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Understanding high-frequent bus riders: Congestion, education, and riders' preferences

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A B S T R A C T

In this article, we quantify the impact of individual and contingent factors on citizens' decisions to regularly use the public bus transportation in Barcelona, Spain. Using data from an original survey, we approximate the effect of traffic congestion as a deterrent to becoming a high-frequent bus rider and show that level of education and employment status, as indicators of environmental concerns, fuel the regular use of bus services. Simulations conducted to identify the group of citizens most prone to changing their transportation habits additionally show that regular commuters in the urban area and with a higher level of education are more responsive to reductions in congestion that increase their probability of becoming frequent bus users.

1. Introduction

Mobility is a major concern for individuals. As shown by Redding and Turner (2015), who collected data from several surveys in various member countries of the Organization for Economic Co-operation and Development, from 2000 to 2005 the mean round-trip commute in those countries took approximately 40 min, or 7.5 % of daily work time.[3] More recent data for countries in the European Union (EU) confirm that the average commuting time in those country was between 24 and 28 min in 2019, but with a high heterogeneity ranging from 33 min in Lavia to 20 min in Greece.[4]

Among the different modes of public transportation, bus services represent a service of proximity given the high density of bus stops per spatial unit relative to, for example, subway or rail stops. Bus service thus affords the greatest degree of capillarity among all modes of public transportation (e.g., Tiznado-Aitken et al., 2020; Vermesch et al., 2021).

Barcelona is an interesting case study for bus services given the relatively high demand for bus trips among the city's residents. In 2017, the supply of public transportation in Barcelona was 3,388.12 million places on buses and 16,668.78 million places on the metro rail system, whereas the demand for bus trips was 196,97 million against 390.4 million places for the metro. The ratio of the supply of places between the metro and bus was 4.91, whereas the ratio of the demand is 1.98. The higher demand for bus trips is apparent in the occupancy rate on buses (4.98) versus the occupancy rate on the metro (4.33).[5]

However, riding the bus presents the major drawback of frequent delays, especially along urban routes, owing to traffic congestion that often extends for the duration of journeys and, to some extent, affects the

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[3] Redding and Turner (2015) have also provided evidence showing that the costs of commuting represented approximately 14% of the annual average household budget in Spain from 1990 to 2009.
[4] Source: Statistics Explained (https://ec.europa.eu/eurostat/statisticsexplained/) – 09/08/2023.
[5] Data were taken from Transport Metropolitans de Barcelona (2018).

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reliability of bus services (Deb and Mokaddes, 2018; Tyndall, 2018), even for regional rides (Handy and Thigpen, 2019).[6] The reduced reliability of bus services also lowers the probability that individuals become frequent bus riders.

Therefore, in our study, we sought to identify individual and contingent characteristics that influence the likelihood of regularly using public bus transportation systems.[7] By centering our analysis on the determinants of riders' choice to use bus services and linking those determinants to the individual characteristics of riders, we have produced new quantitative evidence of the role of selected individual characteristics (i.e., education, income, and occupation) as factors shaping riders' preferences in selecting buses as a mode of transportation. Those individual characteristics are usually approximated by grouping them together and treating them as a unique latent variable. In our study, by contrast, we overcame that limitation by identifying each of those characteristics separately in a way that allowed more accurate conclusions about their different roles. The quantitative output can illuminate the potential effects of public policies targeting the increased use of the bus public transport network among different groups of citizens. Such evidence, both original and novel, contribute to extending the results of not only Aklin et al. (2013) but, more importantly, Allen et al. (2019) regarding the city of Barcelona.

To the best of our knowledge, data that separate individual income and education are unavailable in the official statistics and surveys that we could have access to as previous contributions did (e.g., Allen et al., 2019).[8] In response, we overcame that limitation by conducting an original survey, the results of which allow this article to offer novel insights. Among those insights, our results emphasize the relevance of traffic congestion as a key factor shaping riders' choice to become frequent bus users. Although the magnitude of the estimates is not homogeneous across all riders, it is influenced by individuals' education and occupation, whereas income is not statistically relevant, as aligns with what Munim and Noor (2020) have suggested in their discussion.

As the results in our case show, the propensity to regularly use bus services is independent of users' incomes but positively associated with their education and employment status. In particular, education is discriminating enough to allow approximating the impact that changes in the degree of traffic congestion have on the probability of becoming a frequent bus user. We can appreciate those effects in the predictions that we performed to approximate the likelihood of becoming a frequent bus user in light of variations in traffic congestion's effects and each individual's education. Our predictions emphasize that congestion's effects mostly deter the regular use of public transportation within the city for educated citizens, whereas the magnitude of the effect is, on average, 3 % less in the case of mixed rides (i.e., urban and extra-urban rides). That tendency is intensified by being a daily commuter and more pronounced in the case of urban rides. Similar to other results in the literature, education is a pivotal discriminating factor fueling pro-environmental behavior and the prospective frequent use of Barcelona's public transportation system.[9] However, congestion's effects emerge as the most relevant deterrent in reducing that propensity given the possible opportunity costs implied. In our closing discussion, we highlight a few considerations that those and other findings suggest for public transportation policies in urban areas.

In what follows, Section 2 sketches the research setting as a means of framing our analysis, after which Section 3 presents data used in our analysis. Next, Section 4 describes our empirical strategy and presents our results, followed by a discussion of the results in Section 5. Last, Section 6 concludes the article. Additional material and material are provided in the appendices.

2. Theoretical background and research hypotheses

Individual socioeconomic characteristics, contingent factors, purposes of travel, and time pressure are crucial factors in shaping a traveler's willingness to prefer private over public transport (Paleti et al., 2015). The role of individual socioeconomic status (SES) in determining the choice of means of public transportation has been explored in other city-specific studies, including for London (Grisé and El-Geneidy, 2017), and among selected group of citizens in different places, including older adults in Malta (Mifsud et al., 2017) and students in Kandy, Sri Lanka (Dias et al., 2022). However, none of those studies focused on how SES factors and congestion impact the willingness of riders to become regular bus users.

The burden associated with the costs of traveling, above all commuting, is mostly linked to the time expected to be needed to cover the trip's distance. On that count, the share of time spent commuting reduces the possibility of devoting said time to productive activities and, in turn, of increasing the level of disposable income for worker–consumers, which stands to improve their purchasing capacity. At the same time, the costs of commuting reduce the amount of income that a worker–consumer devotes to purchasing consumable goods and thus constrains the maximum level of utility that they can achieve.[10]Under those circumstances, income level is expected to be a factor of individuals' decisions to become frequent bus users. Indeed, Nilsson and Delmelle (2018) have argued that public transportation systems support the mobility of all residents but especially ones with low income.

Given those circumstances, our first hypothesis (H_1) concerns the relationship between income and the probability of an individual's becoming a regular bus user:

H_1: Bus riders' income can significantly affect their frequent use of bus services.

Of course, income is not the sole factor influencing such decisions. Literature on public transportation also emphasizes the role of congestion's effects, for example, in fueling the use of public bus services. In Melbourne, the city's bus services are considered to be a strategic option for reducing congestion's effects caused by the use of private transport. In their study, Nguyen-Phuoc et al. (2018) analyzed survey data representing 187 bus passengers and found that increased bus operations would decrease congestion by 10.7 % and reduce travel times by 1 % despite the stop-and-start operations necessary at bus stops. Anderson (2004) found similar results in the case of Los Angeles. At the same time, the benefit of so-called congestion relief due to the use of public transit is counterbalanced by problems created by transit strikes (Adler and van Ommeren, 2016).

Therefore, the literature highlights that the effects of congestion affect the reliability of bus services. In that vein, our data allowed the direct quantification of attitude (i.e., propensity to be a regular bus user) with respect to the degree of congestion, which influences the reliability of bus rides. Therefore, our second hypothesis (H_2) is:

[6] The social cost of unreliability in public transport is not marginal. Referring to the Australian city of Sydney, Tirachini et al. (2014) have elaborated a novel framework that introduces variability in travel time as a source of disutility for car and bus users, which exerts an overriding impact on their attitudes toward public bus transportation systems and strongly shapes their preferences.

[7] Per the theory of planned behavior, an individual's behavior is driven by intention but also by personal and societal beliefs. By contrast, the customer satisfaction theory mostly relies on the individual perception of the quality of the service provided.

[8] In this article, *education* refers to the highest educational (i.e., academic) degree achieved by an individual.

[9] Gaborieau and Pronello (2021) have argued that policies targeting education jointly with targeted advertising make individuals more (emotionally) sensitive to environmental issues and improve their attitudes toward ecologically sustainable forms of mobility.

[10] A theoretical framework illustrating those effects is detailed in Appendix B.

H_2: The probability of becoming a frequent bus rider is mostly driven by the level of congestion experienced during bus rides.

However, beyond contingent factors such as congestion, individual characteristics such as education and occupation also influence individuals' decisions to become frequent bus users. One channel through which individual characteristics impact individuals' propensity to be frequent users of public transportation, including bus services, is individuals' pro-environmental behavior. The literature is conclusive about the positive green returns, meaning pro-environmental behavior, of education in several countries around the world (e.g., Chankrajang and Muttarak, 2017; Mayer, 2015). As discussed by Harring and Jagers (2018), people with university degrees have certain values and the analytical skills needed to understand the complex effects and consequences of climate change and thus feel more responsible for those effects and consequences than people without such education. In general, knowledge positively influences the perceived value of green (i.e., sustainable) behavior and, in turn, individuals' attitudes toward such behavior (Roh et al., 2022).[11] Those types of attitudes in relation to green responsibilities are mostly present in young (e.g., students) and old (e.g., retirees) cohorts of citizens (Ágoston et al., forthcoming) and lead them to be more prone to using greener modes of transportation. Along those lines, Hamilton (2011) found that, in the United States, environmental concerns increase with education among Democrats, whereas the reverse is true for Republicans. That additional evidence emphasizes how pro-environmental behavior, in being reinforced by personal beliefs, norms, and environmental awareness, is the product of a self-reinforcing process (Lee et al., 2023). Thus, our third hypothesis (H_3) focuses on the relevance of individual characteristics, including green responsibility, as determinants of becoming a frequent bus user conditioned on the individual's perception of congestion's effects:

H_3: Education and occupation, in influencing individuals' green attitudes, make individuals more prone to becoming frequent bus users conditioned on their perception of congestion's effects.

Fig. 1 summarizes the relationships we aim at approximating:

3. Research strategy and data statistics

Our empirical analysis exploits data obtained with an original ad-hoc survey conducted in Barcelona in 2017. In its structure, the survey followed similar surveys in the field and consisted of 22 questions, most of which were close-ended;[12] a few were open-ended to allow respondents to add their opinions and ideas. The survey was available in three languages—Catalan, English, and Spanish—and was made accessible online and on paper by contacting an enumerator. Data collection occurred in the fall of 2017, and we had a random sample of 757 observations. The survey was distributed online by means of the networks of several civic associations in Barcelona as well as two of the major universities (UB and UAB). Furthermore, we relied on the field work of a dedicated full-time enumerator who interviewed people at the most important bus stops of the public transport networks and also approached older persons at some of their meeting point to offer them assistance completing the survey. Citizens were offered a bus card, granted on a lottery basis, as an incentive for taking the survey.

3.1. The city of Barcelona

According to the city's official statistics,[13] in 2017, the population of Barcelona in Spain was approximately 1,620,000 inhabitants. The urban area of the city covers about 10,216 (ha). TMB (Transports Metropolitans de Barcelona[14]) is the management unit of the companies Ferrocarril Metropolità de Barcelona SA and Transport de Barcelona SA. These last two companies operate the metro and bus network on behalf of the Àrea Metropolitana de Barcelona (AMB). The AMB became an institution of the public administration in 2010, having emerged from the growth and interconnection of cities surrounding Barcelona (36 municipalities with more than three million inhabitants) with the scope of rationalizing metropolitan governance from the territorial, social, demographic, cultural and economic perspectives.

TMB is the transport operator for Barcelona and 10 municipalities of the metropolitan area. In 2017, the public bus service managed by TMB operated a total of 98 bus lines (urban and interurban) and a fleet of 1,085 buses for a network of 833 km that included 2,541 bus stops. In the same year, the TMB bus line service transported 202 million travelers over 45,478 km. The commitment of the company was to provide comfortable bus journeys by means of a public service accessible to all. It is worth noting that the bus fleet in Barcelona is relatively modern (the average age of the buses is about 10 years old). This is tangible evidence of the company's implementation of a strategic plan that aimed to reduce CO_2 emissions, create energy savings by developing synergies jointly between the metro and bus service, and strengthen its deep commitment to a greener future not only by reducing reliance on hybrid or electric buses but also reinforcing the use of renewable energies.

Garcia-Lopez et al. (2021) identified that citizens in Barcelona, especially immigrants, consider the city's bus service as their preferred mode of public transportation. The attractiveness of this mode of transport is endorsed by evidence: the number of bus passengers increased by 10 % from 2013 to 2017 in contrast to a 5 % increase for the metro service for the same period.[15]

3.2. Our survey and data statistics

Our original survey conducted among a representative sample of bus users in Barcelona (Spain) provides information and knowledge not only about riders' degrees of satisfaction with Barcelona's bus service and their ideas for improving it but also information about a few individual characteristics (particularly, the individual's socioeconomic status) in order to assess the impact of individual socioeconomic features on the propensity to become a frequent bus user.

The data that we analyze purport the daily bus rides taken by a random sample of citizens in Barcelona in combination with aspects of their SES. That combination adds significant value to our data and differentiates our survey from others that have overlooked precise indicators of respondents' SES. Beyond that, for each ride included in the survey, we can retrieve the zip codes of the origin and the destination, the scope of the trip, and the weekly frequency of the ride.

Taking as a reference the type of surveys in Nguyen-Phuoc et al., 2022 or Deb and Mokaddes, 2018, our survey addresses important pieces of information, such as level of income and level of education, as separate variables. These data are important because they allow us to determine the probability of an individual becoming a regular bus user in association with his or her level of income, level of education, and

[11] De Silva and Pownall (2014) have provided evidence that not only education but also gender are important factors of green (i.e., sustainable) attitudes.

[12] The text of the survey appears in Appendix A.

[13] Ajuntament de Barcelona Anuari Estadistics de la Ciutat (2018) available at https://ajuntament.barcelona.cat/estadistica/catala/Anuaris/Anuaris/anuari18/index.htm.

[14] TMB website: https://www.tmb.cat/en/about-tmb/get-to-know-us.

[15] Source: Ajuntament de Barcelona Anuari Estadistics de la Ciutat (2018) available at https://ajuntament.barcelona.cat/estadistica/catala/Anuaris/Anuaris/anuari18/index.htm.

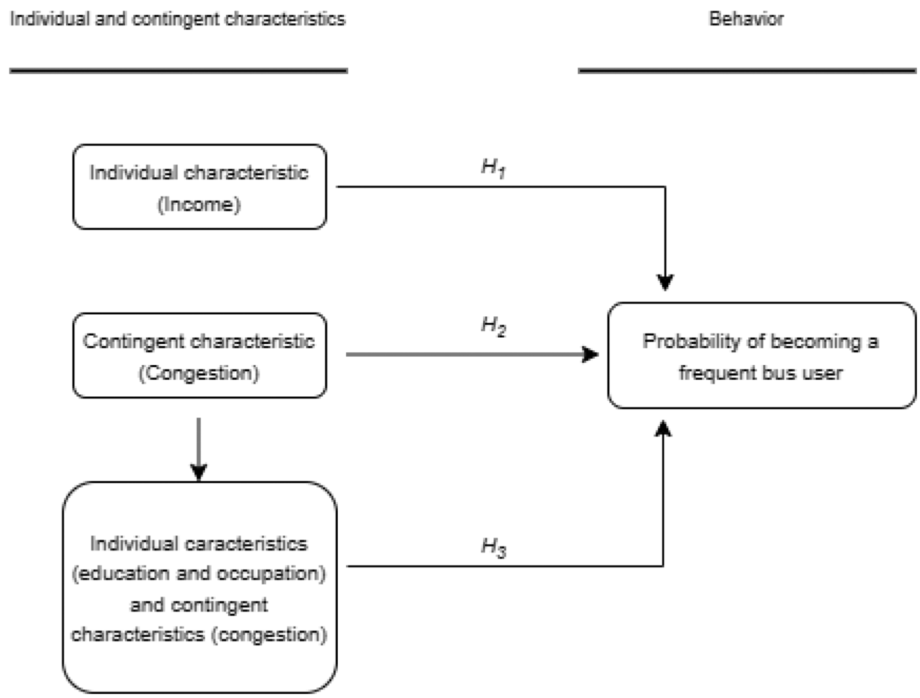

Fig. 1. Research model.

occupation.

A preliminary data analysis was performed to gauge our sample's representativeness.[16] The results presented in Table 1 are organized according to selected principal criteria: gender, age, place of birth, education, and occupation. The Wilcoxon signed-rank test confirmed those dimensions.

The results in Table 1 also allow deducing important features of bus users. A sizable number of individuals more than 65 years old who completed the survey and reported being born in Spain but outside Catalonia were immigrants who relocated to the city for work during the waves of immigration in the 1950s and 1960s. By contrast, most other immigrants (i.e., foreign-born individuals) arrived in Barcelona during the influx of international immigrants in the 2000s.[17]

Perhaps most interestingly, as shown in Table 2, nearly a third of the sample declared having income exceeding €30,000 per year, with approximately 12 % declaring income less than €10,000. Therefore, unlike in US cities, bus service in Barcelona is not a transportation service that is mostly appreciated and utilized by low-income individuals (Giuliano, 2005).

We also performed various tests to identify possible bias in our sample. Little's missing completely at random (MCAR) test confirmed that we could not reject the hypothesis that missing data are not MCAR—the statistical value exceeded the threshold value of 0.005—and, no specific pattern was detected in the missing data (Little, 1988). According to Harman's one-factor test, the explanatory value of a single factor is 17.635 %, which was well below the recommended value of 50 % concerning the proportion of observed values through the principal component that a single factor explains (Podsakoff et al., 2003). Last, the indicator for the common variance method, a method used to measure potential bias in participants' survey responses because

[16] Additional tests addressing the representativeness of the survey are presented in Appendix C.

[17] A discussion that synthesizes views on the topic can be found in Garcia-Lopez et al., (2021).

Table 1
Descriptive statistics of the full sample.

		Sample (%)[a]	Official Data (2016) (%)
Gender	Female	60.8	52.7
	Male	39.2	47.5
Age	< 15 years	0.27	12.6
	[15–25]	8.65	8.83
	[26–40]	27.16	22.61
	[41–65]	37.84	34.32
	>65	26.08	21.64
Place of birth	Barcelona	48.92	
	Rest Catalunya	13.84	
	Rest Spain	18.11	
	Spain	80.27	83.44
	Europe	6.49	6.22
	Asia	2.3	3.91
	Africa	0.27	1.21
	North America	0.68	0.24
	Central and Latin America	9.86	4.94
	Oceania	0.14	0.03
Education	Illiterate	4.76	3.12
	Primary	10.96	19.0
	Secondary	23.65	21.1
	Higher	58.39	55.3
Occupation	Employed	52.21	50.45
	Student	8.86	11.5
	Retired	26.75	24.2
	Unemployed	8.67	9.2
	Other	3.51	3.12
	TOTAL	**757**	**1.608.745**
Wilcoxon signed-rank test (H_0: Sample = Official Data)			
By Gender	$z = -0.447$ (Prob > $\|z\|$ = 0.657)		
By Age	$z = -0.405$ (Prob > $\|z\|$ = 0.685)		
By Place of Birth	$z = -0.169$ (Prob > $\|z\|$ = 0.865)		
By Education	$z = -0.365$ (Prob > $\|z\|$ = 0.715)		
By Occupation	$z = -0.135$ (Prob > $\|z\|$ = 0.892)		
Little 's MCAR test (Survey)	Prob > χ^2 = 0.0775		
Harman single factor	17.635 %		
CMV	24.650 %		

[a] Percentage over the total sample of complete answers for each category.

Table 2
Bus users by level of income (2017).

Income Level	Bus Users (%)
No reply	2.25
< 10 000 €	12.02
10 000 € – 20 000 €	27.34
20 000 € – 30 000 €	29.06
> 30 000 €	29.33
Average sample: 2.774 (20 000 € – 30 000 €)	
Average official statistics (INE): 20,128 €	

of raters, is 24.650 % and thus below the suggested threshold of 50 % needed to discard the presence of that potential bias.[18] As for the pattern of missing values in the survey responses, we produced some statistics (Table 1C–6C in Appendix C) to assess the distribution patter of missing values over time. Overall, respondents to the survey in December were more careful in replying to the questions than respondents in other months; the principal missing values referred to individual opinions about the degree of satisfaction with bus services or about the evaluation of the quality of the services. Women were usually more precise than men in replying, while older individuals (i.e., >65 years old) were more committed to providing high-quality replies, especially in the last period of data collection, whereas young persons (i.e., 15–25 years old) worsened quality in their replies over time.

As for the satisfaction of our sample with the city's bus service, more than 50 % of respondents expressed satisfaction, most often related to ease of accessibility and good connections with other public transportation services. However, some were critical about the length of time required per trip and generally cited the lack of sufficient speed in reaching destinations in limited amounts of time as a result of, for example, peaks in congestion. On that topic, the survey allowed respondents to formulate open-ended suggestions, displayed in Table 3, that largely explain their desire to continue enjoying a valuable public service for getting around in Barcelona. However, congestion is a relevant factor that hampers the perception of the quality of the bus service, as similar evidence in the literature has also indicated (e.g., Kim and Schonfeld, 2015).

The opinions expressed by bus users in our survey, in combination with the results of official statistics presented by Allen et al. (2019), directly suggest a clear concern about the effects of congestion. Beyond that, our survey's added value was the possibility of matching users' opinions with direct indicators of their SES (e.g., income, education, and occupation), which provides an interesting platform for directly assessing the relationship between income and the propensity to regularly use public bus services. According to the conclusions drawn by Nilsson and Delmelle (2018), low-income families are expected to be more prone to using public transport systems relative to other families. However, the distribution of the level of income in our sample, shown in Table 2, reveals another reality.

Table 3
Ideas from interviews for improving the bus service (2017).

Response rates (%)	Ideas
26.95	Increase frequency of trips per bus line
18.25	No idea
10.04	Increase speed to reduce trip time
9.64	New bus lines
8.06	Improve connection between bus lines and other means of transport
5.02	Improve material and internal organization of buses
1.72	Reduce changes in organization of services and provide more information to users at bus stops and in buses

4. Empirical analysis: Results and discussion

In order to run our empirical analysis, we organize the information we gathered in our survey in quantitative variables. The variables are described in Table 4.

4.1. Data Description

Beyond the variables extracted by the survey, we created the variable traffic *Congestion* (Table 4). To compute this variable, we first needed to compute the distance (in kilometers) for each trip (i.e., *Distance*). Among the different options that the survey allowed, we focused only on the most frequent trip indicated by users, whose motivation could have been related to their job or other reasons. Knowing the zip codes of the place of residence and the destination, we computed the distance to be covered by public transport according to data provided by Google Maps.

When both locations fell within the same zip code, we assigned a one-kilometer distance as the average representative distance inside each zip code given their current area in Barcelona.[19] In the case of not knowing the precise zip code of the place of residence or the destination, the interviewed persons either did not provide the information or approximated it by using the name or code of the neighborhood or district in Barcelona. In that event, we approximated the zip code of residence or destination with the zip code of the centroid of each neighborhood or district in order to be able to approximate the distance between these two points. Having elaborated that variable, we computed an index for *Congestion* by dividing the time for the bus trip as reported by respondents by the corresponding distance.

A wide body of literature discusses the different options for defining the appropriate indicator of congestion in a way that approximates its impact on existing public transport (Nguyen-Phouc et al., 2020). In this vein, our indicator measures the intensity of the congestion and approximates the amount of delay due to congestion experienced on the bus network in the urban (Barcelona) and extra-urban (Barcelona Metropolitan area) public bus network.

Preliminary descriptive statistics illustrate some interesting features of the variables for that part of the econometric analysis, as shown in Table 5.

The descriptive statistics highlight that the number of respondents using the bus service more than three times per week (*regular bus user*) is relatively important. Nearly all such respondents are daily commuters, irrespective of the means of transport used. The average degree of congestion means that it takes about 12 min to cover 1 km,[20] and our original data (available upon request) reveal that the average distance covered in a trip is approximately 6.36 km and the average time approximately 35 min. In addition, about 40 % of users are immigrants, and 60 % are women. Regarding the categorical variables of *income*, *level of education*, and *occupation*, most respondents are employed or retired; their average level of education is the completion of secondary school; and their average annual income exceeds €20,000.

[18] We replicate the same tests for the sub-sample exploited in the estimation in Section 5 (and results are reported in the correspondent tables) and results are in line with those obtained for the full sample.

[19] The average dimension of a zip code in Barcelona is about 2km x 2km. Assuming 1-km distance for the trip inside the same zip code approximates its radius.

[20] In our survey, we did not gather information to distinguish peak and off-peak hours. Also, we do not dispose of the precise information users get on and off a bus. Thus, all of our analyses were performed with mean values.

Table 4
Definition of variables.

Variables	Description	Frequency	Percentage (%)
Age	*Count variable:*		
	1: < 15 years-old	*2*	*0.26*
	2: [15, 25]	*64*	*8.45*
	3: [26, 40]	*201*	*26.55*
	4: [41, 65]	*280*	*37.00*
	5 > 65	*193*	*25.50*
	(No answer)	*17*	*2.25*
Regular bus users	*Dummy variable:*		
	1 the user takes the bus more than 3 times a week[a]	*206*	*27.21*
	0 Otherwise	*551*	*72.79*
Congestion (Cong)	*Ration between trip time (average minutes for the representative bus ride for each individual) and the length (in Km) of the ride*		
Daily commuters	*Dummy variable*		
	1: Yes	*687*	*90.75*
	0: Otherwise	*70*	*9.25*
Degree of satisfaction	*Dummy variable:*		
	1 Yes (including replies from 1 to 5 in question 20 survey Appendix A)	*429*	*56.67*
	0 Otherwise	175	23.12
	(No answer)	153	*20.21*
Education	*Count variable:*		
	1: Illiterate or less than primary	*36*	*4.76*
	2: Primary	*83*	*10.96*
	3: Secondary	*179*	*23.65*
	4: Higher	*442*	*58.39*
	(No answer)	*17*	*2.25*
Gender	*Dummy variable:*		
	1 Female	*450*	*49.45*
	0 Male	*290*	*38.31*
	(No answer)	*17*	*2.24*
Immigrants	*Dummy variable:*		
	1 Immigrant (born out of Spain)	*280*	*36.99*
	0 Otherwise	*477*	*63.01*
Improvement quality bus service	*Dummy variable:*		
	1 Yes (including all replies but answer 6 in question 19 survey in Appendix A)	*513*	*67.77*
	0 No (answer 6 in question 19 survey in Appendix A)	*138*	*18.23*
	(No answer)	*106*	*14.00*
Income	*Count variable:*		
	1: < 10,000 €	*91*	*12.02*
	2: [10,000€; 20,000€)	*207*	*27.34*
	3: [20,000€; 30,000€)	*220*	*29.06*
	4: > 30,000 €	*222*	*29.33*
	(No answer)	*17*	*2.25*
Occupation	*Count variable:*		
	1: Employed	*395*	*52.21*
	2: Students	*67*	*8.86*
	3: Retired	*202*	*26.75*
	4: Unemployed	*66*	*8.67*
	5: Other	*27*	*3.51*
Quality of the service	*Count variable:*		
	1: Very bad	*3*	*0.40*
	2: Bad	*17*	*2.25*
	3: Average	*174*	*22.99*
	4: Good	*370*	*48.88*
	5: Very good	*103*	*13.61*
	(No answer)	*90*	*11.89*
Physical disease	*Dummy variable*		
	1: Individual with physical disease	*65*	*8.58*
	0: Individual without physical disease	*671*	*88.64*
	(No aswer)	*21*	*2.78*

[a]This definition of “frequency” allows for identifying users with a minimum regular weekly schedule in the use of the public bus public transport quantified -ideally – by a return trip (referring to their place of residence) every other day.

Table 5
Descriptive statistics.

Variable	Observations	Mean	Std. Dev.	Min	Max
Regular bus user	757	0.272	0.445	0	1
Quality of the service	667	3.823	0.727	1	5
Degree of satisfaction	604	0.710	0.454	0	1
Improvement quality bus service	651	0.788	0.409	0	1
Physical disability	736	0.089	0.285	0	1
Daily commuters	757	0.907	0.289	0	1
Gender	740	0.608	0.488	0	1
Immigrant	757	0.369	0.483	0	1
Congestion	722	11.78	15.94	0.33	150
Income	740	2.774	1.011	1	4
Education	740	3.388	0.869	1	4
Occupation	757	1.968	1.189	1	5

4.2. Estimations and results

In a preliminary set of estimations (refer to Appendix D), we explore the relative importance of individual characteristics in the individual decisions to become frequent bus users (results are in Table 3D). Regarding economic background, respondents with a high degree of education, irrespective of their level of income (H_1), are frequent users of the bus service but also critical when asked to appraise its quality. Moreover, high-income respondents are likely to be positive in their evaluation of the quality of the bus public service, although our estimations are inconclusive about the probability that this group could become regular bus users. Hence, we can conclude that education and occupation (with different relative importance on the bases of the estimated coefficients) are common factors influencing the degree of satisfaction and the probability of becoming a regular bus rider. It is also worth noting that making criticisms or comments about the quality of the bus service and proposing improvements do not prevent these individuals from regularly using bus transportation. However, at this stage, congestion effects are irrelevant. However, the lack of statistical significance of the congestion effect could be associated with the absence of the spatial dimension in the model specifications proposed in Table 3D. Episodes of traffic congestion are usually concentrated in neuralgic points of the urban transport network.[21]

In this vein, one can think that the congestion effects are not uniformly spread throughout Barcelona (and its metropolitan area) as well. Bus users who live in specific neighborhoods could be more affected than users who reside elsewhere simply because their residences are within neuralgic spatial units of the transport network. Hence, place of residence turns out to be a key factor for approximating the probability of experiencing the effects of congestion when thinking about being or becoming regular bus users. Therefore, we aim to take a further step in our analysis and investigate the extent to which the congestion effect may be a deciding factor for bus riders in Barcelona that influences their decision to become regular bus users.

In performing that second step of the empirical analysis, we are also able to provide evidence concerning two types of bus rides: urban rides and extra-urban (i.e., “mixed”) rides. The former type takes into account bus trips made inside the city of Barcelona, whereas the latter considers the situation of riders who reside in the Barcelona metropolitan area and commute to the city daily. Thereby, we can offer two approximations of

[21] An indirect insight from Echaniz et al. (2022) is the relevance of the spatial dimension of congestion in the city of Santander (Spain) so as to endorse the spatiotemporal distribution of the degree of satisfaction in a city.

the propensity to become regular bus users by taking into consideration the case of users who reported choosing the means of transport for short- and medium-length daily trips.

To reach that point, we produce a new set of estimations in Tables 6 and 7. In this set of estimations, we embed the relevance of the spatial dimension of the place of residence of our sample by clustering the errors by zip code.[22] Furthermore, clustering by place of residence allows accounting for all poorly defined spatial and socioeconomic features of neighborhoods in which users reside. However, this decision comes at the cost of losing observations because not all respondents provided the precise zip code of their residence. Despite the strategy we adopted to overcome this problem when computing the congestion effects, here we cannot approximate it with the zip code of the centroid of the district or neighborhood in Barcelona since districts or neighborhoods are often heterogeneous in terms of traffic.

In order to perform this empirical analysis, we will focus on the subsample of data by exclusively including individuals whose trip has a precise point of departure and involves having (at least a partial) urban tract. Therefore, we take out of the full sample all the individuals using the bus service just for interurban ride. Overall, de facto, our sample shrinks to 541 observations. The Little MCAR test, the Harman single factor test, CMV test and the VIF included in Table 6 and referring to this sample confirm that this subsample preserves the property of the full sample (as discussed in Table 1).

Table 6
Estimations: Mixed (urban and extra-urban) bus rides. Dependent Variable: *Regular bus users* Method of estimation: *Linear probability*.

	(1)	(2)	(3)	(4)
Constant	0.406***	−0.116	−0.111	−0.283**
	(0.031)	(0.129)	(0.128)	(0.138)
Congestion	−0.003***	−0.002*	−0.002*	−0.002*
	(0.008)	(0.001)	(0.001)	(0.001)
Education		0.118***	0.119***	0.119***
		(0.028)	(0.027)	(0.027)
Occupation		0.05**	0.05**	0.05**
		(0.020)	(0.020)	(0.020)
Gender			0.021	
			(0.045)	
Immigrant			−0.058	
			(0.039)	
Daily commuter				0.175**
				(0.073)
Mean VIF	*1*	*1.20*	*1.13*	*1.47*
Adj- R-squared	0.011	0.048	0.048	0.049
Log-Likelihood	−368.423	−357.21	−356.07	−356.20
AIC criterion	1.369	1.335	1.339	1.332
BIC	−2655.307	−2665.143	−2654.84	−2662.72
Observations	541	541	541	541
Clusters	*114*	*114*	*114*	*114*
Statistics sample				
Litte MCAR test	*0.7098*			
Harman single factor	*26.182*			
CMV	*35.356*			

Level of significance: *** 1%, ** 5%, *10%. Standard errors are clustered by zip code place of residence and shown in brackets.

[22] The step was the first in the analysis for embedding the urban spatial structure due to the absence of any direct way to map bus lines or zip codes with georeferenced data compatible with the city's administrative organization.

Table 7
Estimations: urban bus rides. Dependent Variable: *Regular bus users* Method of estimation: *Linear probability*.

	(1)	(2)	(3)	(4)
Constant	0.427***	−0.097	−0.064	−0.228
	(0.036)	(0.141)	(0.140)	(0.169)
Congestion	−0.004***	−0.002**	−0.002**	−0.002**
	(0.008)	(0.001)	(0.001)	(0.001)
Education		0.122***	0.123***	0.122***
		(0.029)	(0.028)	(0.022)
Occupation		0.043*	0.044**	0.043*
		(0.022)	(0.021)	(0.022)
Gender			0.000	
			(0.999)	
Immigrant			−0.089**	
			(0.041)	
Daily commuter				0.135
				(0.104)
Mean VIF	1	*1.20*	*1.12*	*1.56*
Adj- R-squared	*0.016*	*0.055*	*0.059*	*0.054*
Log-Likelihood	*−314,42*	*−304.24*	*−302.22*	*−304.07*
AIC criterion	1.376	1.340	1.340	1.342
BIC	−2179.247	−2187.36	−2179.13	−2182.61
Observations	460	460	460	460
Clusters	*62*	*62*	*62*	*62*

Level of significance: *** 1% **, 5%, *10%. Standard errors are clustered by zip code place of residence and shown in brackets.

The results in Tables 6 and 7 are quite comparable, and the congestion effects were found to be highly relevant.[23] Congestion's effects discourage individuals from becoming frequent bus users, as hypothesized in H_2, irrespective of their other characteristics, and the estimated coefficient is largely identical for both types of rides. Level of education seems to fuel the regular use of bus services, as proposed in H_3, presumably because people with more education are likely to be more aware of pollution and environmental problems, and for them, using public bus services can be a means of exercising control. Overall, gender does not play a significant role in favoring the regular use of bus services; however, students and retirees are more likely to be frequent riders.

In view of the previous results, the profiles of regular riders on mixed and urban rides seem to differ. Daily commuters are more likely to be frequent users of mixed rides, possibly in association with the high degree of accessibility that bus services can guarantee. In that sense, daily commuters may take advantage of trips to perform several tasks a day. By contrast, immigrants are less likely, at least from a statistical perspective, to be frequent bus users on urban rides, possibly for two reasons. First, immigrants usually live outside Barcelona or on its outskirts (Garcia-Lopez et al., 2021) and may prefer alternative means of transport (e.g., the subway). Second, they might live near their workplace and simply commute on foot. With that framework, we determine the importance of level of education in engaging in pro-environmental behavior. The attitudes of more-educated persons dispose them to becoming frequent users of public transportation systems, albeit depending on certain levels of congestion, likely in association with their greater concern for adopting green habits that can help preserve the natural environment.

[23] The goodness of fit of those estimations can be appreciated by the value of Akaike's information criterion and the Bayesian information criterion knowing that smaller values of those indicators have to be preferred. We also report the Adjusted R-squared value as a reference. Each table also report the VIF (Variance inflation factor) statistics: the mean value of this statistics as well as the value associated to each variable is always around 1 confirming the multicollinarity problem is under control.

4.3. Predictions

An interesting extension of our analysis is to construct several predictions to determine the extent to which the trade-off between congestion's effects and level of education can affect the formation of bus users' attitudes and fuel their propensity to become frequent users. In practical terms, we can produce a few predictions about the possibility of switching from being a sporadic to a regular bus user, particularly because of reductions in congestion. To perform such predictions, we considered selected examples of user profiles (i.e., highly educated and less educated individuals, immigrants, and commuters) and assumed that the effect of congestion would drop by 10 % (i.e., from 11.78 to 10.60 min/km).[24] Predictions are presented in Table 8. On average, the reduction in congestion increases the probability of becoming a frequent bus user by 30 % in the case of mixed rides and by nearly 40 % in the case of urban rides.

Again, congestion emerges as a true deterrent for the use of a public transportation system—in our case, bus services—for urban rides, as previously detected and discussed by Nguyen-Phuoc et al. (2018) in the case of Melbourne. Those predictions also confirm the results obtained earlier: immigrants are not sensitive to congestion's effects, whereas commuters are the most reactive to changes in the level of congestion, particularly for urban rides.

5. Discussion

Overall, our empirical exercise indicates that (i) congestion is a true deterrent for becoming a frequent user of bus services; (ii) the drawback's effects are more relevant for educated people as these individuals are likely to be identified as having more pro-environmental attitudes; and (iii) congestion's effects have a stronger impact on urban rides than mixed ones. These results entail a few considerations in terms of policies that local authorities can implement. First, because congestion is a key factor in becoming a frequent user of public transportation systems, initiatives targeting the reduction of congestion and its effects and, in turn, reducing travel times for urban rides are, above all, likely to be the most effective strategy for promoting such means of transportation. The duration of the ride is the crucial feature that could bear weight in motivating educated people to become frequent bus users, especially because the implicit costs of congestion are expected to shrink. As discussed by Allen et al. (2019), good initiatives in that respect could be to increase the frequency of urban rides and, beyond that, the efficiency of the new public bus network. In that regard, a solution to the open question could be linked to the effectiveness of a transfer-based network that is able to combine different types of public means of transport. However, the available evidence is less conclusive about this last point. For instance, referring to Delhi (India), Suman and Bolia (2019) concluded that limiting intermediate transfers can be an effective way to leverage the use of the public bus system.

Last, because of the lack of evidence on whether income has a clear, statistically significant impact on the probability of becoming a regular bus user, a pricing policy for bus services may need to be reconsidered for various directions. The increasing adoption of digital transport cards allows local transport administrations to enact policies that tailor prices in tap-on, tap-off ticketing systems according to the ride's effective distance, not according to zoning. The former type of pricing can likely attract a larger group of low-income users while making no difference for higher-income households one way or the other. Another type of pricing policy that could be effective in Barcelona is one linked to the speed of the transport service (e.g., direct rides versus rides with several stops), which can further consider congestion's effects and offer a ticketing scheme that is able to provide better service to overcome potential congestion by providing advantages for direct rides, for instance, albeit at a higher price.

Table 8
Predictions.

10 % Type of user	**Mixed rides** (urban and extra-urban line)	**Urban rides**
Person with university degree	33.7 %	36.7 %
Person with primary education	9.9 %	12.3 %
Immigrant with university degree	28.4 %	31.5 %
Immigrant with primary education	4.6 %	6.8 %
Commuter (any reason) with university degree	34.9 %	37.3 %
Commuter (any reason) with primary education	10.9 %	12.8 %

6. Conclusions

Our findings emphasize the relevance of selected individual (i.e., education and occupation) and contingent (i.e., traffic congestion) characteristics in driving individuals' decisions to become frequent bus users. Traffic congestion was found to diminish the probability of becoming a frequent bus user, and its impact was persistent across all estimated empirical models. Educated individuals, young individuals (i.e., students), and older people (i.e., retirees) are more prone to becoming frequent bus users given their environmental concerns. By contrast, the level of individual income was not statistically significant, a possibility that had remained inconclusive in recent debates.

The results of our estimation constitute valuable input for forecasting how the reaction of different groups of citizens to changes in traffic congestion affect their probability of becoming frequent bus users. Commuters and educated people emerged as the users most reactive to changes in the level of congestion, particularly for urban rides. That outcome can be read as a consequence of the need to combine several activities per day, because commuters are interested in exploiting the accessibility of bus services, unlike other means of public transport, but need the services to be reliable. Educated persons are also highly sensitive to the reliability of bus services, albeit for other reasons. Although we have previously discussed that group's potential environmental concerns, it is worth noting that the bus fleet in Barcelona uses mostly green energy, though the effect of congestion may make the services less reliable than expected.

An important result of our empirical exercise is the lack of evidence regarding any statistically significant impact of income on one's likelihood of becoming a frequent bus user when identifying it directly as an exogenous variable. Although we lack tools to better explore the reasons behind that result, a reading of the result needs to be performed that refers to the general mobility planning of an entire city and including other means of transportation. The result could indicate that the propensity of becoming a frequent user of the bus transportation system in Barcelona, irrespective of level of income, may be a natural outcome due to the lack of proper infrastructure for private transportation (e.g., cars) given the scarcity of parking areas for cars or the high fares for parking in Barcelona.

We would like to be more conclusive about the extent to which our quantitative results are robust and allow the extension of our analysis by including the possibility of accounting for potential synergies between public bus transportation and transportation via the subway or train.

[24] Because our predictions relied on linear probability model estimations, predictions were proportional to changes in the covariate. Therefore, alternative reductions in congestion did not effect change because the linearity preserved the proportionality. We used the case of 10% because it represents a realistic, feasible situation.

Unfortunately, in our survey, we did not collect sufficient data for a robust empirical analysis of the interaction of those modalities and the extent to which certain combinations of different modes of public transportation can improve individuals' attitudes to the point that they become frequent bus users. Those additional options for transportation could generate some nonlinearities in the likelihood of becoming such a user and accelerate the probability of a shift in status once the duration of each ride achieves a certain threshold.

Another important limitation of our analysis was the unavailability of data about the potential delays for bus trips (i.e., urban and mixed urban–extra-urban rides). Thus, we cannot be more conclusive about the potential global benefits, at least at an urban level, that the massive use of public bus transit could generate in terms of reducing congestion and, in turn, pushing citizens to switch from private to public means of transportation. In other words, we could not control for the impact of externalities stemming from the behavior of other users that could influence individuals' choice to become regular bus riders. However, doing so could provide relevant information and should be considered in future research.

CRediT authorship contribution statement

Miquel-Àngel Garcia–López: Conceptualization, Methodology, Formal analysis, Writing. **Rosella Nicolini:** Conceptualization, Methodology, Formal analysis, Writing. **José Luis Roig Sabaté:** Conceptualization, Methodology, Formal analysis, Writing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Structure of the survey

1)	**Gender**	1: Female
		2: Male
2)	**Age**	1: <15 y
		2: Between 15 and 25
		3: Between 26 and 40
		4: Between 41 and 65
		5: >65
3)	**Place of birth**	1: Barcelona
		2: Rest Catalunya
		3: Rest Spain
		4: Rest Europe
		5: Asia
		6: Africa
		7: North America
		8: Central and South America
		9: Oceania
4)	**If you were not born in Barcelona, in which year did you arrive?**	"YEAR"
5)	**Zip Code of your place of residence?**	"CODE"
6)	**Level of education (completed)**	1: Less than primary or illiterate
		2: Primary
		3: Secondary
		4: Higher
7)	**Occupation**	1: Employed
		2: Student
		3: Retired
		4: Unemployed
		5: Other
8)	**Level of income (2016)**	1: < 10,000 €
		2: Between 10,000–20,000€
		3: Between 20,000–30,000€
		4: >30,000€

(*continued on next page*)

(*continued*)

9)	**Suffering from physical disease?**	1: Yes 2: No
10)	**Do you commute daily in BCN for:**	1: Work 2: Study 3: Personal reasons 4: NO
11)	**Provide zip code of your destination at question 10.**	"CODE"
12)	**Average travel time to reach the destination at 11?**	"MINUTES"
13)	**Which means of transport do you use to travel to destination at 11?**	1:Only BUS 2: Only metro 3: Only train 4: Only car 5: Only bike 6: Only motorbike 7: Only walking 8: Bus + metro 9: Bus + car 10: Bus + bike 11: Bus + walking 12: Other
14)	**If you do not use the city bus service for the destination at 11, what do you use the city bus service for other reasons?**	1: NO 2: For work related reasons 3: To go to school/university 4: For personal/family matters 5: For leisure 6: For other reasons
15)	**If you answered affirmatively to Question 14, then do you take the bus regularly or irregularly?**	1: Irregularly (<3 times/week) 2: Regularly (>3 times/week) 0: no answer
16)	**Which bus line do you most often take?**	"Number"
17)	**Dummy variable**	1: at question 16 the responder indicates more than one line 0: at question 16 the responder indicates ONLY one line
18)	**If you replied that you take the bus regularly in Question 15, then are you satisfied with the quality of the bus service in Barcelona?**	1: Yes because of easy access and number of stops 2: Yes because it is overall convenient 3: Yes because it is fast 4: Yes because it is convenient for transfers to other public transport services 5: Yes because of other reasons 6: No because there are no stops near my preferred destinations 7: No because it is slow 8: No because buses do not arrive often enough 9: No because of lack of transfers to other means of transport 10: No because daily timetable is limited 11: No because of other reasons
19)	**Drawing upon your personal experience, what would be a valuable improvement to the city bus service in Barcelona?**	1: Additional and new bus lines (new connections) 2: Faster buses to reduce the length of the trip 3: More daily trip scheduled for each trip (to reduce the occupancy rate) 4: More convenient transfers with other means of transport 5: New buses (better material, better internal space organization, better keeping, reducing obstacles for aged users) 6: Nothing 7: To better the bus frequency during peak hours, weekends, August 8: Improve driver's way of driving and, in general, they behavior vs passengers 9: Reduce the price of the service; implement more precise price differentiation for type of destination and type of client 10: Too many changes in the line network 11: Too many changes in bus stops; number of bus stops below the expected number; better bus information at bus stops; bettering th structure of the bus stops for passengers standing in line 12: Be more environmental friendly 13: Be pet friendly (dogs) 14: be on time; reduce delays; more service during strikes
20)	**How do you perceive the quality of the bus service in Barcelona?**	1: Very bad 2: Bad 3: Average 4: Good 5: Very good
21)	**Other comments**	1: Solve accessibility problems, bus occupation; space organization in buses; modern vehicles; more information; easy access to information

(*continued on next page*)

(*continued*)

	2: Adjust prices and tariff to the different group of users; no paper transport card; be available other no-cash types of payment on buses
	3: Improving the abilities of bus drivers
	5: Improve numbers of daily trips per bus lines; more frequency; more speed; solve time-schedule problems for lines V21 and 92; improve the service during weekends and August
	6: Be more pet friendly
	7: Respondent very satisfied/satisfied with the bus services, the TMB engagement for transport quality in Barcelona; Praise the introduction D20 line; acknowledge this survey
	8: New orthogonal model is not adequate. Claims for the elimination of lines 57, 64, 20 (SERVERAL), 91, 16, 24, 40, 10 and changes in 92. Improve the number of "bus de barrio"
	9: Praise the introduction of H lines; Claims or praise the introduction of V lines (missing in Nou Barris)
	10: Metro service is definitely better than bus service

Appendix B

Theoretical setting

On the topic of public transportation, the literature, perhaps best reviewed by Duranton and Puga (2015), showcases patterns in households' choices of location. In the United States, the wealthy are more prone to reside in single-family dwellings often located in the urban periphery, also referred to as the suburbs, and to use their relatively higher incomes to cover the costs of commuting.

We sketch a simple theoretical framework in which we approximate individual utilities and individual budget constraints to produce a few insights into the role played by selected variables in minimizing (direct and indirect) commuting costs in order to formulate the hypotheses to be tested in the empirical analysis. In line with Redding and Turner (2015), the general setting comprises a number of locations, i, belonging to a spatial unit, N.[25] Each location, i, is populated by a continuum mass one of group of representative consumer–worker who are free to move across the locations i in N. The consumer–workers are all endowed with an identical unit of time to devote to labor (supplied inelastically) and to their commute. For each unit of labor for consumer–workers residing in i, only a share θ_I (with $0 < \theta_i < 1$) is devoted to productive activities that involves earning a wage, w, such that their income turns out to be $w\theta_i$, and the remaining fraction of available time $(1 - \theta_i)$ is devoted to moving across locations. Consumer–workers are required to move for several reasons: to travel to their workplaces (i.e., in any i within N), to obtain nontradable amenities (A_i)—such as housing—or to purchase goods to be consumed in i (C_i). The costs of commuting (CT_i) can, therefore, be quantified by the following expression:

$$CT_i = \tau f(d_i; 1-\theta_i) \quad f'(\cdot) > 0; f''(\cdot) < 0 \tag{B1}$$

which is the product of transport costs, τ, and a function combining the distance commuted from i (d_i) and time devoted to commuting $(1 - \theta_i)$ for an individual in i. Thus, the function embeds the cost of congestion as part of the cost of commuting; what matters is not only the distance between two locations but also the time needed to make the trip.

The utility function of consumers is modeled as a Cobb–Douglas function with constant returns to scale representing the consumption of a composite good, C_i, and another good, A_i, as an amenity:

$$U_i = C_i^{\mu} A_i^{(1-\mu)} \quad 0 < \mu < 1 \tag{B2}$$

The composite good, C_i, is defined according to the canonical definition in the literature as an index of the consumption of tradable goods with a constant elasticity of substitution. Along those lines, the price of the composite good C_i is defined by a price index, P_i.[26] The amenities, A_i, are associated with another price, r_i. The budget constraint of the representative consumer–workers used is defined in Equation (B.3):

$$w\theta_i = P_i C_i + r_i A_i + \tau f(d_i; 1-\theta_i) \tag{B3}$$

The maximization of Eq. (B2) under the constraint of Equation (B.3), taking previous definitions into consideration, yields the result that consumers spend a consistent share of their income, μ, on the composite good, C_i, and a share $(1 - \mu)$ on the amenities, A_i, such that the total amount of purchased goods is

$$C_i = \frac{\mu[w\theta_i - \tau f(d_i; 1-\theta_i)]}{P_i} \tag{B4}$$

$$A_i = \frac{(1-\mu)[w\theta_i - \tau f(d_i; 1-\theta_i)]}{r_i}. \tag{B5}$$

Appendix C

Representativeness of the sample

We are interested in assessing whether the data provide a representative picture of the bus line network currently active in Barcelona. To that end, we center our attention on the most preferred bus lines as declared by citizens when completing the survey. We map those results and compare them with the official information provided by TMB. The maps in Fig. 1C and 2C compare the official bus line network coverage in Barcelona (Fig. 1C) to the

[25] In our exercise, the index i indicates a zip code in Barcelona, whereas Barcelona is the spatial unit N.

[26] For simplicity's sake, we do not provide more information about the composite tradable good, C_i, and the correspondent price index, P_i, because they are irrelevant in our analysis.

information retrieved from our survey (Fig. 2C), respectively, thereby indicating the geographic representativeness of the sample. The thickness of the lines (in both illustrations) represents the relative concentration of the number of bus lines covering a specific route of the TMB bus network. Keeping that criterion in mind, Fig. 1C replicates the official information released by TMB referring to their own bus network in 2017, whereas the information presented in Fig. 2C was created by aggregating the information provided by the replies to our survey.

Source: official documents

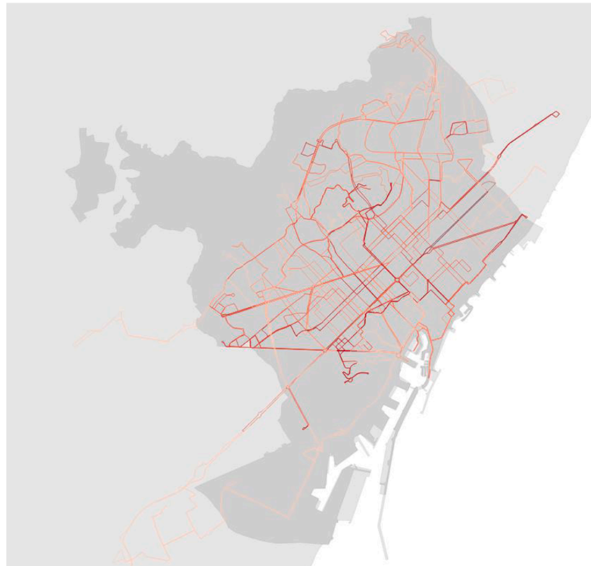
Fig. 1C. Barcelona bus line network (2017). Source: official documents.

Source: own elaboration

Fig. 2C. Representativeness of our survey (2017). Source: own elaboration.

Overall, the responses to our survey enable us to map the greatest majority of the lines belonging to Barcelona's public bus service, including all bus lines in the city center. However, we overlook some peripheral lines and local bus lines active inside selected neighborhoods in the urban periphery.[27] Our data on the use of bus lines also provide information suitable for mapping the preferred directions of bus trips, with results depicted in Fig. 3. The most intensive use of the bus lines is for crossing the city and moving along the coastline. The use of the bus service in neighborhood-based lines in two peripheral neighborhoods, Horta and Sant Andreu, is also intensive.

[27] To be precise, we are referring to the districts of Sarrià-Sant Gervasi and Vallvidrera, including the Tibidabo area, in the west-southwest part of the city. Refer to map in Appendix F.



Legend: Dark (light) red lines are the more (less) intensively used bus routes.
Source: own elaboration from information retrieved from the survey.

Fig. 3C. Concentration of bus routes (2017). Legend: Dark (light) red lines are the more (less) intensively used bus routes. Source: own elaboration from information retrieved from the survey.

A second exercise is designed to test the representativeness of the survey by comparing selected statistics obtained from our survey data with other official statistics. To do so, we compare the results from our survey with statistics taken from the Statistical Yearbook of Barcelona (2017).

We also performed an analysis about the missing value pattern of our sample first, overall, and then by discriminating by gender, group of citizens and time. Tables from 1.C to 6.C present those statistics. Those tables are built by, first, expressing the percentage of full complete replies to the survey and, then, it follows the combination of missing values for selected variables (listed below the table).

Table 1C
Missing value pattern: all sample.

Percent	Pattern												
	1	2	3	4	5	6	7	8	9	10	11	12	13
74 %	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	1	1	1	1	1	1	1	0	0	0	0
2	1	1	1	1	1	1	1	1	1	1	0	1	1
<1	1	1	1	1	1	1	1	1	0	1	1	1	1
<1	1	1	1	1	1	1	1	1	1	1	0	1	0
<1	1	1	1	1	1	1	1	1	1	1	1	0	1
<1	1	1	1	1	1	1	1	1	1	1	0	0	0
100 %													

Variables are (1) Regular bus user (2) Immigration (3) Age (4) Daily commuter (5) Education (6) Income (7) Occupation (8) Time (9) Physical disease (10) Gender, (11) Congestion (12) Improvement (13) Quality of the service.

Table 2C
Missing value pattern by gender.

Percent	Female				Male			
	1	2	3	4		2	3	4
83 %	1	1	1	1	**72** %	1	1	1
8	1	1	0	0	**17**	1	0	0
6	1	1	1	0	**7**	1	1	0
2	1	0	1	1	**2**	0	1	1
<1	0	1	1	1	**<1**	0	1	0
<1	1	1	0	1	**<1**	0	0	0
					<1	1	0	1
100 %					**100** %			

Variables are (1) Physical disease (2) Congestion (3) Improvement (4) Quality of the service.

Table 3C
Missing value pattern by gender and time: Female.

Percent	October			December			
	1	2		1	2	3	4
77 %	1	1	**88 %**	1	1	1	1
17	0	0	**6**	1	0	1	0
5	1	0	**2**	0	1	0	1
1	0	1	**2**	1	0	1	0
			2	1	1	1	1
100 %		**100 %**					

Variables are (1) Improvement (2) Quality of the service (3) Congestion (2) Physical disease.

Table 4C
Missing value pattern by gender and time: Male

Percent	October			December			
	1	2	3		1	2	3
61 %	1	1	1	**85** %	1	1	1
27	1	0	0	**6**	1	0	0
10	1	1	0	**6**	1	1	0
1	0	0	0	**2**	0	1	1
				<1	0	1	0
100 %				**100** %			

Variables are (1) Congestion (2) Improvement (3) Quality of the service.

Table 5C
Missing value pattern by demography: Young (15–25 years old).

Percent	October		December			
	2	3		1	2	3
83 %	1	1	**75** %	1	1	1
17	1	0	**9**	1	0	0
			9	1	1	0
			6	0	1	1
100 %			**100** %			

Variables are (1) Physical disease (2) Improvement (3) Quality of the service.

Table 6C
Missing value pattern by demography: Elderly persons (>65 years old).

Percent	October		December		
	1	2		2	3
76 %	1	1	**90 %**	1	1
17	0	0	**8**	1	0
7	1	0	**2**	0	1
100 %			**100** %		

Variables are (1) Improvement (2) Quality of the service (3) Congestion

Overall, most of the missing values concern the variables embedding the personal opinions about the own satisfaction of the bus service or the quality of the service. The quality of the replies to the survey improved from the beginning of the surveying period (October) to the end (December). Women are usually providing more complete answers than men (both improving the quality of their replies over time). Focusing on the young and elder persons that participated to the survey, the elder citizens are really committed in providing complete answers and they improved a lot whereas young persons worsened the quality of their reply over time by improving the number of missing values.

Appendix D

Some statistics and preliminary analysis

The first set of statistical correlations, with results displayed in Table 1D, emphasizes the relationship between individual socioeconomic characteristics and attitudes toward public bus service. Regarding level of *education*, a highly positive, significant correlation emerged between it, the probability of being a *regular bus user*, and the quality of the service provided, the estimated coefficient of which is negative (although relatively small) with respect to the degree of satisfaction. The level of *income* is positively associated with the appraised quality of service (as in Deb et al., 2022). Table 1D stresses a negative (even if statistically weak) correlation between congestion and being a regular bus rider, even if the riders are generally satisfied with the quality of the service regardless of the congested conditions they experience during their trips. This association could imply that the public bus service is consistently a somewhat reliable public transport service.

Table 1D
Correlation between selected features of user profiles and bus service opinion (2017).

	Education	Income	Occupation	Physical disease	Cong
Regular bus user	0.169***	0.039	−0.133***	0.090**	−0.072*
Quality of the service	0.126***	0.079**	−0.005	0.253***	0.064*
Degree of satisfaction	−0.089**	−0.029	−0.011	0.048	−0.004

Statistical significance: *** 1 %, ** 5 %, * 10 %.

Table 2D elucidates for the same type of exercise, but this time it is in regard to the personal characteristics of users. Elder persons, as well as immigrants, are among those most satisfied with the quality of the bus service.

Table 2D
Correlation between personal features and bus service opinion (2017).

	Gender	Age	Immigrants
Regular bus user	0.047	−0.016	−0.007
Quality of the service	0.018	0.211***	0.155***
Degree of satisfaction	−0.018*	0.015	0.033

Statistical significance: *** 1 %, ** 5 %, * 10 %.

Next, we applied our data in a statistical exercise to approximate a model to clarify preference formation among bus users. We selected three dependent variables: *regular bus users* (i.e., dichotomous variable), the degree of appraisal of the bus service in terms of their *degree of satisfaction* (i.e., discrete choice variable), and *quality of the bus services* (i.e., discrete choice variable). Because we are using dichotomous dependent variables, the most suitable approach that aligns with our scope is a linear probability model, an econometric approach that allows discrete choice analysis without defining any functional form a priori. At the same time, because we are using discrete dependent variables (i.e., count variables), we applied a maximum likelihood estimation method with a Poisson function since our observations exhibit a limited dispersion estimated coefficient and could be interpreted as semi-elasticities.[28]

The total number of survey respondents was 757 citizens, but not all of them replied precisely to all questions. This lack of information reduced the available sample for the empirical analysis in a range between 583 and 600 persons according to the selected variables included in the estimations. As stated, we did not have a precise model in mind for shaping the distribution of our observations; thus, we continued referring to linear probability for our method of estimation. An extended discussion on the argument underpinning that decision appears in Appendix E. The choice of this empirical strategy entails an additional assumption referring to count variables (income, education, and occupation). In particular, introducing count variables in a linear probability model entails that we are expecting a constant impact on the dependent variable when passing from one category to another in each count variable. An alternative solution to overcome this potential limitation would be to transform each count variable in a dichotomous variable by defining an aggregation rule to reduce four or five categories to two. In Appendix G, we produce this exercise, and it is easily recognized that the results are confirmed. In the main text, we are giving preferences to the exploitation of count variables (rather than dichotomous variables) because this prevents us from making our estimation rely on additional hypotheses in terms of aggregation of the categories of the different count variables.

We propose a joint reading of the estimation results for the three variables that turn out to be more closely associated with riders' opinions about the quality of the bus service, which are compiled in Table 3D.[29]

Table 3D
Estimations.

(*continued on next page*)

[28] In all estimations, errors were treated as robust.
[29] The meaning and structure of the variables are included in Table 4 and in Appendix A.

Table 3D (*continued*)

	Satisfaction				Regular bus users		Quality Bus Service	
	1	2	3	4	5	6	7	8
Constant	0.741*** (0.193)	0.780 (0.197)	0.919*** (0.185)	0.949*** (0.191)	-0.210 (0.205)	-0.124 (0.212)	1.119*** (0.075)	1.212*** (0.081)
Gender	-0.081** (0.037)	-0.077** (0.038)	-0.048 (0.0365)	-0.041 (0.037)	-0.002 (0.039)	-0.002 (0.040)	-0.04*** (0.013)	-0.041*** (0.013)
Age	-0.014 (0.022)	-0.010 (0.022)	-0.025 (0.022)	-0.018 (0.022)	-0.032 (0.026)	-0.031 (0.026)	-0.004 (0.009)	-0.006 (0.01)
Immigration	0.017 (0.039)	0.025 (0.04)	0.001 (0.038)	0.007 (0.038)	-0.057 (0.039)	-0.049 (0.040)	0.043*** (0.014)	0.042*** (0.014)
Education	-0.055** (0.024)	-0.056** (0.026)	-0.039 (0.024)	-0.039 (0.026)	0.079*** (0.025)	0.074*** (0.027)	-0.015* (0.008)	-0.016* (0.009)
Occupation	0.016 (0.017)	0.020 (0.018)	0.013 (0.017)	0.018 (0.017)	0.058*** (0.019)	0.063*** (0.019)	0.001 (0.006)	0.001 (0.005)
Income	0.0001 (0.019)	0.006 (0.019)	0.001 (0.019)	0.005 (0.019)	0.006 (0.020)	0.009 (0.021)	0.018*** (0.007)	0.018*** (0.007)
Physical diseases	0.116* (0.07)	0.081 (0.071)	0.134** (0.065)	0.099 (0.067)	0.048 (0.061)	0.019 (0.063)	0.048* (0.025)	0.044 (0.026)
Congestion		-0.001 (0.001)		-0.001 (0.001)		-0.001 (0.001)		-0.000 (0.0004)
Degree of satisfaction					0.039 (0.044)	0.024 (0.045)	0.215*** (0.018)	0.216*** (0.018)
Bus Regularly			0.035 (0.040)	0.021 (0.041)				
Improvement quality bus service			-0.311*** (0.031)	-0.304*** (0.031)	0.214*** (0.043)	0.206*** (0.044)	- 0.101*** (0.015)	-0.099*** (0.015)
Mean VIF	*1.25*	*1.26*	*1.22*	*1.24*	*1.23*	*1.24*	*1.23*	*1.24*
Adj-R-squared	*0.011*	*0.008*	*0.078*	*0.064*	*0.064*	*0.064*	*0.056*	*0.056*
Log-Likelihood	-370.337	-360.87	-347.81	-339.98	-375.68	-367.31	-990.59	-965.78
BIC	-3046.31	-2948.30	-3063.82	-2962.65	-3008.072	-2907.99	-1778.24	1711.04
Observations	600	585	598	583	598	583	598	583
Estimations	Linear Probability				Linear Probability		Poisson	
Errors	Robust				Robust		Robust	

Level of significance: *** 1 %, ** 5 %, * 10 %. Standard errors are shown in brackets.

Appendix E

Econometric strategy: Linear Probability Models (LPM)

The linear probability model (LPM) is a multiple linear regression with a binary dependent variable (y) and a response probability that is linear in parameter β_k, as in the following equation:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \mu \tag{E1}$$

For that equation,

$$E(y|x_1, x_2, ..x_k) = P(y = 1|x_1, x_2, ..x_k) \tag{E2}$$

in which

$$P(y = 1|x_1, x_2, ..x_k) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k \tag{E3}$$

Under that specification, β_k can be interpreted as the change in the probability of $y = 1$ when x_k changes and while keeping all other $k-1$ regressors constant. Given that structure, the R^2 (or Aj – R^2) cannot be considered as a measure of goodness of fit. Instead, it needs to be replaced by other more general indicators—for instance, Akaike's information criterion (AIC) or the Bayesian information criterion (BIC)—that assess the overall fit of the model to identify the model that is most likely to have generated the observed data and allowed for a comparison of nested and non-nested models. The model with the smaller BIC or AIC should be preferred.

The LPM is quite a controversial model in the group of the discrete choice models. Its primary advantage is the possibility of performing econometric analysis whenever the underlying model is unknown or, put differently, without imposing a structure upon the data as with logit and probit models. It is often considered to be a starting point for making the proper adjustments to accommodate the nonlinearity of the predictors. In particular, the model can accommodate situations in which covariates such as x_k are not continuous but instead categorical, as in our study, and allow the linear direct interpretation of the estimation results (Angrist, 2001; Angrist and Pischke, 2008). A few critiques warn against the use of that framework for analysis, however. The two most important ones refer to the heteroskedasticity of the errors and to the fact that the predicted probability can be spread up to more than 1 or below 0. The former problem can be controlled by correcting the structure of the errors in the estimations. In that respect, in our estimation we clustered errors and, in that way, controlled for heteroskedasticity.

To control for the latter problem, however, we checked for the modeled probabilities (i.e., fitted values), and for our sample, the values were in the range of 0.0 and 0.8. Furthermore, according to von Hippel (2017), following Long (1997), as a rule of thumb the LPM can be used whenever the relationship between the values and log odds is nearly linear and within the range of predicted probability.

In our analysis, we performed that test by referring to Model 4 in Table 6 as one of the specifications with the better fit when using the overall sample. Fig. B1 confirms the linearity and, hence, the validity of our choice.

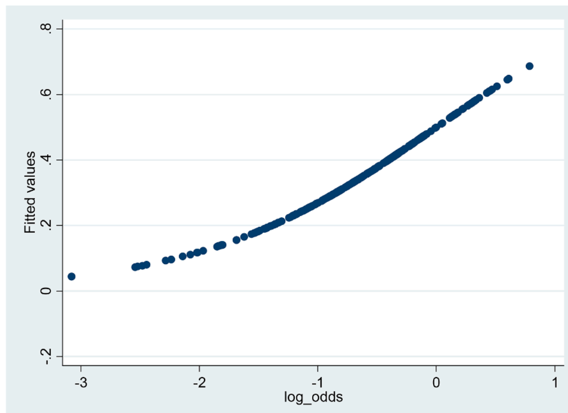
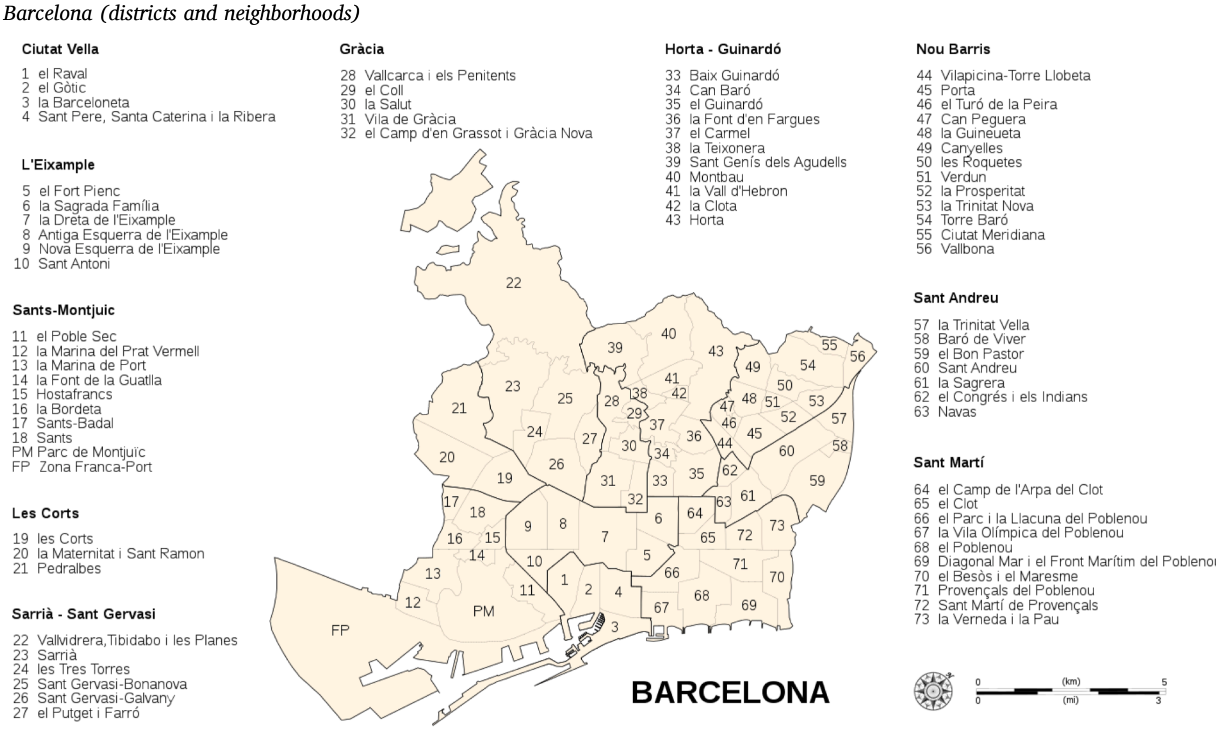


Fig. B1. Relationship between fitted probability values and log odds in Model 4 (see Table 8).

Appendix F

Map of Barcelona (districts and neighborhoods)



Source: Sémhur (2008); Free Art Licence; CC-BY-SA-3.0. Data: Ajuntament de Barcelona

Fig. 1F. Source: Sémhur (2008); Free Art Licence; CC-BY-SA-3.0. Data: Ajuntament de Barcelona.

Appendix G

Robustness checks

Estimation results in Table 6 and 7 could be potentially biased because we are applying a linear probability model to some regressors that are count variables (with more than two categories). From an intuitive perspective, the inclusion of count variable in a linear probability framework involves that we are assigning the same probability to move from one category to another. In order to overcome this possible limitation, we replace the variable *Education* by *D_Education*, and *Occupation* by *D_Occupation* whose descriptive statistics are:

Estimations results for the same specification in Table 6 and 7 but including dummy variables instead of count variables are:

Table 1G
Descriptive statistics.

Variable	Observations	Mean	Std. Dev.	Min	Max
D_Education	542	0.834	0.372	0	1
Dummy variable:					
1: High-level education (Secondary and higher)					
0: Otherwise					
D_Occupation	542	0.878	0.327	0	1
Dummy variable:					
1: Yes (Employed, Retired and Students)					
0: Otherwise					

Table 2G
Estimations: Mixed (urban and extra-urban) bus rides.[a] Dependent Variable: *Bus regularly* Method of estimation: *Linear probability* Errors: *Clustered by zip code place of residence.*

	(1)	(2)	(3)
Constant	0.228***	0.243***	0.067
	(0.087)	(0.066)	(0.085)
Congestion	−0.002**	−0.002**	−0.002**
	(0.001)	(0.001)	(0.001)
D_Education	0.163***	0.16***	0.164***
	(0.052)	(0.051)	(0.052)
D_Occupation	0.205***	0.214***	0.203**
	(0.064)	(0.077)	(0.079)
Gender		0.017	
		(0.042)	
Immigrant		−0.061	
		(0.041)	
Daily commuter			0.17**
			(0.07)
AIC criterion	1.339	1.342	1.336
BIC	−2663.14	−2652.93	−2660.47
Observations	541	541	541
Clusters	*114*	*114*	*114*

Level of significance: *** 1 %, ** 5 %, *10 %. Standard errors are shown in brackets.
[a]As in Table 3D, the estimated coefficient for variable physical disabilities is not statistically significant when included. To the same extent, age and use of the bus service in combination with others means of transport are not statistically significant either. We omitted reporting these estimation results, but they are available upon request.

Table 3G
Estimations: urban bus rides. Dependent Variable: *Bus regularly* Method of estimation: *Linear probability* Errors: *Clustered by zip code place of residence.*

	(1)	(2)	(3)
Constant	0.221***	0.262***	0.099
	(0.057)	(0.068)	(0.133)
Congestion	−0.002**	−0.002**	−0.002**
	(0.001)	(0.001)	(0.001)
D_Education	0.190***	0.189***	0.189***
	(0.052)	(0.05)	(0.051)
D_Occupation	0.202**	0.213**	0.202**
	(0.084)	(0.082)	(0.084)
Gender		−0.003	
		(0.050)	
Immigrant		−0.096**	
		(0.040)	
Daily commuter			0.126
			(0.098)
AIC criterion	1.339	1.337	1.342

(*continued on next page*)

Table 3G (*continued*)

	(1)	(2)	(3)
BIC	−2188.103	−2180.56	−2183.17
Observations	460	460	460
Clusters	*62*	*62*	*62*

Level of significance: *** 1 % **, 5 %, *10 %. Standard errors are shown in brackets.

The results of the robustness checks confirm the conclusions addressed in the main text.

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