urban areas. Tram is very common in Gothenburg but almost exclusively in that urban area. Commuter train is most common in Malmö but is also available in all urban areas. Finally, bus is the most common mode in total.

Table 3. Frequency of urban areas, mode, and recruitment method, quantity and percent.

	Gothenburg	**Malmö**	**Stockholm**	**Total**
Travel mode				
Bus	302 (38.8%)	295 (65.1%)	189 (24.5%)	786 (39.2%)
Metro	-	-	418 (54.2%)	418 (20.9%)
Commuter train	105 (13.5%)	158 (34.9%)	152 (19.7%)	415 (20.7%)
Tram	372 (47.8%)	-	12 (1.6%)	384 (19.2%)
Total	779 (100%)	453 (100%)	771 (100%)	2,003 (100%)
Recruitment method				
Web panel	493 (63.3%)	453 (100%)	488 (63.3%)	1,434 (71.6%)
Recruited during a trip	286 (36.7%)	-	283 (36.7%)	569 (28.4%)
Total	779 (100%)	453 (100%)	771 (100%)	2,003 (100%)

Table 4. Descriptive statistics of travel characteristics.

Variable	Mean value/percent (standard deviation)
Time total trip in minutes	38.4 (27.8)
Time on board main travel mode in minutes	24.2 (17.1)
Purpose of the trip	
- To/from work	41.0%
- To/from studies	10.4%
- Business trip	4.8%
- Other	43.7%
Years of commuting with the current mode	11.8 (10.8)
Same travel mode the entire trip	45.0%
Sitting	
- Was sitting the entire trip	60.9%
- Was sitting the most part of the trip	22.2%
- Was standing the most part of the trip	8.8%
- Was standing the entire trip	8.2%
Level of crowding	
- 0 standing passengers/m^2	20.6%
- 1 standing passenger/m^2	32.2%
- 4 standing passengers/m^2	38.7%
- 8 standing passengers/m^2	8.5%
Started same time as usual	58.5%
Comparison with usual crowding level	
- More crowded	6.4%
- Same level of crowding	79.5%
- Less crowded	14.1%

In Table 4 we present descriptive statistics of the travel characteristics, i.e. the variables that characterize the respondents' reference trip. It is shown that the mean time spent on board the main travel mode is about 24 minutes, whereas the entire trip is about 38 minutes on average. The most common single purpose with the trip is to travel to or from work, and, on average, the respondents have been commuting with the current mode for around twelve years. Most of the respondents (61 percent) had a seat the entire trip, 45 percent traveled with the same mode the entire trip, and 59 percent started their trip the same time as usual. The most common crowding level was 4 standing passengers per square meter, even if 1 standing passenger per square meter was also very common. Remarkable is that almost 9 percent experienced a trip with a crowding level of 8 standing passengers per square meter, which implies a very heavy crowding. The respondents who have made the same trip more than once indicated in most cases that the crowding level was as high as usual.

2.3 ESTIMATION METHOD

The outcome of the SP choices is analyzed by a mixed logit model (see e.g. Hensher & Greene, 2003) within a random utility framework, which is a standard discrete choice method for bivariate discrete choice. The utility of an individual *i* is given by the equation:

$$U_{ijk} = \mathbf{x}'_{ijk}\beta_i + \varepsilon_{ijk}, \quad (1)$$

where *j* (1,2) denotes the alternative trips in the specific question, *k* (1,…,8) denotes the different questions, β_i denotes the parameters to be estimated, and **x** denotes the variables included in the SP experiment. ε_{ijk} is the random part that is not observed by the analyst.

Alternative 1 is chosen if $U_{i1k}>U_{i2k}$ and by assuming an individually independent extreme value distributed error term, the model can be estimated by the mixlogit command in Stata 12 (StataCorp, 2011). As recommended by Revelt and Train (1998), 500 Halton draws are used for the simulated maximum likelihood, as the bias of the simulating procedure decreases when the number of draws increases.

The mixed logit model allows for random parameters, but can be sensitive to which parameters are treated as random and the assumed distribution for the parameters. The normal distribution is the simplest distribution to assume, but it has the drawback of taking positive values for some individuals, although the theoretical guidance states that the marginal utility is always non-positive, such as travel time and price. Instead, the log-normal distribution can be used, which restricts the marginal disutilities to a given sign for all individuals. Travel time (*TT* in the equations hereafter), price (*P*), and crowding levels (*CL*) are all assumed to have a non-positive marginal disutility and we assume their parameters to be log-normally distributed. For standing (*ST*), on the other hand, we assign a normally distributed marginal utility in our estimation. The main argument is that it is relatively common to observe travelers in the local public transport who are standing in the vehicle although there are available seats. Thus not all travelers will have a negative utility change by standing instead of sitting.

In the model, we also include interaction terms between standing and crowding levels, which means that the effect of sitting is allowed to vary with the crowding level and the effect of reduced crowding is allowed to be different for sitting condition and standing condition. These parameters have no specific theoretically expected sign, although we except that it is more likely for those parameters to be negative than positive. Negative parameters mean that crowding is afflicted by more disutility when the traveler is standing compared to when the traveler is sitting. Still, the unpredictable sign implies that we use a normal distribution for the parameters of these interacted variables.

For the random parameters with a log-normal distribution we follow the recommendation by Meijer and Rouwendal (2006) to interpret the median as the marginal utility. The reason for not using the mean is that the log-normal distribution can be heavily skewed to the right with a long tail, which in such cases implies that the mean value is not representative for the respondents. The median of a log-normal distribution is calculated as $\exp(\beta_i)$. Since all log-normally distributed parameters are negatively influencing utility, we have to incorporate minus signs in the formulas. A good feature of a log-normal distribution is that it can be placed in the denominator and still produce a WTP distribution with finite moments (Meijer & Rouwendal, 2006).

In the data for analysis we have excluded choices where the respondent has chosen neither of the alternative trips, i.e. have chosen *equivalent alternatives* or *none of the alternative trips*.

To estimate WTP for comfort and crowding reductions, based on the estimated model, we divide the marginal utility of each travel condition with the estimated marginal utility of the price. In addition, standing and crowding variables are all multiplied by travel time in each hypothetical alternative to be interpreted in the travel time unit. The reason is that the same comfort and crowding levels occur during the whole trip in our scenarios. With this multiplication we can thus interpret the effects of seating and crowding reduction directly in a travel time unit. As an example the formula for the WTP of reducing the crowding from 8 standing passengers per square meter to 0 standing passengers per square meter will, if the traveler is sitting, be given as:

$$WTP_{CL8} = \frac{-\exp(\beta_{CL8})}{-\exp(\beta_P)}, \quad \text{(2A)}$$

or if the traveler is standing by:

$$WTP_{ST,CL8} = \frac{-\exp(\beta_{CL8}) + \beta_{\mathrm{ST}} + \beta_{ST*CL8}}{-\exp(\beta_P)}. \quad \text{(2B)}$$

WTP for other travel conditions are calculated analogously.

In the same way, the WTP for travel time reductions, conventionally known as the value of travel time savings (VTTS) is given by:

$$VTTS = \frac{-\exp(\beta_{TT})}{-\exp(\beta_P)}. \tag{3}$$

Equation (3) is showing VTTS for the reference case in the estimated model, which we set to sitting in a crowding level of 0 standing passengers per square meter. To calculate VTTS in other travel conditions we need to incorporate the coefficient of these indicators in the numerator of Equation (3). As an example, the VTTS for standing in a crowding level of 8 standing passengers per square meter is calculated as:

$$VTTS_{ST,CL8} = \frac{-\exp(\beta_{TT})+\beta_{ST}-\exp(\beta_{CL8})+\beta_{ST*CL8}}{-\exp(\beta_P)}. \tag{4}$$

Dividing $VTTS_{ST,CL8}$ calculated in Equation (4) with the reference VTTS calculated in Equation (3), implies the expression for the multiplier for standing in a crowding level of 8 standing passengers per square meter, i.e. how travel time savings in that particular travel condition is valued relatively to travel time savings in the reference travel condition:

$$Multiplier_{ST,CL8} = \frac{VTTS_{ST,CL8}}{VTTS} = \frac{-\exp(\beta_{TT})+\beta_{ST}-\exp(\beta_{CL8})+\beta_{ST*CL8}}{-\exp(\beta_{TT})}. \tag{5}$$

The multipliers for the other travel conditions will be calculated analogously. In total, 7 multipliers relative to the reference VTTS can be estimated. These are: sitting in a crowding of 1 standing passenger per square meter, sitting in a crowding of 4 standing passengers per square meter, sitting in a crowding of 8 standing passengers per square meter, standing in a crowding of 0 standing passengers per square meter[5], standing in a crowding of 1 standing passenger per square meter, standing in a crowding of 4 standing passengers per square meter, and standing in a crowding of 8 standing passengers per square meter. Finally, note that WTP and multipliers are estimated in the statistical software Stata (StataCorp, 2011) and that their standard errors are calculated by the delta method (see e.g. Cameron & Trivedi, 2005, p. 231-2).

3. RESULTS

3.1 ESTIMATED MODEL, WTP, AND MULTIPLIERS

In Table 5, the estimated results of the discrete choice model specification are presented. All coefficients in the model are set as random. Price, travel time, and crowding level are considered

[5] Here, the respondent is the only standing passengers in the vehicle.

as disutilities and cannot be positive, and therefore the coefficients were estimated by assuming log-normal distributions. Standing and the interaction between standing and crowding level can be either positive or negative and therefore we estimate them by assuming normal distributions.

Note that the crowding levels of 0 and 1 standing passenger per square meter are merged into the same category in the estimated model. This means that we assume that no WTP for reducing this relatively low level of crowding exists. We have tested models including indicators of 1 standing passenger per square meter and these models showed some non-credible results. In particular, the model resulted in an insignificant effect of 1 person per square meter compared to no person standing – when sitting. When standing, the effect of 1 person standing per square meter was larger than the one of 4 persons standing per square meter, resulting in the WTP to reduce the number of those standing to 0, was large in the condition of 1 person standing per square meter, but insignificant in the condition of 4 persons standing per square meter. Note that by merging these two crowding levels, we will estimate 5 VTTS multipliers of comfort and crowding level.

Table 5. Estimates from the discrete choice models. Median and standard deviation.

Variable	**Coefficient**	**Standard error**
Median		
Price	-.153***	.008
Travel Time	-.106***	.008
Sitting	Reference	
Standing	-.104***	.006
Crowding 0-1/m^2	Reference	
Crowding 4/m^2	-.014***	.004
Crowding 8/m^2	-.051***	.005
Standing*Crowding 4/m^2	-.004	.006
Standing*Crowding 8/m^2	-.051***	.010
Standard deviation		
Price	.642***	.107
Travel Time	.246***	.035
Standing	.106***	.007
Crowding 4/m^2	.037***	.006
Crowding 8/m^2	.016	.009
Standing*Crowding 4/m^2	.039***	.010
Standing*Crowding 8/m^2	.111***	.013
Log-likelihood	-6686.390	
Pseudo R-square[a]	0.283	

Notes: The estimations are based on 13,459 choices of 2,003 respondents. Number of Halton draws is 500. *p < 0.05, **p < 0.01, ***p < 0.001. Standing and crowding levels are multiplied by travel time to be interpreted in the travel time unit.

[a] Estimated by $1 - \frac{\ln \hat{L}(M_{Full})}{\ln \hat{L}(M_{Intercept})}$.

The estimated results show that the parameters estimating the main effects are strongly statistically significant. The interaction between standing and crowding is non-significant for 4 standing passengers per square meter. For 8 standing passengers per square meter, on the other hand, the interaction effect between standing and crowding is negative and significant. Thus the effect of standing is worst when the crowding level is extremely high.

The estimated standard deviations show large variation for some marginal utilities and remarkably small variation for other marginal utilities. This result has intuitive explanations. Price, travel time, and standing all have a large variation of the individual preferences. This means that some travelers dislike increases in these travel characteristics to a large extent while others tend not to care about such changes. This is also the fact with the crowding level of 4 standing passengers per square meter and the interaction between standing and crowding levels, which the travelers tend to value in a very heterogeneous way. When it comes to the crowding level of 8 standing passengers per square meter, that is the extremely high crowding, the standard deviation is not significant, meaning that the travelers treat this extreme crowding homogeneously. In other words, all travelers tend to refuse this crowding level strongly, which is intuitive as this particular crowding level is extremely high. In addition, regarding the standing coefficient, we can calculate the fraction of the travelers who actually prefer to stand as the preference heterogeneity is normally distributed. Based on the standardized normal distribution[6], we calculated the relatively large share of about 16 percent of the travelers that prefer standing to sitting. This seems in fact intuitive since many trips in local public transport are short and it is common to observe people standing although there are available seats.

In Table 6, we present the WTP estimates for crowding reductions, seating, and travel time savings calculated as described in Equations (2) and (3). Note that the WTP for simultaneous crowding reduction and comfort improvement can be calculated by adding up the corresponding WTP estimates.

Crowding reductions from a crowding of 4 passengers standing per square meter to no crowding, is worth SEK 6 per hour when the traveler is sitting, and SEK 7 when the traveler is standing. If instead the crowding level “before change” is higher, the WTP is, as expected, higher. Note that a reduction from 8 passengers standing per square meter to no crowding is worth twice as much when standing is compared to sitting. The WTP for increased comfort, i.e.

[6] *Z*-value of the standardized normal distribution for positive marginal utility is .104/.106 = 0.98. The share with a higher *z*-value than 0.98 is about 16 percent.

to get a seat, is worth SEK 41 or SEK 61 depending on the crowding level. At the highest crowding level, a seat is worth significantly more than at the other two crowding levels.

Table 6. Estimated hourly WTP for changes in crowding, comfort, and travel time.

Reduction of crowding		WTP (SEK/h) [Confidence interval]
Before change	**After change**	
Sitting, crowding 4/m^2	Sitting, crowding 0-1/m^2	6 [2 – 9]
Sitting, crowding 8/m^2	Sitting, crowding 0-1/m^2	20 [17 – 24]
Standing, crowding 4/m^2	Standing, crowding 0-1/m^2	7 [4 – 11]
Standing, crowding 8/m^2	Standing, crowding 0-1/m^2	40 [32 – 48]
Increasing comfort (seat)		
Before change	**After change**	
Standing, crowding 0-1/m^2	Sitting, crowding 0-1/m^2	41 [36 – 45]
Standing, crowding 4/m^2	Sitting, crowding 4/m^2	42 [37 – 48]
Standing, crowding 8/m^2	Sitting, crowding 8/m^2	61 [52 – 70]
VTTS		
Reference condition (sitting, crowding 0-1/m^2)		42 [36 – 48]

Notes: The confidence intervals are at 95 percent level and calculated based on standard error calculated with the delta method. The WTP estimates are either a change from a travel condition with crowding to a travel condition without crowding, or from a standing travel condition to a sitting travel condition. Given in SEK, SEK 10 ≈ EUR 1.

As described earlier, VTTS multipliers are commonly used (e.g. Wardman & Whelan, 2011) to interpret the comfort and crowding reducing benefits. In these cases, the WTP for reducing the travel time in a given travel condition is calculated relative to the VTTS for the reference travel condition. Recall that we have defined the reference travel condition as sitting where there is no standing crowding in the vehicle. In Table 7, the estimated VTTS multipliers are presented.

Table 7. Estimated VTTS multipliers for standing, and crowding

Travel condition	VTTS multiplier [Confidence interval]
Sitting, crowding 0-1/m^2	1 (reference)
Sitting, crowding 4/m^2	1.13 [1.06 – 1.21]
Sitting, crowding 8/m^2	1.48 [1.38 – 1.58]
Standing, crowding 0-1/m^2	1.98 [1.82 – 2.13]
Standing, crowding 4/m^2	2.15 [1.96 – 2.33]
Standing, crowding 8/m^2	2.94 [2.60 – 3.28]

Notes: The confidence intervals are at 95 percent level and calculated based on standard error calculated with the delta method.

The multipliers can be used to calculate the VTTS of the different travel conditions, i.e. Equation (4). For example, by multiplying VTTS for the reference condition by 2.94 we get the VTTS for the travel condition standing at the crowding level of 8 standing passengers per square meter, which is SEK 123 per hour.

In Figure 3, the VTTS multipliers are presented graphically. It is clear that the highest crowding level is considered as much worse by the respondents than the other crowding levels, especially when standing. We can also see that the two graphs, for sitting and standing respectively, are close to parallel between 0-1 standing passengers per square meter and 4 standing passengers per square meter, which illustrates the non-significant estimated parameter for standing interacted with crowding level of 4 standing passengers per square meter.

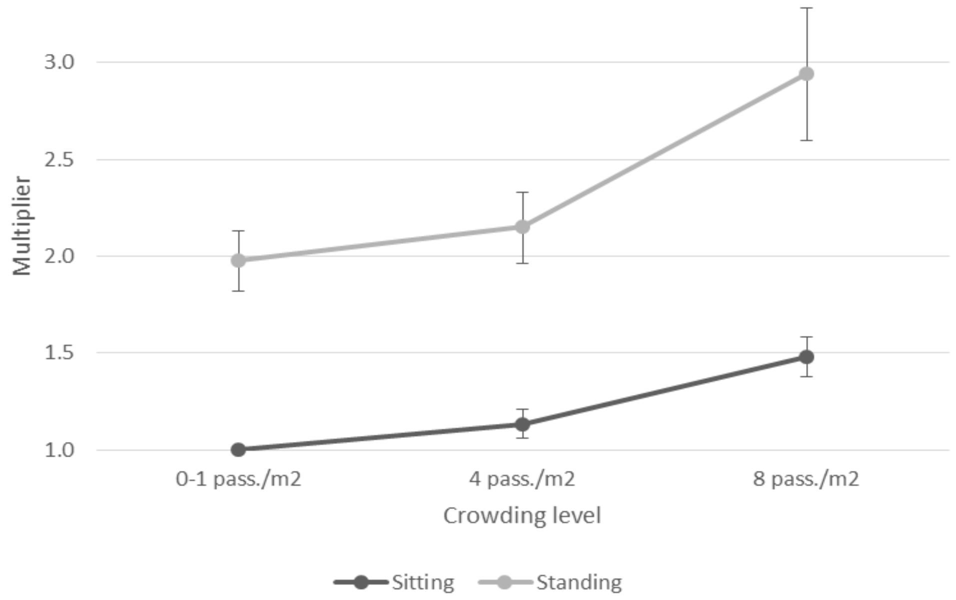

Figure 3. Estimated VTTS multipliers and 95% confidence intervals for comfort and crowding levels.

3.2 ANALYSIS OF ROBUSTNESS

We have analyzed the robustness of the estimated results with respect to different questionnaire and respondent characteristics. The objective of this exercise is to check whether different sub groups have different values of comfort and crowding reduction. VTTS is well known to differ between different individual characteristics, both theoretically and empirically (Mackie et al., 2001). Examples are that VTTS increase with income and that VTTS are higher for commuting trips than other private trips.

In Table 8, we present the VTTS for different sub groups and note if the estimated result alters. The results show mainly expected patterns. For example, the high-income group has a significantly higher VTTS than the low-income group, and the group traveling to/from work has a significantly higher VTTS than the group with other trip purposes. The VTTS do not differ between the age groups. Neither is there a difference in VTTS between women and men after potential income effects were controlled for, i.e. we analyzed only the group that have a monthly income of SEK 20,000 to 30,000. The difference between VTTS for bus and rail in the official Swedish CBA values (Trafikverket, 2015) was not entirely supported here, even if there was such a tendency (significant difference when confidence intervals are at 90 percent level).

Table 8. Descriptions of the analysis of robustness.

	VTTS in SEK/h (sitting, crowding 0-1/m^2)	**No. of obs.**
Total sample	42 [36 – 48]	13,459
Income		
- Less or equal to SEK 30,000	31 [25 – 38]	8,192
- More than SEK 30,000	69 [55 – 83]	5,267
Main travel mode		
- Bus	33 [24 – 42]	5,203
- Rail	48 [39 – 56]	8,256
Age		
- 40 years old or younger	47 [40 – 55]	6,494
- More than 40 years old	40 [31 – 50]	6,965
Gender, given monthly income of SEK 20,000 to 30,000‡		
- Women	34 [24 – 45]	2,176
- Men	37 [21 – 54]	1,478
Urban area		
- Gothenburg	40 [31 – 49]	5,125
- Malmö	42 [29 – 55]	3,081
- Stockholm	44 [33 – 56]	5,253
Sampling method		
- Panel	41 [35 – 47]	9,629
- Field	48 [35 – 61]	3,830
Travel length in SP‡		
- Short	46 [35 – 57]	4,896
- Long	40 [34 – 45]	8,563
Purpose of the trip		
- Work	58 [46 – 71]	5,515
- Studies/other	30 [24 – 37]	7,303

Notes: The confidence intervals are at 95 percent level and calculated based on standard error calculated with the delta method.

‡ Because the models separating gender and travel length did not converge, we ran these models with the price coefficient fixed. The values from these models are therefore not fully comparable with the values from the other models.

We also compared the multipliers between the groups, showing that in most cases the multipliers were surprisingly equal. However, this does not mean that the WTP for crowding reduction and comfort has to be equal. If the VTTS for the reference situation differ significantly between the groups, it is very likely that the WTP for crowding reduction and comfort also differ. The multipliers that differ significantly between the groups were the ones for comfort in the comparison of the two age groups, indicating that the older group is, relative to the reference VTTS, experiencing more disutility from standing compared to the younger group. We also found a significant difference between the multiplier regarding sitting in the crowding level of 8 standing passengers per square meter in the groups with different purposes to their trips, where travelers with other purposes than work, have a higher multiplier.

4. DISCUSSION

The result of our study is policy relevant for CBA of public transport services, both regarding service frequency and new investment in public transport. This is a relevant topic in many urban areas around the world which suffer from crowding on board public transport.

Compared to the meta-study of Wardman and Whelan (2011), our VTTS multipliers are relatively similar with a tendency to lower multipliers in our study. This tendency depends on the crowding levels used in these studies. For the highest crowding level used in our study, which is the very high level of 8 standing passengers per square meter, the VTTS multiplier is slightly smaller than three for standing conditions. In Wardman and Whelan (2011), the multiplier of about three is, for leisure trip standing travelers, found for a load factor of around 200 percent. In a study by Haywood and Koning (2015) VTTS multipliers were estimated that are relatively close to our estimates. In addition, our estimated WTP for seating and crowding reductions are generally higher than previous Swedish estimates such as Transek (2006) and Olsson et al. (2001).

This brief discussion leads us to the translation between load factor and the number of standing passengers per square meter, which is not easily established. We have chosen to use the number of standing passengers on a given floor area as it is more general and can be applied to different modes and vehicles. This approach is also used in previous literature (e.g. Basu & Hunt, 2012; Tirachini et al., 2013; Whelan & Crocket, 2009). Tirachini et al. (2013) compare a load factor of 200 percent to about 3 standing passengers per square meter. If this is the real case, our multipliers are much lower than the multipliers of Wardman and Whelan (2011) and our crowding level of 8 standing passengers per square meter can be considered as extremely high.

On the other hand, Basu and Hunt (2012) define 7 standing passengers per square meter as heavy crowding and 12 standing passengers per square meter as very heavy crowding. Recall however that this definition is based on Indian conditions.

Furthermore, we have not in our SP design analyzed any WTP of crowding below a condition where all seats are taken. In reality, there are probably travelers that have a willingness to pay for seating with a free seat next to them. On the other hand, we argue that increased service of public transport cannot target individuals with such preferences, especially when a lot of public transport in urban areas suffers from overcrowding, and since public transport is highly financed by the tax payers. Therefore, we decided to not incorporate such alternatives in our SP design as it would have increased the complexity radically.

There may be other negative effects of crowding that are not captured in this study, i.e. travel time increases as more passengers board and alight the vehicles. Also, more travelers on stations and platforms imply longer walking time, which in turn make the entire trip last for a longer time. See Tirachini et al. (2013) for discussion about these additional effects of crowding in public transport.

The risk of hypothetical and strategic bias in our SP-based WTP estimates need a brief discussion. We have conducted sensitivity analysis and checks of robustness which show that the results are robust to, for example, urban area and sampling method. As another check of the plausibility of our results, the reference VTTS is estimated to SEK 42 per hour, which is close to the official Swedish CBA values (Trafikverket, 2015) of SEK 33-69 for short private trips in public transport depending on mode and purpose of the trip. In addition, expected variations of VTTS occur for income, trip purpose, and with a tendency also towards a difference across bus and rail modes. For example, by splitting the sample with respect to median income, reference VTTS for the high-income group is SEK 69 and reference VTTS for the low-income group is SEK 31. All these features are close to our expectations and we thus conclude that we do not have any evidence of problems with hypothetical bias or strategic bias.

5. CONCLUSION

The purpose of the present study was to estimate the willingness to pay (WTP) for comfort, i.e. to get a seat, and crowding reduction on board local public transport in Sweden, including the modes metro, tram, commuter trains, and local bus. We have used SP data based on 2,003 respondents consisting of both frequent public-transport users and non-frequent public-transport users.

WTP for seating is estimated to SEK 41-61 per hour depending on the crowding level. The WTP for crowding reductions are estimated to SEK 6-7 for a reduction from 4 standing passenger per square meter to 0-1 standing passengers per square meter, i.e. very similar for sitting and standing. A reduction from 8 standing passengers per square meter to no standing passengers is valued SEK 20-40 depending on sitting or standing, i.e. higher for standing than for sitting. These estimates are higher than previous Swedish estimates (Olsson et al., 2001; Transek, 2006).

If we instead interpreted our estimated results as multipliers of the value of travel time savings, the worst travel condition in our study, i.e. standing in a crowding of 8 standing passengers per square meter, has a multiplier of about 2.9. This means that the travel time saving in this travel condition is valued 2.9 times the travel time saving in the reference travel condition of sitting when there are 0-1 standing passengers per square meter. This multiplier seems relatively close compared to the results of a current meta-study (Wardman & Whelan, 2011), where a multiplier of 3 is found for standing in the load factor of 200 percent for leisure trips. It is not easy to translate load factor to number of standing passengers per square meter though, but for most of the modes we can approximate 200 percent with 3 standing passengers per square meter (Tirachini et al., 2013). In such a case, our multipliers are lower than the multipliers of Wardman and Whelan (2011). On the other hand, our estimates are more in line with a recent study by Haywood and Koning (2015). All in all, we conclude that our results seem plausible as they are in the middle of other studies that have evaluated comfort and crowding reductions.

In addition, sensitivity analysis and checks of robustness also show that the results vary as expected with respect to income and purpose of the trip. Along with further robustness checks, we conclude that no evidence of problem with hypothetical or strategic bias occur in our SP study.

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