

On the value of crowding in public transport for Île-de-France

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1. BACKGROUND

Since the mid 90's, public transport patronage in Île-de-France (the Paris region) has increased substantially: over the last decade alone a 20% growth was observed. This growth, even though it was an aim of the Sustainable Urban Mobility plan adopted in 2000, was not completely anticipated. Consequently, the capacity is no longer sufficient to meet the demand during the peak hours, particularly on several parts of the network in the dense central area of the region. This results in over-crowded vehicles and long waiting times for passengers at rail platforms and bus stops. The lack of maintenance and modernisation of the transport system causes additional operational difficulties.

Renewal of the rail infrastructure and rolling stock is necessary to cope with this situation. But renewal alone will not be enough. Major investments are planned to increase capacity by either building new lines, or by increasing capacity of existing lines. The Grand Paris Express is the best known of these projects. Furthermore, a number of bus lines will be transformed into tramway lines, railway lines are being renovated, and new automatic systems for railway operation will allow shorter headways between subsequent trains, and thus more capacity. All these projects together should reduce the shortage of capacity substantially by 2020, and totally eliminate it by 2030. As a consequence, crowding levels in public transport will be highly reduced.

For the socio-economic appraisal, it is necessary to quantify all impacts of these investments. The impact on travel and waiting times can be determined by using standard traffic models, such as the ANTONIN model that is used in the Île-de-France area. The reduction in congestion levels can also be forecasted by more using advanced traffic models. However, little is known about the value that passengers attach to these reduced congestion levels (for a review of existing literature, see section 3).

Therefore, STIF commissioned Significance in 2011 to conduct a new study focused on the perception of comfort inside public transport vehicles in general, and more particularly on the issue of crowding. This study was to cover all modes of public transport in Île-de-France.

2. OBJECTIVES AND RESEARCH APPROACH

The study reported here aimed at estimating the perceived value of crowding in public transport vehicles in Île-de-France. Different values and preferences for each available public transport mode had to be derived, where necessary. All results had to be valid for the Île-de-France. The final values are intended for use in cost-benefit analyses appraising the socio-economic effects of public transport projects; and in passenger demand forecasting models predicting mode choice and route choice by public transport users in Île-de-France.

The research approach used for this study consisted of four phases:

- The first phase included a literature review of French and international scientific publications on the value that public transport passengers attach to comfort and particularly to crowding inside the vehicles.
- The second phase was a qualitative investigation of the key factors driving the perception of comfort by different categories of public transport passengers.
- The third phase consisted of the design, execution and analysis of a stated preference survey, to derive coefficients on the value of comfort. Comfort was considered in all its dimensions, but specific focus was put on crowding. In addition to the stated preferences surveys, questions were asked about the passengers' attitudes towards public transport, which resulted in a typology of the respondents.
- The fourth phase consisted of a revealed preferences survey to verify the results of the stated preferences survey. Passenger counts and interviews were carried out at different rail stations to measure the proportion of passengers actually preferring to wait for the next vehicle instead of taking the (more crowded) first vehicle.

The present publication concentrates on the estimation of the value of crowding inside public transport vehicles, and the application of the results obtained in cost-benefit analysis.

3. LITERATURE REVIEW

The literature review demonstrated that only limited knowledge is available about consumers' valuation of crowding inside France, while the value of comfort is almost an entirely new subject. But also outside France the literature on the subject is fairly limited. Li and Hensher (2011) reviewed the international literature available until then, and Wardman and Whelan (2011) provided a synthesis of 20 years of rail crowding valuation studies carried out in the UK. Earlier work includes Douglas Economics (2006) which reported results of rail oriented stated preference research carried out in New Zealand. Other earlier crowding work includes Cox et al. (2006), Baker et al. (2007), Oxera (2007), MVA (2007) and Whelan and Crocket (2009). In France two studies reporting crowding results can be mentioned: a recent one by Haywood and Koning (2011), and another one by Kroes et al. (2006). We shall briefly discuss some of the most interesting results in the following paragraphs.

Li and Hensher (2011) reviewed public transport crowding valuation research using studies conducted in the UK, the USA, Australia and Israel. They identified three measures to value crowding: (1) a travel time multiplier, (2) a monetary value per time unit, and (3) a monetary value per trip, but did not provide a comparison between their performances. They also described associated ways to represent crowding in stated preference experiments, and implied that Stated Preference research is the preferred way of conducting valuation research for crowding. Despite the highly different characteristics of the studies they reviewed, they note that they all reported that crowding would increase the value of travel time savings, which, according to them, "can be viewed as an additional component of generalised time".

Wardman and Whelan (2011) reviewed the extensive research that has been carried out in the United Kingdom into the value of crowding for rail transport during the last two decades, particularly using Stated Preference studies. They did this in a meta-analysis project. They found that, particularly for those passengers that have to stand in the vehicles, there appears to be a substantial disutility of travel. They expressed this disutility as a multiplier for travel time: when crowding levels are low the multiplier is close to one, but when not all passengers can travel seated the multiplier increases to values up to 2.7 for standing passengers in extremely full trains, and 1.7 for seated passengers. This means that the disutility of travel in a very crowded situation is for standing passengers more than twice as high as compared with a situation when seats are available. And even for seated passengers the additional disutility is substantial.

In Paris, Haywood and Koning (2011) reported their study about "Pushy Parisian Elbows" along part of metro line 1 in Paris. Using contingent valuation the authors quantified the passengers' trade-off between crowding and travel time. They found that metro passengers were prepared to travel on average 8 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 euro per trip, which is clearly non-negligible.

Also in Paris, but a few years earlier, Kroes et al (2006) conducted research based upon SP experiments for travel on interurban rail lines. Although the study aimed primarily at measuring the value of punctuality, it also produced penalties for travelling under crowded circumstances, which were expressed as minutes of equivalent travel time. For commuting to central Paris, for instance, they found that the penalty for travelling standing was equal to 4.9 minutes per trip plus 0.3 minute per minute of travel time. So a 20 minute trip would have a penalty of 10.9 minutes additional perceived travel time.

In summary, we have seen a number of common elements emerging from the literature:

- Crowding inside public transport vehicles generates substantial disutility, which adds to the generalised cost of travel;
- The research that has been conducted into the valuation of crowding has almost exclusively used Stated Preference data to estimate the values. This is likely to be related to the fact that it is extremely difficult to find real-life situations where passengers can be observed to trade crowding against travel time or cost;
- Most studies express the disutility of crowding using a travel time multiplier, which is a function of the level of crowding, and which is different for seated and standing passengers.

4. QUALITATIVE RESEARCH

In order to learn more about the key factors driving the perception of comfort (crowding and other elements of comfort) in public transport vehicles, and in order to prepare for the Stated Preference surveys in our study, five focus-group discussions were organized. These consisted of young adults, frequent commuters, occasional and non-commuter traveller's, seniors, inhabitants of more remote suburbs.

The group discussions aimed specifically at understanding passenger's perception of physical comfort inside all types of public transport vehicles in order to identify which dimensions and features are important, and what consequences discomfort has on behaviour. Comfort while waiting at platforms and bus stops was not included in this project.

It was found that the perception of physical comfort in public transport covers a range of aspects including crowding, stability of the vehicle, seat comfort, temperature, smells, noise, comfort when standing, ease of access, and ease of on board circulation. For each aspect of comfort, participants were asked to define what a perfect, a correct, an uncomfortable and an unbearable level was. Table 1 shows the results for the aspect of crowding.

Table 1. **Levels of perception with respect to crowding**

	Level of perception			
	Perfect	Correct	Uncomfortable	Unbearable
Descriptive	<i>"there are a few persons"</i>	<i>"almost all seats are occupied. A few people are standing, one can move easily"</i>	<i>"all seats are occupied. There are people standing, it is not easy to move"</i>	<i>"all seats are occupied. Standing passengers are next to each other"</i>
Impact on passenger	<i>"one can stay where one wants"</i>	<i>"one can choose where to stand but not choose one's seat"</i>	<i>"one has to stand but has a little space to move. One can stay near the seats to be able to sit when one gets free or near doorways to exit easily"</i>	<i>"one cannot move"</i>

Crowding was found to have the following consequences:

- It influences physical comfort;
- It requires not paying too much attention to one's psychological comfort;
- It generates crowd behaviour;
- It is a cause of irregularity of operation of service.

However, even though crowding has a negative impact on public transport image, it was reported to have only a minor impact on trip behaviour for obligatory trips such as commuting. For trips with other purposes crowding was said to have an important influence, and to lead to an increased use of less crowded modes and more travel during off-peak hours.

Behaviours to avoid discomfort that were quoted during the focus groups were:

- Letting one or two vehicles pass by before boarding, especially for modes with little capacity (bus) or with a high frequency (metro);
- Changing itinerary, even if the alternative itinerary is longer and/or requires more transfers;
- Changing the timing of travel, which includes leaving home earlier in the morning for commuters;
- Changing position inside the vehicle.

The results of the qualitative study were used to clarify the questionnaires of the stated preferences study, especially with regard to the presentation of crowding levels to the respondents.

5. STATED PREFERENCE RESEARCH

In order to appraise *a-priori* the perceived benefits of future reductions of crowding levels in public transport, it is necessary to know what economic value passengers attach to specific improvements. One way to estimate this value is to conduct a “stated preference” choice experiment (see eg. Louviere et al. 2000). In such an experiment a sample of passengers is offered a series of choices between two (or more) hypothetical alternative public transport services. These services differ in some key characteristics, such as travel time, waiting time for the next service and level of crowding inside the vehicles. Passengers are asked to state their preferences for one of the alternatives. In the Île-de-France project it was decided to choose this methodology to conduct the research.

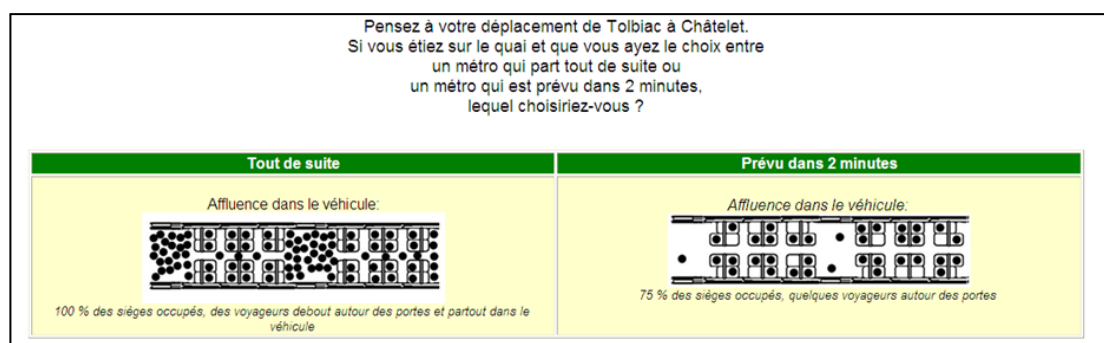
The design of the stated preference survey was based upon previous experience with crowding research reported in the literature (e.g. Li and Hensher 2011, Kroes et. al. 2006, and Wardman and Whelan 2011) and the qualitative research reported in section 4. Some of the main elements are summarised below.

5.1. The choices and choice variables

In order to prevent biases, we designed two different choice experiments to measure the value of crowding:

- In SP1 six choices were offered between taking a crowded service immediately, and waiting for the next service that would be less crowded. Each choice differed in the level of crowding of the immediate and next service (both were specified using eight possible levels) and the waiting time (five levels). An example of such a choice is given in Figure 1;

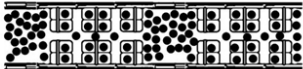

Figure 1 **Example of a choice situation from the SP1 experiment**



- In SP2 six choices were offered between taking a very crowded train with a short travel time, and taking a less crowded train with a longer travel time. Additionally, for each alternative it was specified whether the respondent would be able to find a seat, or that (s)he had to stand. Each choice differed in the level of crowding of the both services (each had eight possible levels), in the travel time (each had eleven possible levels, pivoted on the reported (current) travel time of the respondent), and in the possibility of finding a seat. An example is given in Figure 2.

Figure 2 **Example of a choice situation from the SP2 experiment**

Pensez à votre déplacement de Tolbiac à Châtelet.
 Imaginez que vous ayez le choix
 entre les deux conditions de déplacement décrites ci-dessous.
 Dans laquelle de ces deux conditions de durée, d'affluence et de position
 préférez-vous effectuer votre déplacement ?
 On suppose que la durée totale du trajet, le niveau d'affluence et votre position ne changeront pas pendant tout le trajet.

	Métron voie 1	Métron voie 2
Durée du trajet	14 minutes	15 minutes
Affluence dans le véhicule	 100 % des sièges occupés, des voyageurs debout autour des portes et partout dans le véhicule	 25 % des sièges occupés, et personne debout
Position	Vous pouvez vous asseoir pendant tout le déplacement	C'est à vous de décider de voyager assise ou debout

5.2. The presentation of crowding

Based upon the literature and the tests conducted during the qualitative research, the eight different levels of crowding were presented by means of both a graphic presentation and a description. Both were adapted to the mode of transport used by the respondent: different presentations were used for rail modes (metro, RER, train, tram) and for the bus. Table 2 shows the graphic presentations that were used.

5.3. The sample

In total 3,000 public transport users participated in the stated preference survey. They were recruited among the members of a large internet panel. Respondents had to live inside Île-de-France, and had to have made a journey by public transport recently. They were spread over the different passenger segments that were under investigation. These segments differed by:

- public transport mode used;
- residential area;
- age category;
- gender;
- working status (active versus non-active).

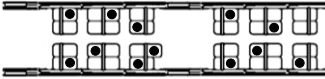
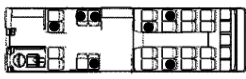
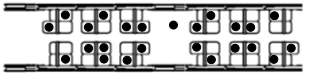
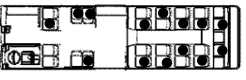
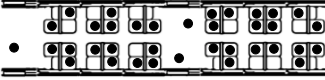
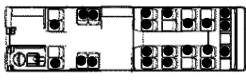
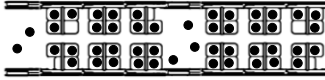
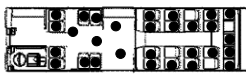
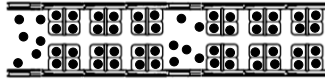
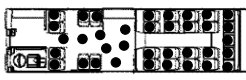
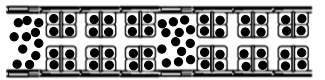
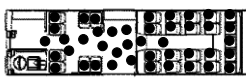
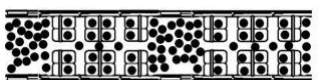
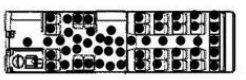

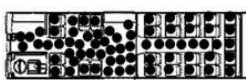
The recruited public transport users were interviewed by internet, using a personalised questionnaire based upon their reported travel characteristics for a recent journey. The interviews took place between September and December 2011.

All responses were subjected to a strict quality control process, checking the following elements:

- responses with out-of-scope origins and destinations were eliminated;
- responses with very short survey completion times were eliminated;
- respondents which did not answer all stated preference questions were eliminated;
- respondents with unrealistically long travel times were eliminated.

After this process we had the SP choices of 2,711 respondents (about 90% of the original sample) available for analysis.

Table 2. **Presentation of the crowding levels by mode**

Level	Number of passengers (% of total number of seats)	Metro, train, RER, tram	Bus
1	25%		
2	50%		
3	75%		
4	100%		
5	125%		
6	150%		
7	200%		
8	250%		

6. A TYPOLOGY BASED UPON ATTITUDES

All respondents that participated in the stated preference survey were also asked to answer a series of questions concerning their attitudes towards public transport. They were invited to give a score from 1 to 10 to express their level of agreement with fourteen statements related to public transport, such as "*In public transport, having to stand during your journey is a nuisance*" and "*When it is very crowded in public transport I do not respect anything, it is everybody for himself*".

A statistical analysis was carried out to identify segments of passengers that were similar in terms of their attitudes with respect to public transport. This resulted in four groups of passengers that were homogenous in their public transport attitudes. These four groups ("types") were:

- Type 1: *Passengers fearing closeness of other passengers* (34% of sample). These passengers have more often than average fear for crowds, for dirtiness and for incidents. Standing is tiresome for them and they consider they have the right to get a seat in public transport. Avoiding underground modes and searching for comfort are important criteria in their route and mode choice when using public transport. This group contains, more than average, (i) women, (ii) persons travelling with time constraints, (iii) persons using surface modes, and (iv) persons who are less mobile.
- Type 2: *Passengers enjoying a time of their own* (23% of sample). For this group, the time spent in public transport is a moment of pleasure and relaxation because they can do things they want during their trip. They are not disturbed by the conditions of transport mainly because they experience public transport only when it is not crowded. This group is, more often than average, (i) male, (ii) retired, (iii) using surface transport modes, and (iv) travelling during off-peak hours.
- Type 3: *Passengers wanting to save time* (18% of sample). For these people travelling is not a moment of pleasure: reducing their travel time is important and they attach importance to being seated. This group is more often than average: (i) female, (ii) relatively young, (iii) students or persons working in private sector, (iv) passengers travelling at fixed hours they don't control, (v) users of underground modes, (vi) passengers travelling during peak hours, and (vii) people not owning a driving licence.
- Type 4: *Passengers acting as individualists* (25% of sample). For this group, comfort, punctuality and travel time do not have a major influence on their choices. They are rather insensible to the world surrounding them and they don't care much for other people. When crowding is high, those persons may show impolite behaviour. This group is more often than average: (i) men, (ii) young people, (iii) students, (iv) travelling at fixed travel time they don't control, (v) travelling off-peak.

This typology shows that behaviours towards comfort and affluence differ a lot according to these different groups of travellers. Two underlying causes may explain these differences:

1. the ability of different travellers to choose different modes, routes and departure times. Some can choose when to travel or which mode (public or private) to take. For others, constraints are stronger and they have no choice: they have to travel by public transport and/or at a certain time.
2. intrinsic character differences between travellers: some people are less sensitive to public transport discomfort and annoyances than others.

7. ANALYSIS OF STATED PREFERENCES

When analysing the responses of the respondents, we noted that a relatively large percentage of the public transport passengers indicated that they were prepared to wait a few minutes in order to travel in a less crowded train: from 13% when the current train is hardly crowded to 75% when the current train is absolutely packed and the next train has seats available. We found this percentage intuitively rather high.

We analysed the choices of the public transport users in the stated preferences experiments to derive the utility weights of each of the service quality variables using discrete choice analysis methods – in this case simple logit analysis based upon maximum likelihood estimation (see eg. Ben-Akiva and Lerman 1985). We have tested a large number of different model specifications. Here we report only some of the most interesting findings.

7.1. Crowding level of first train versus next train

In a first very simple model we estimated only the following coefficients on data from SP1 only:

- seven constants for the crowding levels (level 2 – 8) of the first train¹. The lowest level was constrained to zero.
- seven constants for the crowding levels (level 1 – 7) of the next train. Again, the lowest level was constrained to zero.
- a linear coefficient for the waiting time between the first and next train,
- and a constant which indicates an intrinsic preference to wait for the next train (i.e. an alternative specific constant).

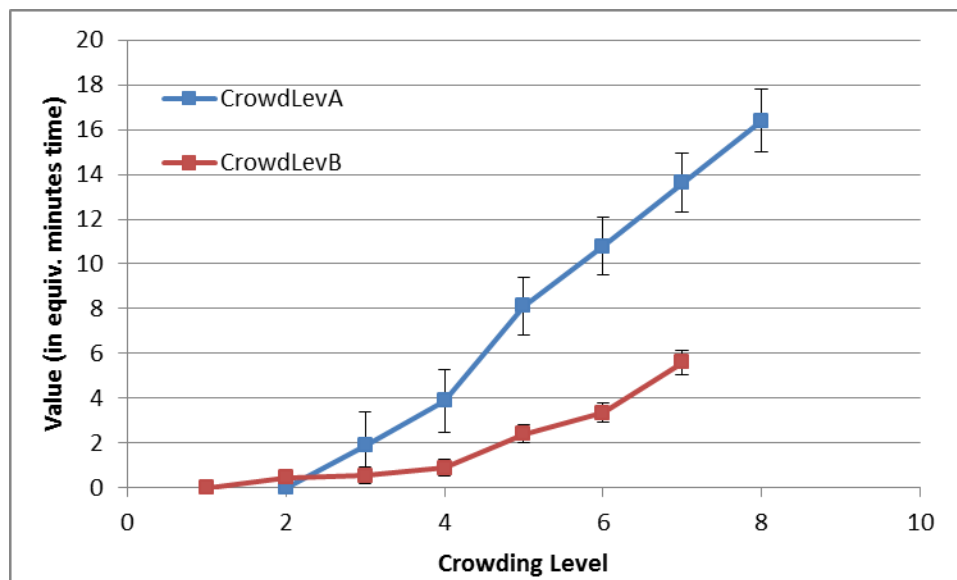
All coefficients had the expected sign and all were highly significant. The sensitivity of the coefficient to the crowding level of the first train was much greater than that of the next train. The passengers appeared to base their choice primarily on the crowding level of the first train to come, as can be seen from Figure 3. Note that in this Figure the crowding coefficients have been divided by the waiting time coefficients to give a vertical scale that can be easily interpreted. A small jump in both the value of the crowding of the first and the next train can be observed between crowding levels 4 and 5, which is exactly the transition to a situation where the traveller can no longer sit if he wants to.

The constant had a value equivalent to 5.2 minutes of waiting time. This can be interpreted as a strong preference to wait for the next train, all other things being equal.

1. In this section, we refer to first “train” and next “train”. However, the analysis was done on a joint dataset for all modes (train, RER, metro, bus, tram).

Whether this is a real effect, or a statement from the respondents that they are very unhappy with crowded trains, is unclear at this point in the analysis.

Figure 3. **Estimated coefficients on crowding**



7.2. Constant value per trip versus travel time multiplier

To express the disutility of crowding one can use a single constant value (or penalty) per trip, as was done in the previous paragraph, or one can use a travel time multiplier value. The first type of specification assumes that the crowding effect is irrespective of the duration of travel, the second specification assumes that the crowding effect is proportional to the travel time. The last specification seems intuitively appealing: the longer the journey, the more important it is to travel comfortably. On the other hand it is rare for travellers making long journeys not to find a seat at some stage during the journey, so the crowding does not produce a constant nuisance during the whole journey.

Therefore, we estimated a second model, again on data from SP1 only, with the following coefficients:

- seven coefficients on travel time, each interacting with a crowding level (level 2 – 8) of the first train. The lowest level was constrained to zero.
- seven coefficients on travel time, each interacting with a crowding level (level 1 – 7) of the next train. Again, the lowest level was constrained to zero.
- a linear coefficient for the waiting time between the first and next train,
- a constant indicating an intrinsic preference to wait for the next train,
- and a coefficient on travel time, indicating an intrinsic preference to wait for the next train that is proportional to travel time.

Table 3 presents the estimation results for both models. From this, we conclude that the constant value per trip provided a significantly better statistical fit to our stated choice data than the multiplier specification:

Table 3. **Estimated coefficients for a model with constants and a proportional model**

	CONSTANTS MODEL		PROPORTIONAL MODEL	
Observations	7638		7638	
Final log (L)	-4477.9		-4645.3	
D.O.F.	14		15	
Rho ² (0)	0.154		0.123	
Rho ² (c)	0.141		0.109	
Time_Wait	-0.2425	(-24.9)	-0.2160	(-23.0)
CrowdLvA2	0	(*)	0	(*)
CrowdLvA3	-0.4615	(-1.3)	-0.04453	(-2.5)
CrowdLvA4	-0.9425	(-2.9)	-0.06402	(-3.9)
CrowdLvA5	-1.969	(-6.3)	-0.08944	(-5.6)
CrowdLvA6	-2.615	(-8.4)	-0.1104	(-6.9)
CrowdLvA7	-3.304	(-10.7)	-0.1279	(-8.0)
CrowdLvA8	-3.975	(-12.8)	-0.1452	(-9.1)
CrowdLvB1	0	(*)	0	(*)
CrowdLvB2	-0.1083	(-1.2)	-0.00484	(-1.5)
CrowdLvB3	-0.1353	(-1.5)	-0.00553	(-1.7)
CrowdLvB4	-0.2172	(-2.4)	-0.00752	(-2.3)
CrowdLvB5	-0.5858	(-6.2)	-0.01868	(-5.5)
CrowdLvB6	-0.8149	(-8.1)	-0.02493	(-7.0)
CrowdLvB7	-1.359	(-10.5)	-0.04303	(-9.5)
ASC_Wait	-1.273	(-4.3)	1.080	(16.5)
ASC_WaitP	0	(*)	-0.09836	(-6.2)

where Wait is waiting time, CrowdLvA2 is the utility for crowding level 2 for vehicle A (first arriving vehicle), CrowdLvB1 is the utility for crowding level 1 for vehicle B (next vehicle) etc., ASC_Wait is a constant for waiting, ASC_WaitP is a preference for waiting proportional to travel time.

It is clear that the CONSTANTS model fits the data much better than the PROPORTIONAL model, even though that model has one additional coefficient. For the SP2 we came to the same conclusion. We also tested a combined model with both constants and coefficients proportional with travel time.

This result is remarkable in that almost all studies in the United Kingdom and several studies conducted elsewhere use the travel time multiplier value to express the disutility of crowding.

7.3. Simultaneous estimation using SP1 and SP2

We have estimated separate models for SP1 and SP2, and then we have tested a single joint model using both data simultaneously. It turned out that the resulting values of crowding were not significantly different between both experiments for any of the crowding levels, provided that we used separated scale factors for both SP experiments to account for differences in error. Consequently we have used the simultaneous model specification for deriving the final application coefficients.

Table 4. **Estimated coefficients for separate and joint models**

	SP 1		SP 2		Joint SP 1+2	
Observations	7638		13116		20754	
Final log (L)	-4477.9		-7755.3		-12241.5	
D.O.F.	14		15		18	
Rho ² (0)	0.154		0.147		0.149	
Rho ² (c)	0.141		0.141		0.141	
Time	0	(*)	-0.1767	(-28.9)	-0.1768	(-29.0)
Time_Wait	-0.2425	(-24.9)	0	(*)	-0.1643	(-16.8)
CrowdLvA2	0	(*)	0	(*)	0	(*)
CrowdLvA3	-0.4615	(-1.3)	-0.3482	(-1.0)	-0.3291	(-1.6)
CrowdLvA4	-0.9425	(-2.9)	-0.8730	(-2.5)	-0.6973	(-3.7)
CrowdLvA5	-1.969	(-6.3)	-1.335	(-4.3)	-1.345	(-7.3)
CrowdLvA6	-2.615	(-8.4)	-1.798	(-5.8)	-1.796	(-9.6)
CrowdLvA7	-3.304	(-10.7)	-2.210	(-7.1)	-2.238	(-11.8)
CrowdLvA8	-3.975	(-12.8)	-2.734	(-8.8)	-2.723	(-13.8)
CrowdLvB1	0	(*)	0	(*)	0	(*)
CrowdLvB2	-0.1083	(-1.2)	-0.2910	(-3.8)	-0.1534	(-3.2)
CrowdLvB3	-0.1353	(-1.5)	-0.2965	(-3.8)	-0.1670	(-3.5)
CrowdLvB4	-0.2172	(-2.4)	-0.3627	(-4.6)	-0.2280	(-4.6)
CrowdLvB5	-0.5858	(-6.2)	-0.3915	(-5.4)	-0.3745	(-7.6)
CrowdLvB6	-0.8149	(-8.1)	-0.7417	(-9.7)	-0.6375	(-11.6)
CrowdLvB7	-1.359	(-10.5)	-1.066	(-11.5)	-0.9783	(-13.9)
ASC_Wait	-1.273	(-4.3)			0.8292	(4.9)
ASC_Q			0.7128	(2.4)	0.7938	(4.4)
StandDum2			-0.6625	(-20.1)	-0.6477	(-20.6)
Scale3	1.000	(*)	1.000	(*)	1.000	(*)
Scale2A	1.000	(*)	1.000	(*)	1.474	(18.7)

A few words about the different time variables that were included in SP1 and SP2: SP1 contained waiting time, and SP2 contained travel time. The ratio between the coefficients for waiting time and travel time can be computed by multiplying the waiting time coefficient in Joint SP 1+2 with the Scale2A coefficient, and dividing by the travel time coefficient. That gives a value of 1.37, which may seem a bit low but is broadly of the expected order of magnitude.

7.4. Differences between passenger types

In section 6, we have concluded that four types of respondents can be distinguished based upon their attitudes. We have tested for observed heterogeneity in the results using a range of different socio-economic variable, a number of trip related characteristics, and the typology presented in section 6. We found that generally there was only limited variation in the results between different groups of passengers, but that the typology showed the largest differences. Below we show the results for the four types we distinguished.

The passengers of type 1, fearing closeness of other passengers, are clearly averse of other passengers: for crowding level 4 they already show a significant disutility, they have the highest standing penalty (4.6 minutes) and a relatively large percentage will wait for another train if that can reduce their level of crowding from level 8 to level 4 (53%).

The passengers of type 4, acting as individualists, also show a relatively high percentage of passengers prepared to wait in order to reduce their level of crowding from level 8 to level 4 (55%).

The passengers of type 3, wanting to save time, show rather different preferences: they clearly dislike waiting (high wait penalty), and consequently relatively few passengers of this type are prepared to wait for a less crowded public transport vehicle (40%). Still the difference relative to type 1 and type 4, the other extremes, is not large in absolute terms.

The passengers of type 2, enjoying a time of their own, fall somewhere in between the types 3 and 4 in terms of percentage waiting for a less crowded vehicle (50%). They do not seem to mind very much to wait for another service, or to stand inside the vehicle.

Overall it is clear that there are differences in preferences for avoiding crowding between the four types of passengers, which are plausible and consistent with the definition of the passenger types. But these differences are not very large.

Table 5. **Estimated coefficients for each passenger class**

	ALL PASSENGERS	TYPE 1 FEARING CLOSENESS	TYPE 2 ENJOYING TIME	TYPE 3 WANT TO SAVE TIME	TYPE 4 ACT AS INDIVIDUALIST
Observations	20754	7198	5007	3858	4691
Final log (L)	-12241.5	-3982.1	-2953.3	-2261.1	-2858.1
D.O.F.	18	18	18	18	18
Rho ² (0)	0.149	0.202	0.149	0.154	0.121
Rho ² (c)	0.141	0.186	0.142	0.151	0.104
Time	-0.1768 (-29.0)	-0.1847 (-17.2)	-0.1911 (-15.2)	-0.2067 (-14.2)	-0.1391 (-11.2)
Time Wait	-0.1643 (-16.8)	-0.1777 (-10.1)	-0.1701 (-8.9)	-0.1812 (-7.3)	-0.1418 (-6.9)
CrowdLvA2	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
CrowdLvA3	-0.3291 (-1.6)	-0.4204 (-1.3)	-0.1481 (-0.3)	-1.268 (-1.8)	0.5137 (1.1)
CrowdLvA4	-0.6973 (-3.7)	-0.8340 (-2.6)	-0.6195 (-1.6)	-1.419 (-2.0)	0.1506 (0.4)
CrowdLvA5	-1.345 (-7.3)	-1.446 (-4.6)	-1.344 (-3.6)	-2.257 (-3.2)	-0.4335 (-1.1)
CrowdLvA6	-1.796 (-9.6)	-2.060 (-6.4)	-1.656 (-4.4)	-2.567 (-3.6)	-0.9738 (-2.5)
CrowdLvA7	-2.238 (-11.8)	-2.500 (-7.6)	-2.260 (-5.9)	-2.936 (-4.0)	-1.343 (-3.4)
CrowdLvA8	-2.723 (-13.8)	-2.912 (-8.5)	-2.936 (-7.4)	-3.419 (-4.6)	-1.775 (-4.5)
CrowdLvB1	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
CrowdLvB2	-0.1534 (-3.2)	-0.1862 (-2.2)	0.00201 (0.0)	-0.1425 (-1.4)	-0.3096 (-2.9)
CrowdLvB3	-0.1670 (-3.5)	-0.2701 (-3.1)	-0.00709 (-0.1)	-0.1621 (-1.6)	-0.1886 (-1.8)
CrowdLvB4	-0.2280 (-4.6)	-0.3076 (-3.4)	-0.1591 (-1.5)	-0.2120 (-2.1)	-0.2405 (-2.2)
CrowdLvB5	-0.3745 (-7.6)	-0.4859 (-5.4)	-0.2527 (-2.5)	-0.3848 (-3.7)	-0.3543 (-3.3)
CrowdLvB6	-0.6375 (-11.6)	-0.7561 (-7.6)	-0.4859 (-4.4)	-0.6634 (-5.4)	-0.6627 (-5.7)
CrowdLvB7	-0.9783 (-13.9)	-1.018 (-8.2)	-0.9339 (-6.4)	-0.9667 (-6.2)	-1.037 (-6.7)
ASC Wait	0.8292 (4.9)	0.6939 (2.4)	1.065 (3.0)	1.782 (2.6)	-0.09981 (-0.3)
ASC_Q	0.7938 (4.4)	0.6585 (2.1)	1.006 (2.7)	1.754 (2.5)	-0.03105 (-0.1)
StandDum2	-0.6477 (-20.6)	-0.8457 (-14.9)	-0.5516 (-8.6)	-0.7337 (-10.0)	-0.4390 (-6.9)
Scale3	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)
Scale2A	1.474 (18.7)	1.470 (10.9)	1.395 (10.3)	1.762 (7.7)	1.314 (8.3)
Wait penalty fac	1.37	1.41	1.24	1.54	1.34
Standing penalty (in equivalent minutes of travel time)	3.66	4.58	2.89	3.55	3.16
Difference in crowding utility between A8 and A4 (in equivalent minutes of travel time)					
A8-A4	11.5	11.3	12.1	9.7	13.8
Percentage waiting 10 minutes for an improvement of A8 to B4	51%	53%	50%	40%	55%

7.5. Coefficients for application

Having observed that the constant crowding effect per trip provided a better explanation of the stated choices than the travel time multiplier value, we have nevertheless derived a set of coefficients for application usage based upon the multiplier specification.

Crowding penalties that are proportional to travel time can easily be added to the models that are used for appraisal purposes, whereas constant penalties are much more difficult to apply in practice. This has to do with the use of public transport assignment software, and the uncertainty about the application of constants for interchanges (does one apply a bus penalty once or twice for a bus-bus interchange?). Also for application in cost-benefit analyses we often know the occupancy rate between different stops, but not the exact numbers of passengers boarding/leaving at each station.

The coefficients for application are given below in Table 6, first for all public transport modes except coach, and then separately for different (combinations of) modes. Here we have constrained the coefficients for crowding levels 1, 2 and 3 to 0 as the values were insignificant.

Table 6. **Estimated mode-specific coefficients for a proportional model**

	ALL NOT CAR	METRO	TREIN+RER	BUS+TRAM
Observations	20754	4490	7668	8596
Final log (L)	-12534.9	-2737.7	-4471.1	-5266.4
D.O.F.	14	14	14	14
Rho ² (0)	0.129	0.120	0.159	0.116
Rho ² (c)	0.120	0.110	0.145	0.110
Time	-0.1473 (-24.4)	-0.1535 (-11.8)	-0.1514 (-15.2)	-0.1434 (-15.2)
Time_Wait	-0.1311 (-12.3)	-0.1219 (-5.4)	-0.1513 (-7.9)	-0.1384 (-7.8)
CrowdLvA23	0 (*)	0 (*)	0 (*)	0 (*)
CrowdLvPP	-0.01217 (-15.8)	-0.01187 (-6.3)	-0.01100 (-10.7)	-0.01465 (-9.8)
CrowdLvB1	0 (*)	0 (*)	0 (*)	0 (*)
CrowdLvB24	-0.00392 (-3.1)	-0.00254 (-1.0)	-0.00539 (-2.8)	-0.00282 (-1.2)
CrowdLvB5	-0.01044 (-6.4)	-0.00630 (-2.1)	-0.01350 (-5.5)	-0.00813 (-2.8)
CrowdLvB6	-0.01620 (-9.0)	-0.01263 (-3.5)	-0.01770 (-6.6)	-0.01680 (-5.2)
CrowdLvB7	-0.02599 (-11.1)	-0.01608 (-3.5)	-0.02762 (-8.0)	-0.03068 (-7.2)
StandDum1	0 (*)	0 (*)	0 (*)	0 (*)
StandDum2	-0.01495 (-6.2)	-0.01553 (-2.8)	-0.01377 (-4.1)	-0.01634 (-3.6)
StandDumPP	-0.00330 (-3.5)	-0.00220 (-1.1)	-0.00375 (-2.9)	-0.00333 (-1.9)
StandDum3	0 (*)	0 (*)	0 (*)	0 (*)
ASC_Q	-0.9021 (-20.9)	-0.8900 (-9.8)	-0.9780 (-12.8)	-0.9062 (-13.5)
ASC_QP	0.03307 (11.6)	0.03861 (5.4)	0.02608 (6.8)	0.04513 (8.1)
ASC_Wait	0.6460 (10.7)	0.5277 (5.0)	1.001 (7.4)	0.6132 (6.5)
ASC_WaitP	-0.03080 (-12.4)	-0.03645 (-5.7)	-0.02796 (-7.7)	-0.03893 (-8.2)
Scale3	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)
Scale2A	1.645 (13.2)	2.088 (5.6)	1.546 (8.7)	1.616 (8.2)

These multipliers for application usage were derived for all modes together but also separately for metro, train+RER (i.e. regional rail), bus and tram. The results are given in Table 7. Note that we have based these values upon the crowding level of the first train only.

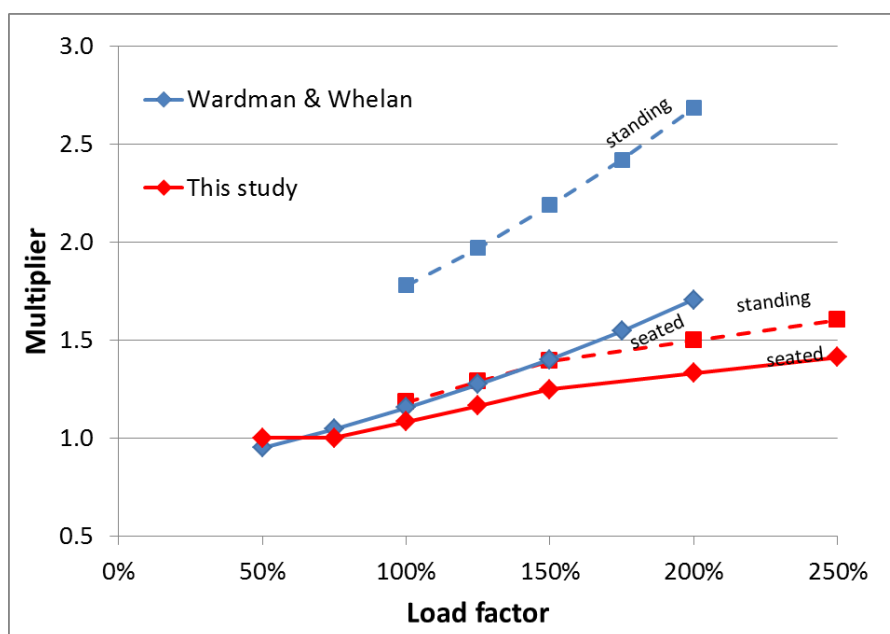
Table 7. **Travel time multipliers as a function of the level of crowding for different public transport modes in Île-de-France**

Crowding level	All modes		Metro		Train+RER		Bus+Tramway	
	Seated	Standing	Seated	Standing	Seated	Standing	Seated	Standing
1	1.000		1.000		1.000		1.000	
2	1.000		1.000		1.000		1.000	
3	1.000		1.000		1.000		1.000	
4	1.083		1.077		1.073		1.102	
5	1.165	1.289	1.155	1.270	1.145	1.261	1.204	1.342
6	1.248	1.394	1.232	1.362	1.218	1.358	1.307	1.467
7	1.330	1.499	1.309	1.453	1.290	1.456	1.409	1.593
8	1.413	1.604	1.386	1.545	1.363	1.553	1.511	1.718

These multipliers can be compared to the multipliers found by Wardman and Whelan (2011) for (longer-distance) rail travel in the United Kingdom. For crowding levels 5, 6, and 7 standing they found respectively 1.97, 2.19 and 2.69, substantially higher than our values (see Figure 4). We can add to that that professor Wardman (2012) has indicated previously that he felt that those UK values, based upon SP, seemed intuitively rather high.

Our results cannot be directly compared to the previous studies in Paris (Haywood and Koning 2011, Kroes et al. 2006), since these researches did not derive travel time multipliers. However, we have converted our final values into similar units as used in these studies, and from this comparison it turned out that our values were in agreement with those results.

Figure 4. **Comparison between multipliers obtained in this study and those reported by Wardman and Whelan 2011**



8. REVEALED PREFERENCE RESEARCH

We have looked for possibilities to verify the findings of our SP survey in a real-world (or Revealed-Preference) situation. We identified some locations where public transport travellers were making trade-offs between waiting time and level of crowding, somewhat comparable with the choice situations in SP1. Just before the metro stations Maison Blanche and Tolbiac (line 7) and just before the RER station Vincennes (line A) two branches of the same railway line come together. These branches have the same frequency of service, but very different passenger numbers. As a result, crowded and less-crowded metros/trains are alternating systematically during the morning peak (in the direction of the city center). Passengers who are familiar with these locations can be expected to be aware of this alternating pattern, and hence the fact that very crowded trains are likely to be followed by a much less crowded train.

During 12 days, we counted both the number of passengers that boarded the crowded trains directly, and the number of passengers that waited for the next (less-crowded) train. This allowed us to determine the percentages of waiting passengers in reality, as a function of the crowding level of the arriving train and the next train, and with a short waiting time between subsequent trains. We interviewed travellers about their reasons for waiting, in order to correct the observed percentages for those people who waited for valid reasons which had nothing to do with the crowding level (e.g. destination not served by certain train). The resulting percentage of passengers waiting (after correction) varied from 0% when the current train was hardly crowded to some 25% when the current train was absolutely packed, see Figure 5.

Figure 5. **Percentage of passengers waiting for next train as a function of crowding level of current train**

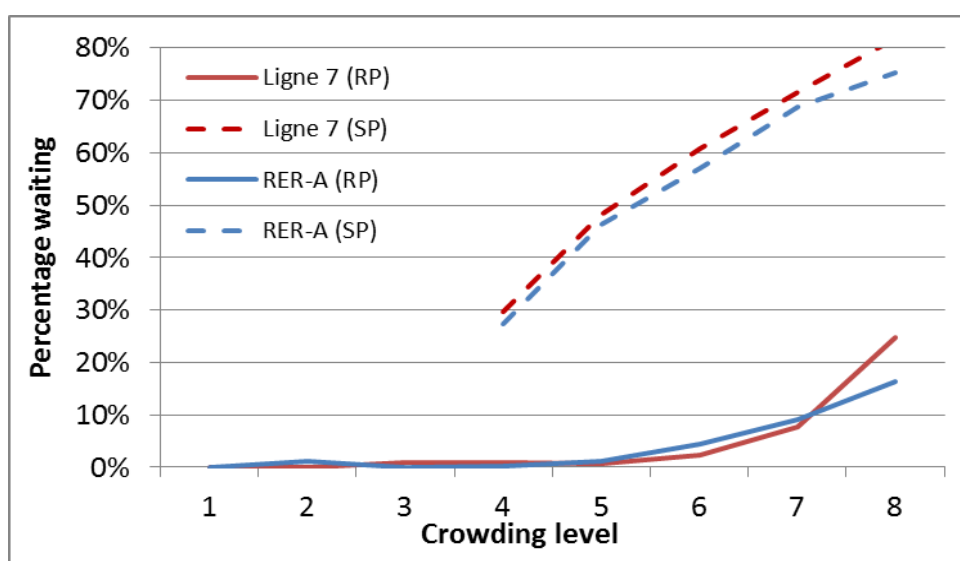


Figure 5 also shows the percentage passengers waiting as derived from the SP models. It appears that the percentages of passengers observed to wait in reality are substantially lower than those obtained from the SP data. So there seemed to be a substantial difference between the SP answers and the RP observations. In the next section we discuss possible reasons for this.

9. DISCUSSION AND RESULTING VALUES OF CROWDING

The question now is what values should be used for application for socio-economic evaluation: the values derived from the seemingly high SP-percentages or values derived from the substantially lower RP-percentages? After some reflection we came to the following reasoning.

There are a number of reasons why it might be useful, and even necessary to correct the results of our SP experiments for application in a CBA context: the possibility of SP bias, the fact that the SP questions assumed constant crowding during the entire journey, and the fact that in the SP questions respondents are 100% certain about crowding level of current and next vehicles and the exact waiting time.

There are also several reasons why the RP data may possibly be flawed as well: not all passengers will know that the next train was likely to be less crowded, in reality passengers have no certainty about the waiting time and about the crowding level of the next train².

So in reality only those passengers who were very experienced might decide to wait, and they would still have uncertainty about what their cost (waiting time) and benefit (improvement in crowding level) would be. This would lead to less passengers waiting relative to the theoretically ideal situation to determine the value of crowding, which would be measured when there is certainty about the variables that are being traded (waiting time versus reduction in crowding level).

On the balance, the SP data may be subject to error, but the direction and the size of the error are unclear. The RP data are also likely to be subject to error, but here the direction of the error is clearer: here we would observe fewer waiting people than would be the case in the ideal trading situation for measuring the value of crowding.

When it comes to answering the question which results, based upon SP or based upon RP data, comes closest to providing the pure value of crowding, we are inclined to give the following answer:

- The real value of crowding is likely to be somewhere between the values provided by the SP data and the RP data.

2. One might argue that in reality there is always uncertainty about waiting times and crowding levels of next trains. However, our aim is to establish values of crowding to assess the crowding benefits of a service that is structurally less crowded, which is the case if you build a parallel line or if you increase the frequencies of vehicle capacities. In these cases you remove the uncertainty, so you want to have a value without uncertainty.

- Theoretically the real value of crowding could be even higher than the SP values;
- But it is extremely unlikely that the real value of crowding will be lower than the RP values; quite the opposite, the value based upon the RP data are almost certainly an underestimation of the real value of crowding;
- On the balance, we feel that the value based upon the SP data is likely to be closest to the real value of crowding.

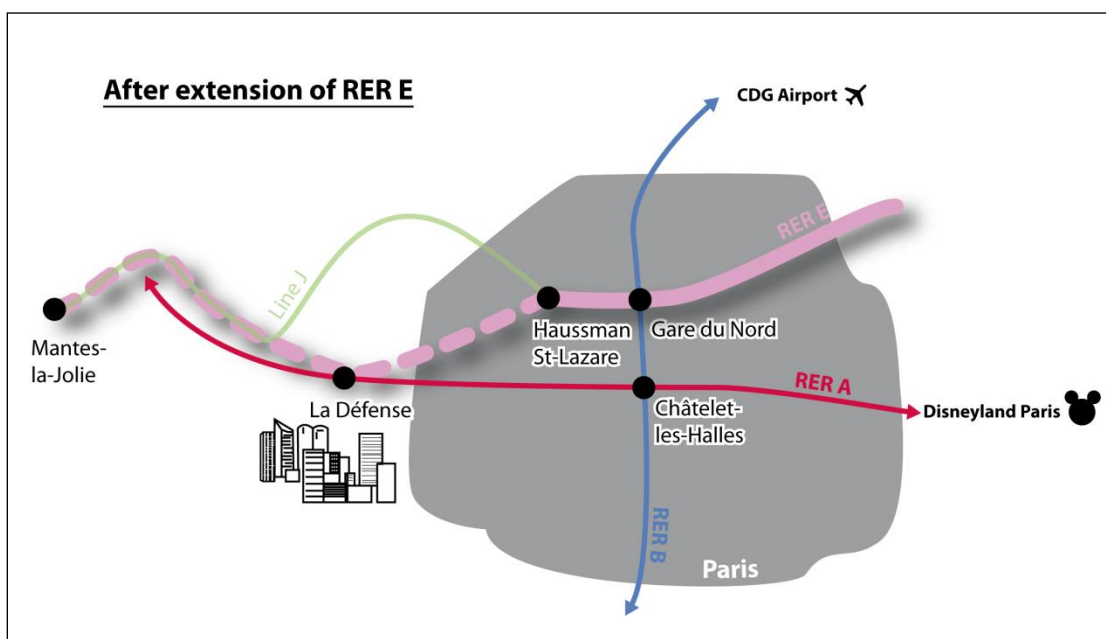
So we concluded that the SP values were to be used for socio-economic evaluation.

10. EXAMPLE OF COST-BENEFIT-ANALYSIS APPLICATION

10.1. Extension project of RER E

The resulting values of crowding as reported in Table 5 have been applied to a specific project: the extension of the regional rail line RER E to the western suburbs of Paris (see Figure 6). The underground tunnel will be extended towards the La Défense business district and connected to an existing suburban railway line which will be upgraded. It will offer an alternative to the existing RER A line, which partially runs in parallel to the RER E extension. At its western end, the line will serve the Seine Aval territory and strengthen the projects of urban regeneration and economic development planned in this area. The cost of investment of the RER E extension is estimated between 3,1 and 3,5 billion Euros. The public inquiry was conducted in 2012 and the project granted approval thereafter. It is planned to open in 2020.

Figure 6. **RER A, RER B, RER E and extension (dashed) in their central sections within ÎLE-de-France**



10.2. Estimation of the discomfort reduced by the project

The estimation of the discomfort that passengers will no longer experience after the construction of RER E, when travelling by RER A and B, is based on the following steps.

Step 1: Traffic forecast

A demand model was used to estimate the number of passengers during the morning peak hour for each link connecting two stations, with and without the extension. Only the sections of RER A and B lines, where high crowding levels have been observed, are expected to experience significant impacts and have been selected for analysis. The project will lead to a diminution of traffic on these links, which are indicated in Table 8.

Table 8. **Results of traffic modelling without and with the extension of RER E (forecasts on a morning peak hour in 2020)**

Line and direction	From	To	Traffic volume		Change (%)
			Without extension	With extension	
RER A westbound	Vincennes	Nation	35,300	34,900	-1%
	Nation	Gare de Lyon	37,100	36,500	-2%
	Gare de Lyon	Châtelet-Les H.	44,700	39,400	-3%
	Châtelet-Les H.	Auber	44,700	39,400	-12%
	Auber	Etoile	40,600	32,300	-20%
	Etoile	La Défense	37,000	28,700	-23%
RER A eastbound	La Défense	Etoile	24,100	20,400	-15%
RER B southbound	Gare du Nord	Châtelet-Les H.	27,400	24,800	-9%

Step 2: Calculation of benefits in equivalent travel time

Traffic levels have been converted into levels of crowding as used in the stated preferences surveys with levels from 1 to 8. At level 4, all seats are taken and at level 8 people are also standing and the maximum capacity of services is reached.

The results of the stated preferences survey gave multipliers to apply to real travel time to obtain perceived travel time according to the experienced level of crowding inside a vehicle. For the specific case of RER E, the corresponding RER coefficients have been used (see Table 2). For the calculation for the RER E project, the expected future capacities for RER A and B were needed:

- For RER A, a capacity of 62,400 travellers per hour during peak hours is considered for the westbound direction and 52,000 for the eastbound direction, 36% of the total passenger capacity consists of seats in both directions.
- For RER B, the capacity during peak hours is the same in both directions: 28,600 travellers per hour, 26 % of the capacity are seats.

The change in time perceived by the passengers is calculated using the following formula:

$$\Delta \text{Time}_{\text{perceived}} = (N_{\text{PAXseatedbefore}} \cdot \alpha_{\text{seatedbefore}} + N_{\text{PAXstandingbefore}} \cdot \alpha_{\text{standingbefore}}) - (N_{\text{PAXseatedafter}} \cdot \alpha_{\text{seatedafter}} + N_{\text{PAXstandingafter}} \cdot \alpha_{\text{standingafter}})$$

where $\Delta \text{Time}_{\text{perceived}}$ is the change in perceived travel time between before and after the project, $N_{\text{PAXseatedbefore}}$ the change in the number of seated passengers before the project and $\alpha_{\text{seatedbefore}}$ the multiplier is for seated passengers before the project, etc. The calculations are done link by link and added to obtain the total value. The results are given in Table 9 below.

Table 9. Perceived travel time with and without RER E extension during morning peak hour taking crowding into account for all passengers per link

Line and direction	From	To	Travel time (min.)	Perceived travel time (hours)	
				Without extension	With extension
RER A westbound	Vincennes	Nation	4	488	431
	Nation	Gare de Lyon	2	337	230
	Gare de Lyon	Châtelet-Les H.	4	733	707
	Châtelet-Les H.	Auber	3	830	545
	Auber	Etoile	3	567	290
	Etoile	La Défense	3	504	83
RER A eastbound	La Défense	Etoile	3	69	0
RER B southbound	Gare du Nord	Châtelet-Les H.	2	458	411
Total				3,936	2,697

In total, during one morning peak hour, the diminution of perceived travel time due to the RER E extension project is estimated at 1,239 passenger hours. To expand the result from one peak hour to a year, this number has been multiplied by 5 to obtain daily results (2 peak hours in the morning and 3 in the evening) and by 210 to obtain yearly results (working days except summer holidays). The result is a total of 1,3 million passenger hours saved in one year.

Step3: Conversion into monetary benefit

Using the standard value of time for public transport project appraisal in Île-de-France (€17,7 per hour, value 2010), this 1.3 million hours has been converted into a benefit of €23 M for a whole year, or €480 M summed over a period of 30 years using a discount rate of 8%. This result can be compared with the investment costs of the project (3.1 to 3.5 Billion Euro) and the operating cost (estimated at 88 M per year). Note that the travel time benefits generated by the project over the 30 year period were estimated at €6,100 M, and the modal shift benefits at €2,300 M. In comparison the crowding effect adds about 6% to the total project benefits.

11. CONCLUDING REMARKS

The most important findings of this research are:

1. We found that passengers' decisions to wait for a less crowded public transport vehicle were primarily determined by the level of crowding of the first vehicle to arrive. The (announced) crowding level of the next vehicle appeared to be much less important;
2. We found that a constant utility per trip specification provided a clearly better fit to the stated choice data than the travel time multiplier specification commonly used in literature. Despite this better fit we have chosen for a multiplier specification for our application coefficients. This choice, however, was entirely based upon practical reasons, the ease of application, rather than upon data-based evidence;
3. We found that the heterogeneity between different groups of passengers was fairly limited. The attitude-based typology showed the largest discrimination in preferences for avoiding crowding, with for instance the time-sensitive type of passengers (Type 3) being clearly less inclined to wait for another less crowded public transport service than the (Type 1) passengers fearing closeness of other passengers.
4. We found that revealed preference data suggested a much lower willingness to wait for less crowded vehicles than the stated choice data suggested. However, there are many reasons why it is likely that the RP data underestimated the real willingness to wait, and therefore we kept the values derived from the stated choices without any downward adjustment;
5. The values of crowding that we found were broadly in agreement with those obtained in two other studies carried out in the Île-de-France region. Compared to the values found for rail travel in the UK, however, they were substantially lower.

It is clear that more value of crowding studies, conducted in similar and different contexts, are needed before more definitive and more general conclusions can be drawn with respect to the value of crowding in public transport. In the meantime, our results will be used for cost-benefit evaluations of transport projects in the Île-de-France region.

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