Pushy Parisian Elbows:
Taste for Comfort in Public Transport

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Abstract

Qualitative aspects of transport are increasingly discussed as factors influencing the choice between individualised motorised transport and public transport. In this article we investigate, both analyticallly and empirically, the utility cost of congestion in public transport networks and the factors influencing it, the congestion being here defined as the space available for travelers in trains.

Using survey data from central Paris subway and contingent valuation methodology, we find first that discomfort in undergrounds generates a considerable disutility for users. This is equivalent to 5.7-8.1 minutes of excess travel, i.e. 29%-42% of average trip duration or 1.01-1.42 euro in monetary terms. These figures rise with trip time as well as levels of congestion. We then show the welfare implications of considering comfort in travels for the Parisian subway commuters.

Work in progress

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1 Introduction

1.1 The qualitative features of public transport

A growing body of literature in transportation economics is today demonstrating that qualitative attributes of public transport may affect individuals' welfare and modal choices (Litman (2008))[1]. Since activities related to transport account for a non negligible part of daily waking time[2], the consumption element of transport choices cannot be neglected. To the "generalized cost" of travels composed of a fixed component (insurance, cost of vehicle...) and a variable one (the time in vehicle), researchers should also consider the qualitative features of public transport - allegedly these have as large an impact on individual welfare as does effective speed (Litman (2008)). In order to understand individual modal choices we have thus to seek the "perceived cost" of transport (Li (2003)). Qualitative improvements in public transport networks may then provide an alternative to "road pricing strategies" (Tsekeris and Voss (2009)) when we try to reduce car dependency and the associated external costs (Parry et al. (2007)). Therefore, the challenge is to correctly assess the attributes offered by public transport (Litman (2008)). An important dimension of public transport quality surely concerns the seating and space available to passengers, i.e. the passenger density. This will be our instrument for comfort in what follows[3].

Overcrowding in public transport may result from policies undertaken to reduce the use of private vehicles in dense areas. This is especially true for networks mainly composed of subways, characterized by a very low elasticity of supply due to the costs of additional investments and the topographics faced by planners. In these networks, a modal shift toward public transport will consequently decrease the level of comfort. One may consider this phenomenon as the reverse side of road congestion externality. Even if the waste differs in nature, the increased use of the network by some makes it's use more costly for all: overcrowding is linked to stress, pickpockets, accidents and hygiene concerns reducing commuters' welfare (Li (2003), STIF (2005), Litman (2008)). For both science and policy considering this "cross-modal externality" seems highly relevant. First, it may weaken the modal shift by

[1] Litman (2008) provides a rich survey of the qualitative dimension of public transport.

[2] Approximately 15% of non-worked waking time by counting 8 hours aspleep, 7 hours worked and 80 minutes commuting (Caenen et al. (2010)).

[3] Other attributes refer to available services, safety and security, maintenance as well as design of vehicles, reliability, access and waiting times in stations (Transportation Research Board (1999), Litman (2008), Wardman (2001)).

raising the "perceived cost" of public transport. Second, cost-benefits analyses of transport infrastructures are also affected as improved infrastructures may lead to more comfortable travelling conditions (Litman (2008), Ministere de l'Equipement (2005)).

This article represents an attempt to study the "taste for comfort" of public transport users. Its objective is twofold. First, it proposes a simple modal choice model integrating a qualitative component into the utility function of commuters. Second, we seek to determine the importance and the determinants of the taste for comfort in public transport. We analyse data from a survey carried out on 530 users of line 1 of the Paris underground using contingent valuation methodology.

1.2 The Paris metro: a case study to stress the importance of comfort in public transport

The very wealthy Paris metropolitan area is still today dominated by its core area[4]. This implies a great demand for mobility. Around 1 million employees commute into central Paris daily (Caenen et al. (2010)). Although the closely knit public transport network accounted for 50% of travels in and out of Paris in 2000 (Kopp (2009)), congestion and complaints about motoring remained high[5]. Responding to the demands to restrict these disamenities, the local government elected in 2001 reduced roadspace available for private vehicles ("quantity regulation", see Prud'homme and Kopp (2008)) whilst at the same time increasing the attractiveness of non-motorised transport (tramways, bicycles and boats) and changing the parking's pricing scheme.

The policies implemented resulted in a significant modal switch. Private vehicle use has fallen by -24% in passengers-kilometers (pkms below) between 2000 and 2007, whilst public transport network now accounts for 58% of total travels through the central area. However, the supply of public transport (measured in terms of kilometer-seats) could not follow the demand over this period (+4% versus +14%, RATP (2002) and RATP (2007)). The resulting growth in passenger density (+8% Prud'homme et al. (2010)) has given rise to numerous complaints widely reported in the media, especially during recent elections, either municipal (2008) or regional (2010). Fur-

[4]Central Paris concentrates more than 30% of regional employment while housing less than 20% of the labor force (Baccaini et al. (2007)).

[5]According to URF (2007), Central Paris and its Ring-road accounted for 30% of national queues in 2007.

Table 1: Shares of travels related to Central Paris (billions of passenger*kms)

	2000	2007	Growth rate	Share (2007)
Central Paris subway	6.1	7.0	+13.6%	32%
Regional trains (RER + SNCF)	4.8	5.4	+12.5%	26%
Total rail based traffic	10.9	12.4	+12.5%	58%
Bus	1	0.8	-16 %	4.3%
Private cars	6.7	5.1	-23.7%	23.6%
Private cars (Ring-Road)	1.9	1.7	-7.4%	8%
Taxi	0.2	0.2	+0%	3.4%
Motorbike	1.1	1.4	+36%	2.2%
Total road traffic	10.8	9.2	-13%	41.6%
Overall total	21.7	21.6	-0.8%	100%

Source: Kopp (2009)

thermore, uncomfortable commuting conditions are cited as the main factor worsening working conditions in the Paris metropolitan area (Technologia (2010), ORSTIF (2010)). Finally, recent studies conducted for bicycle and motorbike usage (CCTN (2009), Kopp (2009)) also suggest that comfort is a key consideration for modal choices[6].

To analyse the taste for comfort of Parisian metro users, our research is organised as follows. In Section (2), we introduce a simple model of modal choice in which comfort levels affect individual decisions. Section (3) then briefly presents contingent valuation as a method to study the willingness to pay for comfort while Section (4) describes our survey data. Section (5) empirically investigates the factors influencing the willingness to pay for comfort. Section (6) concludes with policy implications.

2 Comfort as a determinant of modal choice

2.1 Literature review

To move from location A to location B, agents are supposed to choose the mode and route which minimise their travel costs. However, transport activ-

[6]These studies claim that the majority of new twoo-wheels' users, motorized or not, previously performed their travels in the underground network.

ities are characterized by multiple externalities within and across networks. Mohring (1972) popularised the notion of cross-modal externalities: switching from one network to another may create welfare-improvements through economies of scale. For example, as demand for buses increases, operators will raise the number of vehicles in circulation. Therefore, waiting times for users decrease, making busses more attractive compared to private vehicles. The urbanspace's allocation is an alternative way to influence the relative attractiveness of transport choices: by decreasing traffic speeds and raising the generalized cost of private vehicle use, reducing roadspace may thus enhance a modal switch toward public transport and thus give rise to scale economies (Braess et al. (2005)). Finally, Tabuchi (1993) introduces monetary components and crosses the negative externality resulting from private vehicle use with the positive pecuniar externality in public transport resulting from sharing the fixed costs of infrastructures. Interlinkages between networks performances and between individual choices can thus clearly not be neglected.

Recognising that private transport is often priced below its marginal costs (Parry and Small (2005)), the modern literature on modal choice has focused either on road pricing strategies or the "two modes problem". Whilst the former has been widely studied (Tsekeris and Voss (2009)), the latter is more closely related to our work. The problem can be summarized as follows: "How to price mass transit and how to set both highway and mass transit capacity to minimize the resource waste from underpricing auto travel?" (Kraus (2003)). Arnott and Yan (2000) review the analytical foundations for this complex phenomenon. In a "bottleneck model" for both cars and mass transit, Kraus (2003) shows that increasing the number of trains serving a given route and/or the individual capacity of trains may lead to second-best outcomes. Parry and Small (2009) focus on the optimal level of public transport subsidies. Accouting for several externalities of road, bus and train networks, they anatically conclude and empirically proof that subsidies of over 50% of operating costs may be robustly welfare improving.

The model presented hereafter does not compare "first vs. second best equilibria". Rather, we decide to simplify our approach in order to isolate the effect of comfort in trains on the individuals' modal choice. Thus, we do not integrate in the modelling the endogenous supply of infrastructure and public budget constraints. Whilst the models reviewed above do consider public transport capacities, they do not explicitely deal with the qualitative impact density has on the public transport experience[7]. Our model is thus more related to studies of "seat congestion": " As seating or standing make distinct states for the rider, these induce distinct travel costs" (Leurent and Liu (2009)). Our approach differs however: In a simplified model, we explicitely deal with cross-modal externalities and modal choices rather than the choice of public transport routes.

2.2 The Model

Consider a city with N inhabitants individually choosing between using either private vehicles (indexed a) or public transport (m). Each transport system is characterised by an exogeneous supply (road space Q_s^a, public transport capacities Q_s^m). Individuals prefer the transport mode that maximises their utility:

$$u_{ij} = v_j(t_j, p_j, c_j, x_i) + \varepsilon_{ij} \tag{1}$$

for $j \in (m, a); i \in (1, ..., N)$.

The deterministic element (v_j) in equation (1) is supposed to decrease in trip duration (t_j) and monetary costs (p_j). The vector (x_i) describes individual characteristics. The error term (ε_{ij}) can be interpreted as an individual taste shifter constant over changes in other covariates. To include qualitative features of transport choices we now add comfort (c_j). Since our basic hypothesis is that higher demand for public transport lowers comfort levels, we can write:

$$c_m = c_m\left(Q_m^S, N_m\right) \tag{2}$$

with $\frac{\partial c_m}{\partial N_m} < 0$.

In addition, it is well-established that the travel time for private vehicles (t_a) is significantly impacted by the propotion of the population using public transport:

$$t_a = t_a\left(Q_a^S, N - N_m\right) \tag{3}$$

with $\frac{\partial t_a}{\partial N_m} < 0$.

[7]Rather, public transport capacities enter the analysis through public expenditures or via waiting times when the public transport network is saturated, i.e. a bottleneck (Kraus (2003))

Equations (2) and (3) correspond to congestion externalities. We see that individuals' welfare is influenced by others' decisions via two channels: travel speed on the road and comfort in the public transport. Both influence individuals' modal choice.

Taking into account the efficiency and environmental advantages of public transport, planners are interested in making public transport more attractive. This implies:

$$Pr\left(u_{i,m} > u_{i,a}\right) = Pr\left(\varepsilon < v_m - v_a\right) \tag{4}$$

with $\varepsilon \equiv \varepsilon_a - \varepsilon_m$.

Then, using equation (4):

$$Pr\left(u_{i,m} > u_{i,a}\right) = F_\varepsilon(\varepsilon) \tag{5}$$

We can now make distributional assumptions on the combined error (ε) to identify the factors influencing modal choice[8] and the effectiveness of modal shift policies.

2.3 Comfort and modal shift policies

The most common tool advocated by economists to influence modal choice is "price regulation" - increasing the price of car use via road tolls ($\Delta p_a > 0$) or subsidising public transport ($\Delta p_m < 0$). However, we focus here on quantity regulation: planners either reduce the amount of urban space allocated to private vehicle usage ($\Delta Q_a^S < 0$) or invest in additional public transport infrastructure ($\Delta Q_m^S > 0$)[9]. Thus, we fix (p_a) and (p_m) conditional on trip duration ($\Delta p_j = 0$).In addition, we assume that:

1. Public transport speeds are independent of public transport patronage: $\Delta t_m = 0$. In the short run, this assumption is equivalent to assuming that the network is not yet at a bottleneck[10].

[8]Making the binary logit assumption that the individual error terms are distributed according to the extreme value distribution, the combined error term (ε) is distributed logistically and $F_\varepsilon(\varepsilon) = \frac{1}{1+e^{\ (v_m - v_a)}}$

[9]Transportation speeds can sometimes be directly influenced (speed limits on roads - $\Delta t_a < 0$ - or faster public transport - $\Delta t_m > 0$).

[10]Despite considerable overcrowding on the network, the Parisian transport operator (RATP) reported punctuality levels of 98%.

2. The qualitative features of car usage do not depend on trip time (the latter entering independently in the utility function): $\Delta c_a = 0$.

3. Time spent in different modes carries equal utility cost (controlling for (p_j) and (c_j)): $\frac{\partial u_a}{\partial t_a} = \frac{\partial u_m}{\partial t_m}$.

We can now analyse more clearly how restricting roadspace ($\Delta Q_a^S < 0$), as done in central Paris, can influence the fraction of the population preferring public over private transport - given by $F_\varepsilon(\varepsilon)$ in equation (5):

$$\frac{\partial F_\varepsilon(\varepsilon)}{\partial Q_a^S} = f(\varepsilon)\ \frac{\partial \varepsilon}{\partial Q_a^S} = f(\varepsilon)\ \frac{\partial (v_m - v_a)}{\partial Q_a^S} \tag{6}$$

Hence:

$$\frac{\partial F_\varepsilon(\varepsilon)}{\partial Q_a^S} = f(\varepsilon)\ \left[\frac{\partial v_m}{\partial c_m}\ \left(\frac{\partial c_m}{\partial N_m}\ \frac{\partial N_m}{\partial Q_a^S}\right) - \frac{\partial v_a}{\partial t_a}\ \left(\frac{\partial t_a}{\partial Q_a^S} - \frac{\partial t_a}{\partial N_m}\ \frac{\partial N_m}{\partial Q_a^S}\right)\right] \tag{7}$$

Normalizing $N = 1$, so that $N_m = F_\varepsilon(\varepsilon)$, and collecting terms we have:

$$\frac{\partial N_m}{\partial Q_a^S} = -\frac{f(\varepsilon)\ \frac{\partial v_a}{\partial t_a}\ \frac{\partial t_a}{\partial Q_a^S}}{1 + f(\varepsilon)\ \left[\frac{\partial v_a}{\partial t_a}\ \frac{\partial t_a}{\partial N_m} - \frac{\partial v_m}{\partial c_m}\ \frac{\partial c_m}{N_m}\right]} \tag{8}$$

Expression (8) indicates that this policy increases public transport patronage ($\frac{\partial N_m}{\partial Q_a^S} > 0$ since $\partial Q_a^S < 0$). The term in the numerator corresponds to the direct effect of quantity regulation: the utility of car usage increases with traffic speeds, which are lower due to road congestion with less space for a given number of road users. We now also take into account the impact of increased public transport patronage on the utility of users. The denominator thus considers two mitigating second order effects related to modal switch: The first term indicates that higher patronage will decrease private vehicle speeds less than it would have otherwise. It represents the marginal benefit of decongestion for car users ($\frac{\partial v_a}{\partial N_m} > 0$). The second term describes the cross-modal externality related to comfort: a reduced modal switch toward public transport as a result of overcrowding in public transport. This latter effect is characterized by the marginal congestion cost in public transport ($\frac{\partial v_m}{\partial N_m} < 0$).

In summary, our very basic[11] model introduces a congestion externality in public transport in line with complaints about crowded public transport

[11] Potential extensions include the linkage between public transport usage and speeds; betwwen public transport and housing (Kilani et al. (2010)); assessing differentially the

systems. In the following we are interested in studying the determinants and size of the taste for comfort, which we analyse using contingent valuation. This allows us to approximate the marginal cost of public transport congestion ($\frac{\partial V_m}{\partial N_m}$) which appears very policy relevant.

3 Contingent valuation

3.1 Brief presentation of the method

In order to internalise the externalities associated with "non-market goods", economists have been very interested in valuing them. Two strategies are generally taken: the first is based on observed individual behaviors ("revealed preferences", whilst the second uses "stated preferences" in response to hypothetical scenarios. The contingent valuation methodology belongs to the latter approach (see Mitchell and Carson (1989), Haab and McConnel (2003)). Initially developed in the 1940s to appraise the optimal amount of public resources to be devoted to the protection of the environment[12], it has since been extended to other non-market goods.

Consider the indirect utility function ($u_{i,s}$) of an individual i, composed of two types of goods: a composite material good (P) whose price can be normalized and a non market good (z_s). This varies according to the "state of the nature" $s \in (0, 1)$. There then exists a level of money, generally called "willingness to pay" (WTP_i), that - if workers must pay in state 1 and not in 0 - makes individuals indifferent between the two states of the world[13]. This is the "equivalent" (if (z) is a bad) or "compensatory" (if (z) is a good) variation.

$$u_{i,1} = v_i\left(p, z_1, y_i - WTP_i\right) = u_{i,0} = v_i\left(p, z_0, y_i\right) \tag{9}$$

Using surveys, interviewers present scenarios with various quantitative or qualitative levels of a non-market good. Then, they propose bids to reveal

opportunity cost of time in public and private transport; varying the taste for comfort in cars depending on travel speeds, linking investments' decisions to the political process (Bruekner and Selod (2006)).

[12] It was used to apply the "polluter-pays-principle" in the case of the Exxon-Valdez oil spill in 1989.

[13] Another way to value non-market goods with the use of "stated preferences" consists in "willingness to accept" (WTA): In this case, compensations are proposed for a qualitative or quantitative decrease in the furniture of the considered non-market good.

how much individuals value them, i.e. the level of WTP. This identification strategy is consistent if individuals' statements inform us about their real preferences. To address these issues, the precise nature of the questionnaire must minimise differences between intentions and behaviors. The most frequently cited concerns are "strategic" and "hypothetical" biases[14] which may lead to irrelevant answers and, therefore, necessitate cautiousness (Mitchell and Carson (1989), Haab and McConnel (2003)).

3.2 Contingent valuation as a tool to study the taste for comfort in public transport

Contingent valuation has been largely used to value transport externalities such as health damages resulting from motorised transport (Brookshire et al. (1982)) or air traffic noise (Faburel (2002)). Similarly, it has been implemented to assess time opportunity costs related to access and waiting times in stations (Wardman (2001)).

Using this method for valuing the comfort in travels may be justified for practical reasons. We can thus propose bids to evaluate willingness to pay not directly in monetary but in temporal terms: individuals are asked how much they are willing to increase their travel time to compensate for differences in comfort levels. Thus, one could speak of "excess travel" expressed as a percentage of travel time. As a consequence, we will assess first the "willingness to wait for a more comfortable subway". Monetary values and willingess to pay for comfort are then imputed using either officially reported average time opportunity costs (Ministere de l'Equipement (2005)) or values deduced from individual income data (y_i)[15]. This strategy presents at least three advantages. First, it reduces the strategic bias since the payments are purely individual contributions and cannot be manipulated. It also helps to limit the hypothetical bias, according to our case study at least: Parisian commuters confronted with overcrowded vehicles sometimes let a train pass before taking a space on the next one. Finally, proposing bids as an increase in trip fares would necessitate a lot of information and would be time consuming[16].

[14]Strategic bias means that individuals do not reveal their true preferences, preferring to freeride on others' contributions. Hypothetical bias refers to situations where individuals are not able to imagine the proposed scenarios.

[15]According to D4E (2005), the time opportunity cost may be found by applying the following rule based on a job of 135 hours per month: $w_i = (2/3) * y_i / 135$

[16]For example, fares in the Paris metropolitan area vary according to zones and em-

Thus, the trade-off between space and time appears a more natural choice. Performed in this way, contingent valuation is a relevant method to restrict biases linked to individuals' discourses and to produce more robust results. It therefore appears appropriate to gauge the taste for comfort in the Parisian underground network. Actually, public transport fares are highly subsidized in France (Orfeuil (2008))[17]. Hence, travellers do not support the entire cost of their mobility and it might be credible that they may be willing to spend additional resources on travel comfort.

3.3 Values of comfort in public transport

Studying the taste for comfort with contingent valuation may finally be justified by the fact that congestion in public transport has received little attention compared to road congestion. Exceptions are Douglas Economics (2006) and PDFC (2002) who recommend to increase time opportunity costs by 17% to 80%, depending on the level of crowding in trains and trip duration in London and Sydney. Similarly, Armelius and Hultzenkrantz (2006) discretionary propose for Stockholm to double time opportunity costs when users must stand in trains. One should consider these ratios as proxies for the perceived cost of comfort in travels. As the excess travel measure, they correspond to the premium which has to be applied to the generalized cost in order to catch how qualitative features in public transport affect the time consumption.

In France, the official report provided by Ministere de l'Equipement (2005) recommands to double time opportunity costs. However, it simultaneously underlines the need for mor precise studies. A recent cost benefit analysis appraising modal switch toward bicycles thus used stated preferences in order to appraise welfare gains gendered by relieved congestion in public transport (CCTN (2009)). Calculations were based on a 25%-85% increase in the generalized cost of travels when people cannot be seated in trains. However, empirical fondations for these figures were not published and could not be compared. Debrincat et al. (2006) also relied on stated preferences to value the trains' reliability in Ile-de-France region. Using loteries with different delays' frequencies, information and comfort levels, they

ployees often receive subsidies by their firms for travel expenditures.

[17] Prud'homme et al. (2010) estimate the private monetary cost of a trip performed on the inner-Paris network at 0.55 euro, compared to an operational cost of 1.07 euro (RATP (2007)).

conclude that not seating in trains is equivalent to an excess travel ranging from 5 to 20 minutes. This leads to perceived costs ratios equal to 0.3-0.9. In what follows, we will be interested in similar figures, but calculated for the main line of the central Paris network.

4 The survey in line 1

4.1 The survey

Line 1 of the Paris Metro crosses the city East to West and links to suburbs on either end. It is the most important part of the central Paris transport system, with up to 725,000 users per day, and it covers both important economic and tourist centers (the business district La Défense and the Louvre Museum). Furthermore, its frequentation has increased by 25% over 2000-2007 (RATP internal sources), such that decreased comfort and congestion have become an important issue for users and the operator.

The survey used to study the taste for comfort was carried out in the morning rush-hour of June 2009, directly on the platforms of five metro stations. To avoid any waiting times for respondents, the survey was limited to ten questions - answered in between waiting for trains[18]. Our intial panel consists of 684 commuters traveling East towards La Défense between 7.30 and 10.30 A.M.. The morning rush-hour appears a natural choice since we are interested in the effect of congestion in trains on individual welfare. Furthermore, the morning rush hour represents 22% of daily users (RATP (2007))[19]. The mean passenger density for this commute was thus equal to 2.4 pass/m^2 in 2009. Public transport is clearly less comfortable compared to off-peak times, where passenger density was 1.3 pass/m^2. Note that during our contingent valuation survey and calculations performed in Section (6), this 85% difference in density serves as referential. To limit the hypothetical bias, we consequently considered only users who had prior experience of the line during off-peak periods. Finally, passenger density in trains were counted manually at the time of the surveys, i.e. at the beginning of individuals' trips on line 1[20]. This gives us insights on the evolution of levels of comfort within morning-peaks.

[18] The frequency during moring peaks is approximately 1 minute 45 seconds.

[19] 47% for overall peak times.

[20] Density was collected throughout the different parts of the train to account for the unequal repartition of users inside the trains in 15 minutes intervals. Note that one carriage has an area of 180 m^2.

Table 2: Descriptive statistics

	Mean	Std. Dev.	Min.	Max.
Age (years)	37	9.97	+19	70
Male dummy	49%	-	-	-
Monthly income (euros)	2,299	864.85	800	3,500
Time opportunity cost (euro/minute)	0.19	0.07	0.07	0.29
Executive dummy	49%	-	-	-
Central Paris resident summy	57%	-	-	-
Trip durations (minutes)	27	12.37	2	50
Car Ownership dummy	33%	-	-	-
Home-Work commute dumy	86%	-	-	-
Density - manual count (pass/m^2)	1.9	0.65	0.7	3.3
Subjective mark (0-5)	3.4	1.12	0	5

Source: Survey on platforms

4.2 Descriptive statistics

We use 533 observations for which we have complete information.

Table (2) shows that our sample is broadly representative of the working population. Central Parisians represent 57% of the sample; mean age is 37 years and we have 49% males. Given the areas covered by line 1, executives logically represent half of the sample (49%). Average monthly income is 2,000 to 2,500 euros. We can use individual earnings data to calculate time opportunity costs (w_i) - which are found to be on average 0.19 euro per minute of travel. This is surprisingly close to the official opportunity cost of 0.18 euro/minute which may be found for the Paris area in 2009 by following recommandations of Ministere de l'Equipement (2005)[21].

Average travel duration in the sample is 27 minutes. For the vast majority of travellers, the purpose of the trip is naturally to commute from home to work (86%). Only one third (32%) of the sample have a car, result coherent with respect to the high propotion of Parisians in our sample. Finally, two variables allow us to control for the level of comfort in line 1

[21] According to the up-dating recommandations, the average time opportunity cost for travels performed on the regional network equals 10.8 euros/hour.

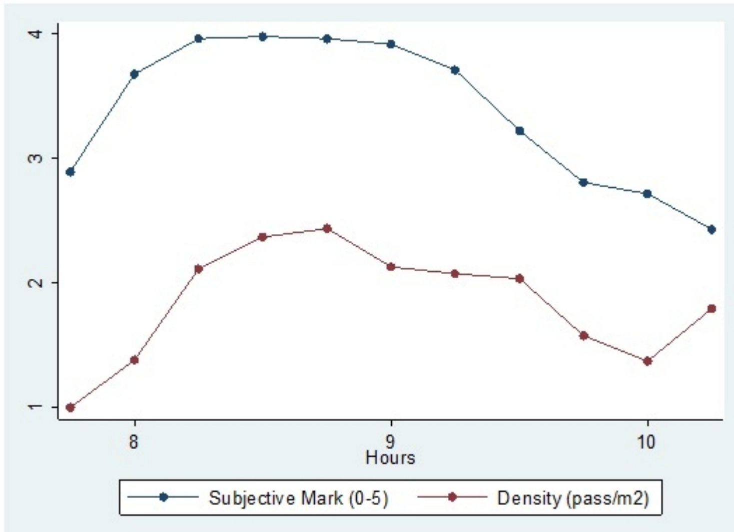

Figure 1: Comparison of subjective and objective measures of congestion

during morning peaks. The first comes from manual counting, i.e. the "objective comfort" at the beginning of individual's trips, with an average of 1.9 passenger/m^2. The second variable is a subjective evaluation of congestion, i.e. the "subjective comfort" on a scale from zero to five. Only 15% of interviewees choose values below 3 and more than 20% give the maximum mark, indicating that the line 1 is perceived as congested. As Figure (1) indicates, objective and subjective measures are highly correlated. They both reach their maximum between 8.30 and 8.45 A.M..

4.3 The valuation of comfort

We make use of the following question in order to evaluate the taste for comfort of Parisian suway users: "To benefit from off-peak levels of density during morning rush-hours, would you agree to use a subway which takes X additional minutes?". The initial bid was fixed at 5 minutes. Bids were then increased in increments of 5 minutes up to 20 minutes, the process stopping with the first negative answer ("multiple bounded bids").

The sample of this question is provided in Table (3). How do we deal with the categorical nature of the answers?[22] By using the conservative

[22]For individuals unwilling to wait 5 minutes, negative values cannot be excluded: cer-

Table 3: To benefit from off-peak comfort, would you wait longer?

	< 5 min	5-10 min	10-15 min	15-20 min	> 20 min
Observations	136	221	153	15	8
Percent	25.5%	41.5%	28.7%	2.8%	1.5%

Source: Survey on platforms

estimate that the willingness to wait equals intervals' inferior bound, an average willingness to wait of 5.7 minutes is found. Using the median value of the intervals, the average increases to 8.1 minutes. Even if these data comport certain limitations[23], they are unambiguous: a large majority of line 1 users (75%) are willing to engage a non-negligible share of their temporal resources, i.e. at least 5 minutes, in order to enjoy more comfortable travel conditions during morning peaks.

The importance of the taste for comfort can also be expressed in terms of excess travel: the proportion of additional waiting time in relation to existing trip duration, i.e. the proxy for perceveid costs of travels. The average excess travel time is 29%- 42% (depending on the interpretation of the intervals) - an order of magnitude coherent with the scarce results from other cities presented previously. Around 10% of our sample present an excess travel equal to 80% or more. Finally, using individual income data (w_i), these stated preferences correspond to values for willingness to pay for comfort improvements of 1.07-1.54 euro per trip. Using the official time opportunity cost (Ministere de l'Equipement (2005)), the value becomes 1.01-1.46 euro. The declared taste for comfort appears therefore non negligible[24]. Above all, these figures will allow us to propose original calculations on the monetary benefits of subway decongestion and congestion (see Section 6).

tain individuals may prefer shorter trip durations on crowded trains.

[23]First, individuals are said to tend to answer Yes to the initial bid. The 5 minutes offer could then be seen as too excessive ("yes-saying"). Second, the fact that we do not use decreasing bids when individuals reject an offer reduces the precision of estimates. Finally, there are scheduling costs related with congestion (Arnott et al. (1900)) which may also influence individual decisions about increased waiting times.

[24]It should be noted that these values are double the monetary cost directly paid by Parisian metro users, but that the ratio is much less given public and employer subsidies.

5 Determinants of the taste for comfort

5.1 Utility specification

In this section we first seek to determine the factors explaining individuals' willingness to pay for comfort - or, given our empirical strategy, their willingness to wait for more comfortable trains. Using the standard formulation of the random utility model we have:

$$u_{is}(t_i, p_i, c_s, X_i) = v_s(t_i, p_i, x_i) + \varepsilon_{is} \tag{10}$$

Whereas previously we considered the choice between different modes of transport (see equation (1)), we now compare different levels of comfort, here indexed s - peaks ($s = 0$) and off-peak periods ($s = 1$). Again, (t_i) represents the trip duration, (p_i) its monetary cost, (x_i) a vector of individual characteristics and (ε_{is}) is an individual taste shifter constant over changes in other covariates. For the functional form of the utility, we here assume the additive separability:

$$u_{is} = \alpha_s + \beta_s\ p_i + \gamma_s t_i + \theta_s x_i + \varepsilon_{is} \tag{11}$$

The difference in comfort between peaks and off-peaks ($c_1 > c_0$) implies that there exists some value (WTW_i) that compensates individuals between the two states. This is the "equivalent variation in trip duration" which makes individuals indifferent between the level of comfort associated to peaks and the one associated to off-peaks:

$$\alpha_1 + \beta_1 p_i + \gamma_1 t_i + \theta_1 x_i + \varepsilon_{i1} = \alpha_0 + \beta_0 p_i + \gamma_0 (t_i + WTW_i) + \theta_0 x_i + \varepsilon_{i0} \tag{12}$$

Rewriting equation (12), we get:

$$WTW_i = \alpha + \beta p_i + \gamma t_i + \theta x_i + \eta_i \tag{13}$$

where $\alpha = \frac{(\alpha_1 - \alpha_0)}{\gamma_0}, \beta = \frac{(\beta_1 - \beta_0)}{\gamma_0}, \gamma = \frac{(\gamma_1 - \gamma_0)}{\gamma_0}, \theta = \frac{(\theta_1 - \theta_0)}{\gamma_0}$ and $\eta_i = \frac{(\varepsilon_{i1} - \varepsilon_{i0})}{\gamma_0}$

We can further simplify this expression if we assume that the marginal disutility of monetary cost is equal among and across the two states ($\beta_1 = \beta_0 < 0$)[25]. Second, we suppose that whilst the marginal disutility of trip

[25] This is particularly useful as we do not have any information on the monetary costs of travels.

duration is lower for congested trips (because comfort is lower) it is constant within each "state of the nature"$(0 > \gamma_1 = k > \gamma_0 = k')$[26].

5.2 Explanatory variables

The main explanatory variable we focus on is obviously the trip duration (t_i). This is expected to positively influence willingness to wait: the more time spent in public transport, the more valuable the comfort of travels. Other variables include individual characteristics such as age, gender, place of residence, possession of a private vehicle or socio-economic status.

We also include our indicators of comfort in the peak period (objective and subjective measures of congestion). This is not common practice in the contingent valuation framework where states of nature are typically considered to be discrete. However, transportation congestion being a non-uniform phenomenon, it strongly varies according to temporal and geographical scales. In our case, levels of comfort in public transport are continuous, especially during morning peaks. Thus, adding these measures indicates how the willingness to wait varies over different degrees of congestion. Given the strong correlation between the two indicators (see Figure (1)), we decide not to include the two simultaneously.

Finally, equation (13) does not explicitly consider individual income (y_i) - generally considered a major determinant of willingness to pay. This is consistent since the individual income drops out of the equation as long as marginal utility of income is contant across different states of the nature, i.e. congested or not. However, we decide to include the individual income into (x_i) as a control variable for the willingness to wait for more comfortable trains. Note also that individual income does enter the picture if we move from willingness to wait to willingness to pay (since income determines opportunity cost of time). In that case, one should nevertheless be aware that covariates may suffer from reverse causality. For that reason, estimates of willingness to pay do not consider car ownership and place of residence as explanatory variables. Conversely, we introduce a dummy characterizing the socio-economic status, i.e. executives or not.

[26]We could actually relax this assumption by integrating the trip duration under a logarithmic form and estimate the logarithm of the excess travel instead of the absolute willingness to wait.

5.3 Econometric strategy

The multiple bounded bids system used in the survey implies an ordered choice of different intervals, that we can treat using ordered latent variables. Thus, we estimate:

$$Pr\,(WTWdec_i = m) = Pr\,(\tau_m \leq WTW_i < \tau_{m+1}) \quad (14)$$

where $(WTWdec_i)$ refers to the declared willingness to wait and (τ_m, τ_{m+1}) are the bounds associated to the different bids. Using equation (13) and simplifying, we can rewrite this as:

$$Pr\,(WTWdec_i = m) = Pr\,(\tau_m \leq alpha + \gamma t_i + \theta x_i + \eta_i < \tau_{m+1}) \quad (15)$$

After simplifications and transformation of the error term, we finally get:

$$Pr\,(WTWdec_i = m) = F_{\mu i}(\tau_{m+1} - \alpha - \gamma t_i - \theta x_i) - F_{\mu i}(\tau_m - \alpha - \gamma t_i - \theta x_i) \quad (16)$$

where F is the cumulated density function of the new error term (μ_i).

If we assume a normal distribution we have the ordered probit model, assuming a logistic distribution gives the ordered logit. As the variance of this term is not identified - typically Var(μ_i)=1 is assumed in the ordered probit model and Var(μ_i)=$\pi^2/3$ for the ordered logit. For comparison we also compute linear interval data regressions.

5.4 Results

Tables (4) and (5) present estimates of the determinants of willingness to wait and willingness using ordered logit and linear interval data techniques. Both methods produce similar insights.

The results indicate that trip duration influences both willingness to wait and to pay significantly (and in a similar order of magnitude). This result is in line with the literature on the perceived costs of travels: the more time spent in transport activities, the more valuable is the context in which it is consumed. Furthermore, the indicators of congestion (objective and subjective) significantly impact the taste for comfort. Even within rush-hours, the strengh of discomfort levels up the temporal ressources individuals are

Table 4: Determinants of Willingness To Wait for Comfort

	Ordered Logit			Interval Regressions		
	(1)	(2)	(3)	(4)	(5)	(6)
Duration (min)	0.01*	0.01*	0.01*	0.03*	0.03*	0.03*
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Home-Work	0.31	0.30	0.28	0.55	0.55	0.42
commute dummy	(0.25)	(0.26)	(0.25)	(0.73)	(0.72)	(0.72)
Car ownership dummy	0.21	0.21	0.18	0.57	0.59	0.5
	(0.18)	(0.18)	(0.18)	(0.48)	(0.48)	(0.48)
Central Paris	0.16	0.24	0.16	0.20	0.45	0.19
resident dummy	(0.17)	(0.17)	(0.17)	(0.46)	(0.45)	(0.45)
Age (years)	0.00	0.00	0.00	0.01	0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Male dummy	-0.04	-0.04	-0.05	-0.07	-0.07	-0.06
	(0.16)	(0.16)	(0.16)	(0.44)	(0.44)	(0.44)
Income (euros)	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Density (pass/m^2)	-	0.30**	-	-	0.86***	-
manual count		(0.12)			(0.32)	
Subjective mark	-	-	0.13*	-	-	0.35*
(0-5)			(0.07)			(0.20)
Observations	533	533	533	533	533	533
Log-Likelihood	-653.99	-651.01	- 652.32	-714.64	-711.10	-713.10
Pseudo R^2	0.01	0.01	0.01	0.01	0.01	0.01

Table 5: Willingness To Pay for Comfort

	Ordered Logit			Interval Regressions		
	(1)	(2)	(3)	(4)	(5)	(6)
Duration (min)	0.01**	0.01**	0.01**	0.01**	0.01**	0.01**
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Home-Work	0.43**	0.40*	0.38*	0.30**	0.30**	0.28**
commute dummy	(0.21)	(0.21)	(0.21)	(0.14)	(0.14)	(0.14)
Age (years)	0.03***	0.03***	0.03***	0.02***	0.02***	0.02***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Male dummy	0.03	0.03	0.03	0.07	0.07	0.08
	(0.15)	(0.15)	(0.15)	(0.09)	(0.09)	(0.09)
Executive dummy	0.97***	0.97***	0.98***	0.67***	0.66***	0.67***
	(0.11)	(0.17)	(0.17)	(0.09)	(0.09)	(0.09)
Density (pass/m^2)	-	0.27**	-	-	0.17**	-
manual count		(0.11)			(0.07)	
Subjective mark	-	-	0.17**	-	-	0.08*
(0-5)			(0.07)			(0.04)
Observations	533	533	533	533	533	533
Log-Likelihood	-1225.22	-1222.25	-1222.45	-789.54	-786.53	-787.54
Pseudo R^2	0.03	0.03	0.03	0.03	0.03	0.03

willing to engage in order to enjoy better travel conditions. Note that coefficients of objective congestion may be under-estimated since this variable does not really describe the “true” variation in passenger density, i.e. counts were made at the trips’ beginning[27].

By contrast, heterogeneity across observed individual characteristics in willingness to wait is fairly low. Certain characteristics (age, socioeconnomic status etc.) significantly influence willingness to pay - but their influence appears to act by influencing income rather than willingness to wait. Thus, individual income may not be a good indicator of people’s perceived opportunity cost of time. The taste for comfort seems therefore to be mainly influenced by trips’ characteristics.

[27]For that reason, we will not use those obtained with linear interval regressions to calculate welfare improvements in Section (6).

6 Policy Implications

6.1 The benefits associated to improved comfort

According to the survey, users of line 1 declared they are willing to increase their trip durations by 5.7-8.1 minutes in order to enjoy off-peaks travel conditions during rush-hours[28]. By considering the corresponding willingness to pay, one can approximate the welfare benefits induced by a policy of increasing infrastructure to reduce passanger densities on that line. We can also attempt to extrapolate our results to the whole Parisian network, recognising however that passenger density is relatively high in line 1 (which will lead to higher values of willingness to pay)[29]. To counteract the potentially high estimate of willingness to wait from line 1 we use conservative estimates of the other parameters. Thus, we use the (lower) time opportunity cost reported by Ministere de l'Equipement (2005) and the lower bounds of the intervals, giving an average willingness to pay of 1.01 euro per trip (see Section 4).

Applying our estimates to the 47% of peak-time trips on line 1 in 2008 (RATP internal sources), a potential welfare improvement of 101 million euros is found (given 213 million trips). With 1,388 million trips in the central Paris network (RATP (2007)), benefits now rise to 659 million euros. Therefore, there is room for considering the taste for comfort in economic appraisals of transport policies. For that purpose, one useful exercise is to look at the marginal benefits of subway decongestion.

6.2 Marginal benefits of subway decongestion

The methodology used below is closely inspired by CCTN (2009). We simply add the willingness to wait for more comfortable trains to the actual trip time to generate the perceived cost of travels ($Pc(q)$). This will then vary in a discrete way according to density levels (q). The marginal benefit of subway decongestion ($Bm(q)$) may be expressed as follows:

$$Bm(q) = \frac{\Delta Pc(q)}{\Delta q} \; q_p \; \frac{w}{s} \tag{17}$$

where (w) represents the time opportunity cost, i.e. 10.8 euros/hour according to our case study, (q_p) is the passenger density during peak-periods

[28]Since average passenger densities are equal during morning and evening peaks, we now refer to peaks by considering both periods.

[29]By contrast, average trip duration is relatively representative of other lines.

and (s) refers to the speed of subways[30].

The declared excess travel lies between 29% and 42% (see Section 4). We also use here the lower bound as a conservative estimate. The hypothetical change in passenger density proposed to travelers is approximately equal to 85%, i.e. 2.4 pass/m^2 during peaks vs. 1.3 pass/m^2 during off-peaks (STIF internal sources). However, the figure for off-peak density indicates that off-peak travels may also be seen as uncomfortable: the density allowing every individual a seat in line 1 is around 0.9 pass/m^2. Therefore, we consider two cases:

1. First we assume that off-peak travel does not generate any welfare losses, i.e. that perceived cost here equals generalized cost. In that case, the marginal benefit of subway decongestion is found to be 0.23 euro/pass km.

2. Alternatively, we apply a 25% comfort cost to the cost of off-peaks travels (in line with the difference to a situation where all are seated). We then obtain a value for equation (17) of 0.28 euro/pkm.

6.3 Comfort and cost-benefit analysis

A first example may be drawn from Prud'homme et al. (2011) who evalue the costs and benefits of a new tram line built in Paris in 2006. Using survey data, they show that around 35% of the new tram users were previously travelling with the Parisian underground. Considering an annual modal switch of 28.8 million pkms, the benefits of decongestion during peak-periods induced by the tram are 3.2-3.8 million euros. This compares to benefits of shorter trip duration estimated by Prud'homme et al. (2011) to be 2.7 million euros. Therefore, these figures indicate that whilst relatively modest taking into consideration the qualitative features of travel conditions may importantly influence Net Present Values calculations.

As already mentionned, Kopp (2009) recently studied the modal switch towards motorbikes and mopeds in Paris. He finds that the majority of new motorbike users previously used the underground network. Around 200 million pkms were thus eliminated from trains in 2007. This phenomenon should lead to improved travel conditions for remaining underground users during peak-periods. Using the calculations and the parameters from above,

[30] Approximately 30 km/h for Parisian underground.

we find benefits of subway decongestion ranging from 21.6 to 26 million euros. These are equal to 10% of time savings resulting from modal switch[31].

Finally, approximating the evolution of congestion costs in the central Paris underground may be temptative. Actually, Table (1) highlighted that the Paris subway usage has known an important increase over 2000-2007: around 900 million pkms. In order to calculate subway congestion costs, we have however to postulate two assumptions. First, we consider that these additionnal pkms enter the Paris network in a "'representative"' fashion of 2008 usage, i.e. 47% during peak-periods. Second, we assume that benefits of increased comfort are symmetric to losses inflicted by decreased comfort: In other words, willingness to pay and willingness to accept should be equal, assumption which would necessitate further investigations[32]. Considering this, incremental congestion costs of 97-118 million euros are found.

Therefore, these figures underline that neglecting crowding in public transport may seriously lead to misevaluation of transportation conditions: road congestion is not the sole transportation externality to be relevant, more has to be known on the perceived cost of travel in public transport. To illustrate this, consider that Leurent et al. (2009) approximate road decongestion marginal benefit at 0.45 euro/pkm for central Paris. Even if this figure is 60% our estimates of subway decongestion benefits, one easily understands that, due to the major patronage of the entire central Paris underground, the public transport network would quickly become unattractive for commuters if nothing is done.

[31]Kopp (2009) thus estimates welfare improvements related to time savings of 290 millions euros.

[32]Horowitz and McConnel (2002) thus suggest this may not be the case evaluations of willingness to accept do not include a budget constraint.

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