

Value of Crowding on Public Transport in Île-de-France, France

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This paper describes the results of a research project that aimed to establish passenger values of crowding on public transport services in the Paris region. Qualitative research, stated preference (SP) experiments, and passenger counts and surveys were conducted to obtain such values. A simple method was developed to quantify the passenger benefits of specific public transport projects aiming to reduce crowding on existing lines. This method was applied in a case study to the regional rail (RER) RER Line E extension project. With regard to the value of crowding, the research indicated that the perceived disutility of crowding could be more accurately described as a constant disutility per trip than as a travel time multiplier. However, for ease of application often the multiplier formulation was preferred. When the value of crowding was expressed as a travel time multiplier, values were obtained ranging from 1.0 when all passengers could be seated to 1.7 for standing bus passengers when the vehicles reached their maximum capacity. Also for seated passengers, multipliers well above 1.0 were observed for (highly) congested vehicles (maximum value = 1.5 for bus passengers). These values were applied in a case study that estimated the effects of an extension of the regional rail line RER E in the western direction, partially running parallel to the existing RER Line A. This extension would reduce the current (very) high crowding levels on the RER A and B lines to more moderate levels and generate benefits of about €23 million per year.

Since the mid-1990s public transport patronage in Île-de-France (the Paris region) has increased substantially; during the past 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 entirely anticipated. Consequently, the capacity on several parts of the network in the dense central area of the region is no longer sufficient to meet the demand during peak hours. The result is overcrowded vehicles and long waiting times at rail platforms and bus stops. The lack of maintenance and modernization of the transport system causes additional operational difficulties.

The renewal of rail infrastructures 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 increasing the capacity of existing lines. Of these projects, the Grand Paris Express is the best known. 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 trains per hour. All these projects together should reduce the shortage of capacity substantially by 2020 and eliminate it by 2030. As a consequence, crowding levels in public transport will be highly reduced.

For the socioeconomic appraisal, it is necessary to quantify all effects of these investments. The effect on travel and waiting times can be determined by 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 forecast by more advanced traffic models. However, little is known about the valuation of these reduced congestion levels (see section on the review of the literature).

The Syndicat des Transports d'Île de France (STIF), therefore, in 2011 commissioned Significance 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 research was aimed at all modes of public transport in Île-de-France.

OBJECTIVES AND RESEARCH APPROACH

The study reported here aimed at estimating the following:

- Perceived value of crowding in public transport vehicles,
- Passengers' preferences for other aspects of comfort inside public transport vehicles, and
- Passengers' preferences for different public transport modes.

Different values and preferences for each available public transport mode should be derived, where necessary. All results should be valid for Île-de-France. The final values will be used in cost-benefit analyses appraising the socioeconomic 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 the following 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 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 (SP) survey to derive coefficients on the value of comfort. Comfort was considered in all of its dimensions, but specific focus was on crowding. In addition to the SP surveys, questions were asked about the perception of public transport; these questions resulted in a typology classification of respondents.

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• The fourth phase consisted of a revealed preference (RP) survey to verify the results of the SP survey. Passenger counts and interviews were conducted at different stations to measure the proportion of passengers preferring to wait for the next vehicle instead of taking the (more crowded) first vehicle.

The present paper concentrates on the value of crowding inside public transport vehicles. The work was documented in detail in Kroes et al., a French language technical report (1).

LITERATURE REVIEW

A review of the literature 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. The literature outside France on the subject is also limited [see, e.g., Li and Hensher (2)].

A recent study in France reported by Haywood and Koning covered part of Metro Line 1 in Paris (3). Using contingent valuation they found that metro passengers were prepared to pay €8 (median value) (1€ = US\$1.39, in 2011) to reduce the high peak hour level of crowding to the level of crowding experienced outside the peaks.

Another French result based on SP experiments for travel on inter-urban rail lines was reported in Kroes et al. (4). Although the study was aimed primarily at measuring the value of punctuality, it also produced penalties for traveling 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 traveling while standing was equal to 4.9 min per trip plus 0.3 min per minute of travel time (so a penalty of 10.9 min for a 20-min trip).

In the United Kingdom the value of crowding for rail transport has been researched during the past two decades, particularly by using SP studies. The results of this work have been synthesized in a meta-analysis by Wardman and Whelan (5). They found that, particularly for those passengers that have to stand in the vehicles, there is a substantial disutility of travel. They expressed this as a multiplier for travel time: when crowding levels are low the multiplier is close to 1, but when crowding levels increase the multiplier increases to values of up to 2.7 for standing passengers. This result means that their disutility of travel in a very crowded situation is twice as high as in instances in which plenty of seats are available.

QUALITATIVE RESEARCH

To learn about key factors driving the perception of comfort a series of five focus group discussions was organized. For each group eight to 10 public transport users in Île-de-France were recruited. To obtain

a diversified panel of users, each group consisted of a different type of traveler. The five groups were as follows:

- Young adults,
- Frequent commuters,
- Occasional and noncommuter travelers,
- Seniors, and
- Inhabitants of more remote suburbs.

The group discussions aimed specifically at understanding a passenger's perception of physical comfort inside all types of public transport vehicles (trains, metros, tramways, and buses) to identify which dimensions and features are important, and what consequences discomfort has on behavior. 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 the following range of aspects:

- Crowding, which influences any or all of the following: the possibility of finding a seat, the necessity of having to push other passengers when entering or exiting a vehicle, and the possibility of standing without being disturbed;
- Stability of the vehicle, which is linked to the way the vehicle is driven, to the type of road or track, and to the length between stops and stop duration;
- Seat comfort, which includes the amount of space in front of the seat;
 - Temperature;
 - Smells;
 - Noise, which includes that generated by the vehicle and by other passengers;
 - Comfort when standing, which includes availability of handholds, possibility to lean on something, and ease of finding stop buttons;
 - Ease of access between the vehicle and the platform at doors, which includes number and width of doors, automatic opening or not, platform screen doors, and presence of impediments in the vehicle; and
 - Ease of onboard circulation, which includes width of path, presence of stairs, and possibility to go from one coach to the other.

For each aspect of comfort, participants were asked to define a perfect, a correct, an uncomfortable, and an unbearable level. Table 1 shows the results for the aspect of crowding. Crowding was found to have the following consequences:

- It influences physical comfort; an active mobilization of physical and psychic resources are required to cope with disturbances, and crowding can lead to stress and tiredness. All passengers feel those consequences to some extent.

TABLE 1 Levels of Perception with Respect to Crowding

Aspect of Comfort	Response, by Level of Perception			
	Perfect	Correct	Uncomfortable	Unbearable
Descriptive	"There are a few persons."	"Almost all seats are occupied. A few people are standing; one can move easily."	"All seats are occupied. There are people standing; it is not easy to move."	"All seats are occupied. Standing passengers are next to each other."
Impact on passenger	"One can stay where one wants."	"One can choose where to stand but not choose one's seat."	"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."	"One cannot move."

- It requires not paying too much attention to one's psychological comfort and accepting the loss of part of the control of one's activities, it impairs one's self-image, and it leads to the loss of privacy.
- It generates crowd behavior, which diminishes individual responsibility and leads to less polite behavior.
- It is a cause of operation irregularity, delays, and increased duration of stops during the journey.

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

The following behaviors engaged in to avoid discomfort were quoted during the focus groups:

- 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, requires more transfers, or both;
- Changing the timing of travel, which includes leaving home earlier in the morning for commuters; and
- Changing position inside the vehicle.

The results of the qualitative study were used to clarify the questionnaires of the SP study especially with regard to presenting crowding levels to respondents.

SP RESEARCH

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 an SP choice experiment [see, e.g., Louviere et al. (6)]. 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 vehicles. Passengers are asked to state their preferences for one of the alternatives. In the Île-de-France project that methodology was chosen to conduct the research.

The design of the SP survey was based on previous experience with crowding research reported in the literature [e.g., Li and Hensher (2), Kroes et al. (4), and Wardman and Whelan (5)] and the qualitative

research reported in the previous section. Some of the main elements are summarized below.

Choices and Choice Variables

For prevention of biases, two choice experiments were designed to measure the value of crowding, as follows:

- 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 had eight possible levels) and the waiting time (five levels). An example of such a choice is given in Figure 1.
- 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. In addition, for each alternative it was specified whether the respondent would be able to find a seat or would have to stand. Each choice differed in the level of crowding (each service had eight possible levels), in the travel time [each service had 11 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.

Presentation of Crowding

On the basis of the literature and the tests conducted during the qualitative research, the eight different levels of crowding were presented by means of a graphic presentation and a description. Both were adapted to the mode of transport: different presentations were used for rail modes [metro, regional rail (RER), train, and tram] and for the bus. Figure 3 shows the graphic presentations that were used.

Sample

In total, 3,000 public transport users participated in the SP survey. They were recruited from 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 the following:

- Public transport mode used,
- Residential area,

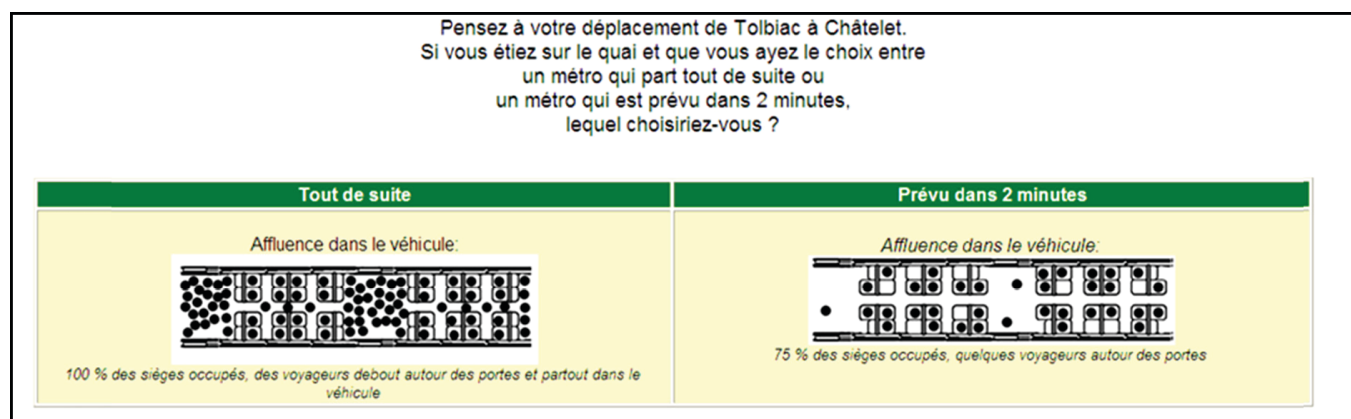


FIGURE 1 Example of choice situation from SP1 experiment.

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.

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

FIGURE 2 Example of choice situation from SP2 experiment.

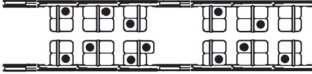
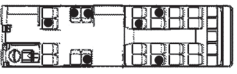
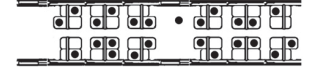
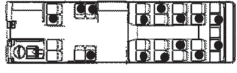
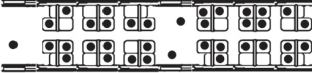
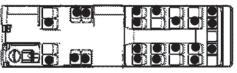
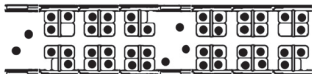

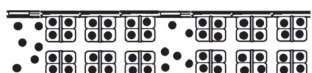

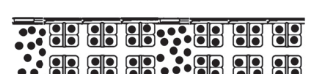



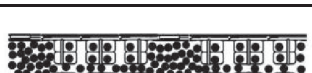

Level	Number of passengers as percentage of total number of seats	Metro, train, RER, tram	Bus
1	25		
2	50		
3	75		
4	100		
5	125		
6	150		
7	200		
8	250		

FIGURE 3 Presentation of eight crowding levels by mode.

- Age category,
- Gender, and
- Working status (active versus nonactive).

The recruited public transport users were interviewed through the Internet; a personalized questionnaire based on their reported travel characteristics for a recent journey was used. The interviews took place between September and December 2011.

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

- Responses with out-of-scope origins and destinations were eliminated.
- Responses with very short survey completion times were eliminated.
- Respondents who did not answer all SP questions were eliminated.
- Respondents with unrealistically long travel times were eliminated.

After this process, the SP choices of 2,711 respondents were available for analysis.

ANALYSIS OF SPs

When respondent responses were analyzed, it was noted that a relatively large percentage of public transport passengers indicated that they were prepared to wait a few minutes to travel in a less crowded train, from 13% when the current train was hardly crowded to 75% when the current train was absolutely packed and the next train had seats available.

The choices of the public transport users in the SP experiments were analyzed to derive the utility weights of each of the service quality variables with discrete choice analysis methods—in this case logit analysis based on maximum likelihood estimation [see, e.g., Ben-Akiva and Lerman (7)].

A large number of different model specifications have been tested. Here the most important findings are reported.

Simultaneous Estimation Using SP1 and SP2

Separate models for SP1 and SP2 were first estimated, and then a joint model was tested. It was found that the resulting values of crowding were not significantly different between the two experiments for any of the crowding levels, provided that separate scale factors were used for the two SP experiments to account for differences in error. Consequently the simultaneous model specification was used for deriving the final application coefficients.

Fixed Effect Versus Travel Time Multiplier

To express the disutility of crowding one can use a single constant value (or penalty) per trip or a travel time multiplier value. The first type of specification assumes that the crowding effect is independent 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. However, it is rare for travelers 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 entire journey.

Both specifications have been tested, and the constant value per trip was found to provide a significantly better statistical fit to the stated choice data than did the multiplier specification, as follows:

- Constant value per trip, for 20,754 observations and 18 degrees of freedom, the log likelihood value = 12,241.5 and rho squared (c) (rho squared relative to a model with alternative specific constants only) = 0.141.
- Multiplier (i.e., proportional with travel time), for 20,754 observations and 20 degrees of freedom, the log likelihood value = -12,533.7 and rho-squared (c) = 0.120.
- The total disutility of the multiplier model when applied to the average trip (with a travel time of about 20 min) is about the same as the disutility for the constant value model. But for the observed distribution of trips, the constant value per trip specification provides a better goodness of fit to the data than the multiplier specification.

This is a remarkable result, as almost all studies in the United Kingdom and several elsewhere use the travel time multiplier value to express the disutility of crowding. One could raise the question of whether this is an effect resulting from the SP experiment, but almost all UK results were based on SP data as well.

Coefficients for Application

Although it was observed that the constant crowding effect per trip provided a better explanation of the stated choices than the travel time multiplier value, a set of coefficients was nevertheless derived for application use based on 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 use in practice.

These multipliers for application use were derived for all modes together and separately for metro, train + RER (i.e., regional rail), bus, and tram. Results are given in Table 2.

These multipliers can be compared with the multipliers found by Wardman and Whelan for (long-distance) rail travel in the United Kingdom (5). For Crowding Levels 5, 6, and 7, they found, respectively, multipliers of 1.97, 2.19, and 2.69, substantially higher than the values found here. Add to that, that Wardman also had previously indicated he felt that those UK values, based on SP, intuitively seemed rather high (8). But in addition, their results relate to longer-distance rail travel, for which it may be even more important to have a seat than in urban and regional travel.

The results in this paper cannot be directly compared with the previous studies in Paris—Haywood and Koning (3) and Kroes et al. (4)—since those research efforts did not derive travel time multipliers. However, the final values in this paper can be converted into units similar to the units used in those studies, and from that it is found that the values in this paper are in agreement with those results.

RP RESEARCH

The authors have looked carefully for a possibility to verify the findings of the SP survey in a real-world (or RP) situation. A few locations were identified where public transport travelers were making trade-offs between waiting time and level of crowding in a way that seemed comparable with the choice situations in SP1.

TABLE 2 Travel Time Multipliers as Function of Level of Crowding by Public Transport Modes in Île-de-France

Crowding Level	All Modes (not car)		Metro		Train + RER		Bus + Tramway	
	Seated	Standing	Seated	Standing	Seated	Standing	Seated	Standing
1	1.000	na	1.000	na	1.000	na	1.000	na
2	1.000	na	1.000	na	1.000	na	1.000	na
3	1.000	na	1.000	na	1.000	na	1.000	na
4	1.083	na	1.077	na	1.073	na	1.102	na
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

NOTE: na = not applicable.

Just south of the metro stations Maison Blanche and Tolbiac (Line 7) and just east of the RER station Vincennes (Line A) two branches of the same line come together. As a result, crowded and less-crowded metros and 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 that pattern.

During 12 days in the morning peak hours, the number of passengers that boarded the crowded trains directly were counted, as well as the number of passengers that waited for the next (less-crowded) train. This approach allows one 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. Travelers were interviewed about their reasons for waiting, to correct the observed percentages for those people who waited for valid reasons that had nothing to do with the crowding level. The resulting percentage (after correction) varied from 0% when the current train was hardly crowded, to some 25% when the current train was absolutely packed (see Table 3 for an example). It appears that the percentages of passengers observed 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 absolute percentages of people waiting.

DISCUSSION AND RESULTANT VALUES OF CROWDING

The question now is what result should be used for application for the socioeconomic evaluation: the seemingly rather high percentages of crowding derived from the SP data or the substantially lower percentages of crowding observed in the RP results? Ideally a combined SP-RP model should have been estimated, but the RP data were not sufficient for that.

After some reflection a number of reasons were identified as to why one could expect differences between the SP data and the RP data in the percentages of passengers waiting, including the following:

- The SP choice situation descriptions gave passengers certainty about their waiting time and the crowding level of their next train. Also passengers were asked to imagine that the same crowding level would persist during their entire trip.

TABLE 3 Percentage of Passengers Observed Waiting at RER Station Vincennes for Next Train as Function of Crowding Level of Current RER Train and Next RER Train to Arrive

Level of Crowding at RER Train Arriving at Platform	Percentage of Passengers, by Level of Crowding of Next RER Train to Arrive ^a							Distribution
	2	3	4	5	6	7	8	
2	—	—	2.3 (1)	—	2.3 (1)	—	—	2.3
3	—	—	—	—	5.4 (2)	—	—	6.2
4	—	—	2.3 (3)	3.3 (7)	5.5 (11)	3.8 (5)	5.1 (3)	4.2
5	15 (1)	—	8.8 (8)	6.3 (10)	5.6 (7)	4.4 (18)	4.2 (3)	5.6
6	—	10.4 (2)	12.2 (7)	13.8 (11)	9.6 (7)	10.3 (15)	7.4 (3)	10.9
7	11.1 (1)	10.3 (1)	20.1 (11)	20.7 (13)	18.4 (11)	15.8 (14)	12.1 (7)	17.4
8	—	—	19.1 (1)	25.5 (2)	26.5 (6)	23.5 (6)	31.1 (1)	25.0
Average	—	—	—	—	—	—	—	12.2

NOTE: — = no observations made.

^aEntries in parentheses indicate the number of trains observed.

- In the RP choice situations, passengers were uncertain about the exact waiting time and even more so about the crowding level of the next train. For the regular passengers there was an expectation of improvement (of unknown size), but for the irregular passengers the level of crowding to be expected was unknown.

If the aim were to provide a realistic forecast of the number of passengers waiting at the platform, the RP data would clearly provide the better basis for that. But in this research, that forecast is not really the objective: the aim here is to estimate the value that passengers attach to an improvement to the public transport system providing increased capacity, where passengers can experience substantially lower levels of crowding with a high degree of certainty. That situation is clearly a different one, and in the authors' view the SP data come much closer to measuring that situation.

It may still be that the SP data contain a certain bias: after all, people do not always choose exactly what they say they would choose. But during the statistical analysis of the time–crowding trade-offs in the SP data, a correction was made for that possibility: for instance, alternative specific constants have been estimated for irrational preferences for waiting for the next train when there was no expected benefit of such waiting. This effect is isolated from the pure time–crowding trade-off, so the value of crowding derived from the SP data does not include this effect.

So it was concluded that the SP values of crowding and time trading, and the corresponding travel time multipliers reported in Table 2, were to be used for socioeconomic evaluation.

EXAMPLE OF COST–BENEFIT ANALYSIS APPLICATION

Extension Project of RER E

The resulting values of crowding have been applied to a specific project: the extension of the regional rail line RER E (see Figure 4). This is one of the five regional mass transit lines in Île-de-France. It links the eastern suburbs of the region to the center of Paris and has two underground stations inside Paris: Magenta (which is connected to the international Gare du Nord railway station) and Haussmann–

Saint-Lazare (located in the central business district of Paris connected to the Gare Saint-Lazare railway station).

The project consists of an extension of the line to the western suburbs of Paris. The underground tunnel will be extended toward the La Défense business district and connected to an existing suburban railway line that will be upgraded.

It will offer an alternative to the RER A line, which runs partially 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 is estimated to be between €3.1 billion and €3.5 billion. The public inquiry was conducted in 2012 and the project granted approval thereafter. It is planned to open in 2020.

With 110,000 jobs today (expected to grow to 150,000) and a high modal share of public transport among salaried employees (85% use public transport), La Défense is a very attractive destination particularly during peak hours. The extension of RER E will offer an alternative to reach the area from the Gare du Nord hub and the center of Paris. Therefore, it will relieve traffic on the two most crowded lines of the Paris public transport network: the central sections of RER A (west–east mass transit line) and RER B (north–south line serving Roissy Charles de Gaulle Airport).

Estimation of Discomfort Reduced by Project

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

Step 1. Traffic Forecast

For each link connecting two stations, a traffic model was used to estimate the number of passengers during the morning peak hour with and without the extension. Only the sections of RER A and B lines where high crowding levels have been observed are expected to generate significant effects and have been selected for analysis. The project will lead to a diminution of traffic only on these links, which are indicated in Table 4.

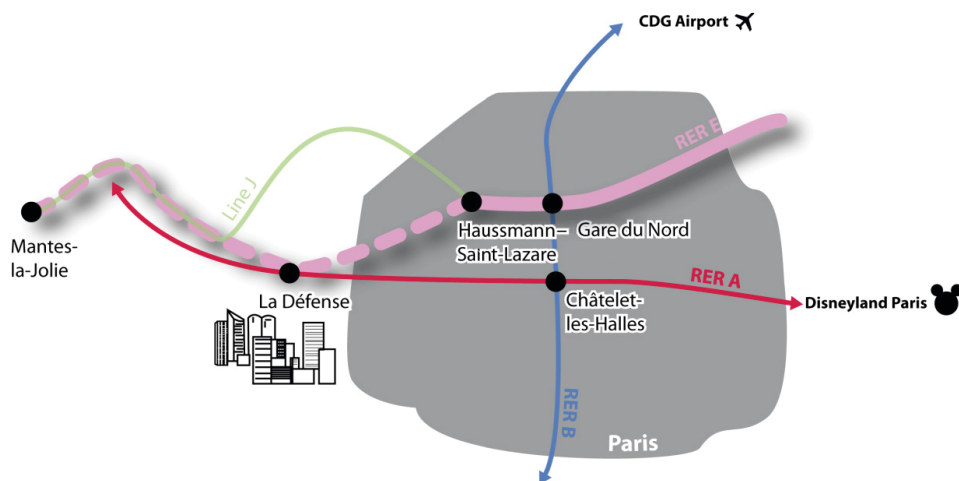


FIGURE 4 RER A, RER B, RER E, and extension (dashed) in their central sections in Île-de-France (CDG = Charles de Gaulle).

TABLE 4 Results of Traffic Modeling With and Without Extension of RER E: Forecasts for a Morning Peak Hour in 2020

Line and Direction	From	To	Number of Passengers Without Extension	Number of Passengers With Extension	Traffic Diminution (relative proportion) (%)
RER A westbound	Vincennes	Nation	35,300	34,900	-1
	Nation	Gare de Lyon	37,100	36,500	-2
	Gare de Lyon	Châtelet-Les Halles	39,600	38,500	-3
	Châtelet-Les Halles	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 Halles	27,400	24,800	-9

Step 2. Calculation of Benefits in Equivalent Travel Time

Traffic levels have been converted in levels of crowding as used in the SP surveys, with levels from 1 to 8. At Level 4, all seats are taken, and at Level 8, people are also standing by four persons per square meter, which is the maximum level set by STIF to define the capacity of services.

The results of the SP survey give multipliers to apply to real travel time to obtain perceived travel time according to the level of crowding experienced inside a vehicle. These coefficients are different for traveling seated or standing. They also differ according to the public transport mode. For the specific case of RER E, the corresponding 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 travelers per hour during peak hours is considered for the westbound direction and 52,000 for the eastbound direction; 36% of the capacity is seats in both directions.
- For RER B, the capacity during peak hours is the same in both directions: 28,600 travelers per hour; 26% of the capacity is seats.

The additional time perceived by passengers is calculated with the following formula for the situation before and the situation after the extension of RER E:

$$\Delta \text{time}_{\text{perceived}} = \text{time}_{\text{travelbefore}} \cdot \left\{ \begin{aligned} &N_{\text{PAXseatedbefore}} \cdot (1 - \alpha_{\text{seatedbefore}}) \\ &+ N_{\text{PAXstandingbefore}} \cdot (1 - \alpha_{\text{standingbefore}}) \end{aligned} \right\} \\ - \text{time}_{\text{travellafter}} \cdot \left\{ \begin{aligned} &N_{\text{PAXseatedafter}} \cdot (1 - \alpha_{\text{seatedafter}}) \\ &+ N_{\text{PAXstandingafter}} \cdot (1 - \alpha_{\text{standingafter}}) \end{aligned} \right\}$$

where

$\Delta \text{time}_{\text{perceived}}$ = change in perceived travel time between situations before project and after project,

$\text{time}_{\text{travelbefore}}$ = travel time before project,

$N_{\text{PAXseatedbefore}}$ = number of seated passengers before project,

$\alpha_{\text{seatedbefore}}$ = multiplier for seated passengers before project,

$N_{\text{PAXstandingbefore}}$ = number of standing passengers before project,

$\alpha_{\text{standingbefore}}$ = multiplier for standing passengers before project,

$\text{time}_{\text{travellafter}}$ = travel time after project,

$N_{\text{PAXseatedafter}}$ = number of seated passengers after project,

$\alpha_{\text{seatedafter}}$ = multiplier for seated passengers after project,

$N_{\text{PAXstandingafter}}$ = number of standing passengers after project, and

$\alpha_{\text{standingafter}}$ = multiplier for standing passengers after project.

The calculations are done link by link and added to obtain the total value. The results are given in Table 5.

In total, during one morning peak hour, the diminution of perceived travel time resulting from the RER E extension project is estimated at 1,239 h.

To expand the result from 1 peak hour to a year, this number has been multiplied by 5 to obtain daily results (2 peak hours in the

TABLE 5 Additional Perceived Travel Time During Morning Peak Hour After Taking Crowding into Account for All Passengers per Link

Line and Direction	From	To	Travel Time (min)	Additional Perceived Time (h)	
				Without RER E ^a Extension	With RER E ^b Extension
RER A westbound	Vincennes	Nation	4	438	431
	Nation	Gare de Lyon	2	337	230
	Gare de Lyon	Châtelet-Les Halles	4	733	707
	Châtelet-Les Halles	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 Halles	2	458	411

^aTotal = 3,936.

^bTotal = 2,697.

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 h saved by passengers in 1 year.

Step 3. Conversion into Monetary Benefit

By using the standard value of time for public transport project appraisal in Île-de-France (€17.7 per hour, 2010 value), this 1.3 million hours has been converted into a benefit of €23 million for a whole year, or €480 million summed over a period of 30 years with a discount rate of 8%. This result can be compared with the investment costs of the project (€3.1 billion to €3.5 billion) and the operating costs (estimated at €88 million per year).

CONCLUDING REMARKS

The following are the most important findings of this research:

1. A constant utility per trip specification was found to provide a better fit to the stated choice data than the travel time multiplier specification commonly used in the literature. Despite this better fit, however, the specification with a multiplier was chosen for its ease of application. This choice, however, was based entirely on practical reasons—the ease of application—rather than on data-based evidence.
2. RP data show a much lower willingness to wait for a less crowded vehicle, and therefore a lower value of crowding, than the stated choice data suggest. However, the RP data reflect a different situation, which is less suitable for deriving a value of crowding for application in a cost–benefit analysis context.
3. The values of crowding that were found are in agreement with two other studies conducted in the Île-de-France region. Compared with the values found for longer-distance rail travel in the United Kingdom, however, the values here are 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, the results here will be used

for cost–benefit evaluations of transport projects in the Île-de-France region.

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The final responsibility for this paper remains with the authors.

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