Suburban Passenger Trains as an Alternative to Car Use in Spain's Major City Suburbs: An Analysis of Commuting

Los trenes suburbanos de pasajeros como alternativa al uso del automóvil en los suburbios de las principales ciudades de España: un análisis de los viajes al trabajo

Fernando Calonge Reillo

Key words

Suburbs
- Car Use
- Train Use
- Daily Commute

Abstract

Given the rising global temperatures, discouraging the use of private cars for daily commutes has become a necessity. This study examines the potential for rail transport as a viable alternative to automobile use for this type of travel in Spain. It relies on data from the Spanish National Statistics Institute's Household Survey. The findings reveal a concurrent increase in both rail and car use in suburban settings, highlighting the significance of contextual factors, especially the lack of car ownership and rail infrastructure extension. While sociodemographic factors appear to be less influential, the study underscores the disproportionate reliance on suburban rail services amongst younger individuals, women, immigrants, and those from lower socioeconomic backgrounds.

Palabras clave

Suburbios
- Uso del automóvil
- Uso del tren
- Viajes al trabajo

Resumen

Ante el incremento de las temperaturas globales, es necesario disminuir el uso del automóvil para los viajes cotidianos. Este artículo investiga las posibilidades de que el tren se constituya como una alternativa al automóvil en los suburbios españoles, y se apoya en la Encuesta de Características Esenciales de la Población y las Viviendas del Instituto Nacional de Estadística. El artículo descubre un notable incremento del uso del automóvil en los suburbios, pero también del tren. Los factores más determinantes para la selección del tren son los contextuales, como el no disponer de acceso al automóvil, y el incremento de la infraestructura ferroviaria. Sin embargo, ciertos factores que apuntan a situaciones de desventaja social, como ser joven, mujer, inmigrante y de menor nivel educativo también condicionan un mayor uso del tren.

Citation

Fernando Calonge Reillo: Universidad Rey Juan Carlos | fernando.calonge@urjc.es

INTRODUCTION

The year 2023 was the warmest on record. According to information from the National Aeronautics and Space Administration (NASA, 2024) in 2023, the Earth's temperature was 1.36 °C higher than the average temperature recorded between 1850 and 1900. The link between fossil fuel consumption, CO_2 emissions and global warming has been recognized at an international level (Intergovernmental Panel on Climate Change, 2023). Much of this high fossil fuel consumption is in response to transportation requirements, especially in suburban and highly dispersed population settings. It has been found that dispersed growth discourages the use of public transport and increases the dependence on cars, which are the main generators of CO_2 emissions. Therefore, research has revealed that total emissions increase significantly in urban areas having population densities of less than 1650 inhabitants per square kilometer, and in which public transport use accounts for less than 15 % of all travel (Gately, Hutyra and Wing, 2015).

In the suburbs, however, train use may offset the increase in travel distances (Cervero and Day, 2008), since it can compete effectively with cars, achieving similar operating speeds, approximately 35-40 km/h (Newman, 2009). Furthermore, suburban trains may become an alternative form of transport to the car when combined with densification and land use policies in these areas (Manaugh and El-Geneidy, 2010).

This article analyzes the conditions for using the train instead of the car to go to work, such that the train may be considered a viable alternative in suburban contexts. Thus, the main objective of this article focuses on determining the factors that influence greater use of the train as compared to the car for commuting to work. It also attempts to establish which of these factors are more decisive in the large Spanish city suburban context, something that has yet to be adequately addressed.

To achieve this objective, data from the Survey of Essential Characteristics of the Population and Housing of the National Institute of Statistics (Spain) were analyzed. This survey included information on travel behavior and other relevant variables such as income and education levels, employment status, and household characteristics. Descriptive statistics were used to determine modal share in suburban municipalities of cities, while logistic regressions were used to identify factors that increased the likelihood of selecting the train over the car.

THEORETICAL FRAMEWORK

There is a wide range of passenger train services. The International Association of Public Transport is one of the most widely accepted classifications of these services. It includes the metro, light rail and other services, such as suburban passenger trains (International Association of Public Transport, 2024). Suburban passenger trains are railway services that regularly cover short distances between a central city and its suburbs. These services may be offered through certain fixed routes, and they permit multi-destination travel. They are operated by companies created specifically to respond to these purposes (American Public Transportation Association, 2023).

The emergence of the suburban phenomenon developed paradigmatically in American cities during the mid-20th century. It may be considered the growth of population and economic activities of a non-central nature, derived from urban expansion, and which incorporates

the constitution of a specific type of life (Ekers, Hamel and Keil, 2012). From a transport perspective, this phenomenon led to an increase in distances and travel times (Chang, Lin and Lindley, 2007; Cervero and Day, 2008; Delclos-Alió and Miralles-Guasch, 2017), which made the automobile the preferred means of transport thanks to its ability to flexibly bridge dispersed locations (Wachs, 2013). In these suburban contexts, only trains showed similar levels of efficiency thanks to their high operating speeds (Cervero and Day, 2008; Pan *et al*., 2017), which results in both means of transport being the only ones to gain passengers in this suburban context (Habib, 2014).

Now, in terms of sustainability, it is not incidental that suburban expansion is produced by greater use of private cars or suburban trains, given that the use of the latter means of transport, together with redensification and land use policies, manage to reduce CO_2 emissions into the atmosphere (Manaugh and El-Geneidy, 2010). This results in a clear need to conduct research focused on analyzing the possibilities of adopting trains as an alternative for daily mobility by suburban area residents.

Various studies have analyzed how suburban train use may serve as a viable alternative for daily travel. These contributions have typically highlighted two types of factors that motivate a greater use of trains compared to automobiles.

Firstly, we have examined how the urban context and the availability of means of transport influence the use of suburban passenger trains instead of cars. More compact suburban growth, with increasing urban densities (Narsi and Zhang, 2019; Shung *et al*., 2014), the reduction of distances to urban centers (Loo, Chen and Chan 2010), to residences (Brown *et al*., 2016; Liu, Yao and Li, 2018) or to workplaces (Cervero, 2006; Pan *et al*.,

2017) results in an increased likeliness of using suburban passenger trains. Likewise, improvements in urban accessibility (Pan *et al*., 2017) and the promotion of diversified land uses (Pinjari *et al*., 2011; Yan and Yang, 2023) favor a greater use of railway transport.

Similarly, many studies have shown that car ownership leads to the extensive use of this vehicle for most daily trips (Khan *et al*., 2016; Chen, Ge and Pan, 2021). This increased use is found to correspond to a decrease in the preference for passenger train use (Combs *et al*., 2016). However, some research has also suggested the opposite direction of this relationship, finding a positive relationship between higher levels of car accessibility and a greater use of passenger trains (Brown *et al*., 2014; Loo, Chen and Chan, 2010). At the same time, the literature has made it clear that greater investments in improving station connectivity (Cervero, 2006; Pan *et al*., 2017), the extension of railway infrastructure (Mohan, 2008; Gao *et al*., 2019), and improved operating speeds (Currie and Delbosc, 2013; Shung *et al*., 2014) all lead to increased train use.

Secondly, it has been shown that certain sociodemographic factors influence greater train use. It has been found that being female (Surprenant-Legault, Patterson and El-Geneidy, 2013), young (Nasri and Zhang, 2019; Yan and Yang, 2023; Senior, 2009) or a member of an ethnic minority (Tammaru, 2005; Brown *et al*., 2014) is associated with increased train use. However, certain inconsistencies appear in the analysis of economic factors, since some works have suggested that individuals from higher-income households are preferential train users (Senior, 2009), whereas others have indicated that these individuals tend to use automobiles (Luo, Xiong and Xiong, 2019). There appears to be considerable agreement that

having a higher educational level leads to greater train use (Nasri and Zhang, 2019; Obry-Legos and Boisjoly, 2024). Finally, it has been shown that nuclear families having children tend to use trains less and rely more on the automobile, given the greater flexibility that it provides when performing childcare tasks (Freudendal-Pedersen, 2009; Puhe and Schippl, 2015).

The varying weight of contextual or sociodemographic factors in explaining the preference for suburban passenger rail is not irrelevant. On the one hand, promoting optimal contextual conditions for rail travel depends mainly on public administrations, which are responsible for guiding urban and transport policies. On the other hand, it is understood that some of the sociodemographic determinants of greater railway use are simultaneously expressive of social situations of greater disadvantage and vulnerability, such as being female, young, having low educational and economic levels, or belonging to an ethnic minority. Paying attention to the prevalence of these factors may provide important indications as to which types of urban and transport development should be promoted, and how these actions condition policies for the social inclusion of the most disadvantaged populations.

This work aims to verify the different influence of both sets of factors on determining the use of suburban passenger trains versus cars, in the case of Spain, a country where such contributions are limited. To the best of our knowledge, this study is one of the first to address the conditions for passenger trains to serve as an alternative to automobiles in suburban Spanish areas.

In Spain, the expansion of suburban trains has improved the accessibility and use of public transport, especially in large cities (Alonso, Monzón and Cascajo, 2015). Little information is available in the literature on the modal share of railway systems, although it appears to be between 10 % and 20 % (Cascajo *et al.*, 2010). This is quite low as compared to the other European countries (Carpintero, Maraña and Barcham, 2010).

It is difficult to find studies based in Spain that analyze the contextual and sociodemographic determinants of commuter train use versus car use. More frequently, this type of research analyzes factors related to car use which may relate to the preference for train use.

Thus, regarding contextual factors, the importance of urbanization levels is highlighted, as compared to the expression of personal behaviors, in explaining the preference for automobile use (Módenes-Cabrerizo and Menacho-Montes, 2019). Similarly, Matas, Raymond and Roig (2009) warned that improvements in accessibility to workplaces or living in city centers suggests less car use. Some studies have analyzed the contextual conditions for the preference for public transport, but they do not include explicit details on train use. In this regard, lower urban densities are related to a larger decline in public transport passengers (Alonso, Monzón and Cascajo, 2015; Cascajo *et al.*, 2010; Oña *et al.*, 2010), and the peripheral location of the residences suggests a lower appreciation of public transport (Oña, Estévez and Oña, 2020; Oña, Estévez and Oña, 2021). At times, however, this location may not be a determinant factor in the selection of the type of transport used (Muñoz *et al.*, 2014). It has also been shown that the extension of the public transport network and the resulting reduction in the distance between stations leads to an improved perception and use by passengers (Oña and Oña, 2022; Marmolejo and Tornés, 2017; Cascajo *et al.*, 2010). Regarding car accessibility, no conclusive results are available. Some authors have found that access to and the

driving of cars results in a poorer evaluation and less frequent use of public transport (Oña, Estévez and Oña, 2020), although no coincidences have been found between motorization rates and the use of public transport (Cascajo *et al*., 2010).

The literature for the Spanish case has also analyzed the role of sociodemographic factors in explaining the selection of transport means. Thus, some agreement exists with regard to the suggestion that men are less likely to value public transport (Oña and Oña, 2022) and they use it less (Matas, Raymond and Roig, 2009). Some studies, however, have indicated that sex is not a good predictor of the use of public transport (Oña *et al*., 2021). Disagreements arise regarding the effect of income level on the choice of transport means in Spain. It has been suggested that high-income individuals prefer automobiles, given their convenience and comfort (Oña, Estévez and Oña, 2021). However, it has been noted that high incomes coincide with a greater ability to choose areas that are better connected by public transport, which could therefore become more widely used (Marmolejo and Tornés, 2017). Correspondingly, low-income residential areas are far from the public transport network, which would result in lower use (Pitarch Garrido, 2013). Finally, it has also been noted that immigrant populations are more dependent on public transport, in which they spend more time for travel (Casado-Díaz *et al*., 2022).

Given the various contributions found for the Spanish case, this article is one of the first to specify the conditions explaining the greater use of suburban passenger trains as opposed to cars in the contexts of the large Spanish cities. Likewise, and as previously revealed, we seek to determine the different influence of contextual factors and sociodemographic factors on the selection of the train as a means of daily transport. This would allow us to identify the possible role played by public institutions in establishing transport policies that promote this type of sustainable transport as a means for universal access to urban space.

CASE STUDY

Suburban passenger train services in Spain, known as the *Cercanías*, began operating in 1954 for recreational purposes, connecting the city of Madrid with the mountains to the north of the country's central mountain range (*Cordillera Central*) (Muñoz Rubio, 2016). During the 1970s, these services helped channel much of the urban development towards the outskirts of large cities, especially Madrid and Barcelona (Muñoz Rubio, 2016). However, the substantial change in the operation of these services occurred in the 1990s, when connections were expanded and reorganized to facilitate commuter travel in fifteen urban areas (Muñoz Rubio, 2016). This expansion led to a substantial rise in trips, increasing from 316 million to 442 million in 2023. As Muñoz Rubio stated (2016: 29), the development of the commuter rail network during the onset of the 21st century was instrumental in consolidating urban growth around the main Spanish cities.

Today (2024), the distribution of commuter train kilometers in the main Spanish cities is shown in Table 1.

These data on the extension of the commuter rail network have been incorporated into the database for this research. However, more detailed studies are needed to address the specific territorial deployment of this network across different municipalities in order to determine how its configuration may influence variations in the different levels of use.

TABLE 1. *Extension in kilometers of the local commuter train network* (Cercanías)

Conurbation	Kilometers
Madrid	391
Barcelona	462
Valencia	366
Bilbao	153
Seville	254
Zaragoza	17
Malaga	70
Palma de Mallorca	140
Murcia	220
Alicante	220
Asturias	369
Santander	86
San Sebastian	80
Córdoba	24
Cádiz	61

Source: Author's creation, using information from the Railway Infrastructure Manager (Adif).

Furthermore, we should mention the high variability in mobility conditions in the different centers analyzed, since it is noted, for example, that the proportion of trips made by car can reach 50 % in cities such as Seville, while in Barcelona it barely reaches 22 % (Metropolitan Mobility Observatory, 2024). In turn, this variability is reproduced when considering the centrality (or non-centrality) of the areas considered. For example, in the center of Madrid, 24.1 % of the trips were made by car, while in the Madrid metropolitan areas, these figures rose to 45.4 % (Metropolitan Mobility Observatory, 2024).

In 2018, Spanish suburban passenger train transport represented 12.8 % of the total number of trips made (Observatory of Transport and Logistics in Spain, 2020). Madrid and Barcelona alone made up 79 % of the total number of suburban train travelers with 230 and 120 million individuals transported yearly, respectively. When adding Valencia, Malaga and Bilbao, a total of 91 % of all travelers was reached (National Commission of Markets and Competition, 2023). In proportional terms, large population centers also stand out, as can be seen from the fact that in Madrid, 14.71 % of public transport trips in 2022 were made on suburban passenger trains. In Barcelona, this figure was 11.7 %. In other cities, such as Seville, only 6.5 % of all public transport trips were made using suburban trains. In line with all of this and beyond the aggregate results included in this article, it is necessary to consider the specific conditions of each of the urban centers analyzed in order to better understand the determinants of train use in suburban areas.

DATA AND METHODOLOGY

This article relies on data from the Survey of Essential Characteristics of the Population and Housing of the National Institute of Statistics (Spain), including characteristics of citizens, their commutes to work and school, households, and dwellings across Spain. This information was complemented using data on the availability of mass transit and suburban rail infrastructure provided by local transport operators and the companies Adif and Renfe.

The initial database collected information for a total of 424 493 sample elements. Sequential segmentations of this sample were produced until the study's target population was attained: individuals from suburban municipalities having commuter rail services who made daily commutes to work, as reflected in the following table.

Descriptive and significance statistics were used to determine the main differences in modal share between residents

TABLE 2. *Sample sizes*

Sample size	Surveyed
Total population	424,493
Population in urban areas served by suburban passenger trains	130,694
Population in urban areas served by suburban passenger trains in central municipalities	36,142
Population in urban areas served by suburban passenger trains in suburban municipalities	94,552
Commuting population in urban areas served by commuter rail in suburban municipalities	38,910
Population that travels by car to work in urban areas with suburban passenger rail services in suburban municipalities	25,603
Population that travels by train to work in urban areas with suburban passenger train services in suburban municipalities	895

Source: Author's own creation based on databases of the Survey of Essential Characteristics of the Population and Housing, INE.

of central and suburban municipalities. The results obtained were significant. Therefore, progress was made in the attempt to identify potential factors for train use in suburban municipalities, based on the variables identified in the literature review.

Logistic regression techniques were applied to identify these factors. These techniques are used to predict the success or failure rates, or the occurrence or non-occurrence of certain events in dichotomous variables, based on the predictor variable values (King and Zeng, 2001). This case examined the probability that individuals who travel to work in suburban municipalities would use the train instead of the car, according to the independent variables identified in the literature review.

These techniques are based on the logistic transformation, which transforms the probabilities of occurrence of the dependent variable through a linear function of the independent variables (Peng *et al.*, 2002). This transformation allows the model to predict an individual's probability of choosing to travel by train, based on the values of the independent variables.

The specific formula for logistic regression used in this study, as detailed by Peng *et al.* (2002: 3) is as follows:

$$\text{logit}(Y) = natural \log(odds) =$$

$$\ln\left(\frac{\pi}{1-\pi}\right) = \alpha + \beta X.$$

Where:

π is the probability of the result of interest.
α is the intersection in Y.
β is the regression coefficient
e is the base of the natural logarithms (Peng *et al.*, 2002: 3).

In order to distinguish the unequal weight of the contextual and sociodemographic factors, a two-step logistic regression method was used. In the first step, contextual variables were included. In the second step, sociodemographic variables were used to determine how they moderated the effects of the first contextual variables. SPSS version 26 was used to perform the analysis.

RESULTS

Modal share and characteristics of commuting in central and suburban municipalities

Overall (Table 3), there was a significant increase in car use as the preferred means of transport for commuting to work (55.6 % of workers travelled by car). This increase was especially pronounced in suburban municipalities, where cars were used by 65.8 % of all workers, as compared to 49.9 % in central municipalities. This difference is statistically significant. (χ^2=, 1.477,817, sig. < 0.000). Only commuter train use also increased in suburban municipalities, although levels of use were quite low (2.3 % of workers in these municipalities, as compared to 1.0 % in central municipalities). In the case of Spain, these data confirmed what has been previously reported in the literature (Habib, 2014) with regard to the increasing use of cars and suburban passenger trains in suburban contexts.

The research reviewed the variables identified in the literature that explain the differential use of trains versus cars, to see if they were applicable to the Spanish case. Table 4 confirms, as another finding of this work, the existence of statistically significant distinct profiles among users of both modes of transport in suburban contexts.

The analysis of contextual variables shows that train users lived in more densely populated municipalities (an average of 6.24 thousand inhabitants per square kilometer) than car users (an average of 3.98 thousand inhabitants per square kilometer). Train users also lived in conurbations having a greater extension of mass transport (236.56 kilometers of these infrastructures) and commuter trains (398.06 kilometers), as compared to car users (150.75 kilometers of mass transport and 284.43 of commuter trains). Thus, among those who traveled to work by car, 96.3 % had a car at home, and of those who traveled by train, only 66.9 % had a car. Likewise, those who traveled to work by car had an average of 1.7 cars at home, as compared to 1.4 cars for those who traveled by train.

Significant differences were also observed in the composition of sociodemographic variables between train and car users. Thus, proportionally, there was a greater presence of women among those using trains (53.0 % versus 43.7 % of those who used the car), of people born outside Spain (35.5 % versus 13.4 % among car users), and of younger people (Table 4). It

TABLE 3. *Modal share for going to work*

	Central municipalities	Suburban municipalities	Total
Automobile	49.9 %	65.8 %	55.6 %
Taxi	0.3 %	0.1 %	0.2 %
Trans. Network Companies	0.1 %	0 %	0.1 %
Motorcycle	5.3 %	2.9 %	4.4 %
Bus	16.8 %	11.3 %	14.9 %
Metro or light rail	7.5 %	5.2 %	6.7 %
Train	1.0 %	2.3 %	1.5 %
Bicycle	3.3 %	1.0 %	2.5 %
Walking	14.8 %	10.6 %	13.3 %
Others	1.0 %	0.8 %	0.9 %

Source: Author's own calculations based on the Survey of Essential Characteristics of the Population and Housing, INE.

TABLE 4. *Descriptive statistics of workers who traveled by car or train within suburban municipalities*

Variable	Values	Automobile users	Train users	χ²	t	Sig.
Area with poor transport connectivity	Yes	10.2 %	8.8 %	374,861		0.000
	No	89.8 %	91.2 %			
Inhabitants per square kilometer (in thousands per municipality)		3.98	6.24		-57.685	0.000
Kilometers of mass transportation (in the conurbation)		150.75	236.56		-85.845	0.000
Kilometers of commuter trains (in the conurbation)		284.43	398.06		-147.017	0.000
Home with automobile	Yes	96.3 %	66.9 %	51,879,513		0.000
	No	3.7 %	33.1 %			
Number of automobiles in the home		1.7	1.4		99.626	0.000
Sex	Men	56.3 %	47.0 %	2,552,179		0.000
	Women	43.7 %	53.0 %			
Age		43.9	41.5		26.398	0.000
Disability	(Scale from 1 to 3)	1.19	1.19		-0.078	0.938
Nationality	Spanish	92.2 %	71.8 %	3,608,209		0.000
	Other	7.8 %	28.2 %			
Country of birth	Spain	86.6 %	64.5 %	4,562,073		0.000
	Other	13.4 %	35.5 %			
Education level	Primary school	3.3 %	9.3 %	304,807		0.000
	Secondary school	40.1 %	37.3 %			
	Baccalaureate	13.9 %	11.3 %			
	Undergraduate	33.5 %	32.6 %			
	Post-graduate	9.1 %	9.5 %			
Monthly household income (€)	Less than 1,000	6.7 %	10.7 %	340,639		0.000
	1,000-1,499	14.6 %	18.6 %			
	1,500-1,999	16.2 %	19.7 %			
	2,000-2,499	16.2 %	14.1 %			
	2,500-2,999	15.0 %	14.6 %			
	3,000-4,999	22.7 %	17.7 %			
	5,000-7,499	5.8 %	3.6 %			
	7,500 and over	2.8 %	1.0 %			
Household composition	Single person	10.1 %	10.6 %	3,727,767		0.000
	Single parent	8.5 %	8.2 %			
	Couple without children	15.6 %	21.0 %			
	Couple with children	54.8 %	39.5 %			
	Home with non-related members	5.4 %	8.2 %			
	Others	4.7 %	12.6 %			
Civil state	Single	36.7 %	44.2 %	2,114,873		0.000
	Married	54.2 %	48.2 %			
	Widow/er	0.9 %	0.5 %			
	Separated	1.2 %	1.2 %			
	Divorced	6.9 %	5.9 %			
Weekly hours devoted to care		40.5	35.4		10.759	0.000

Source: Author's own calculations based on the Survey of Essential Characteristics of the Population and Housing, INE.

is also noted that nearly half of train users were poorer individuals, with incomes below €2000, while only 37.5 % of car users had this purchasing power. However, no conclusive statement could be made regarding educational level, since, except for basic education, at the other levels, the proportions were quite fluctuating (Table 4). The data also reveals a proportionally higher use of cars within traditional families, consisting of married people with children at home (54.8 % of all car users, but only 39.5 % of train users), and a proportionally higher use of trains among members of non-consan-

guineous households (8.2 % of these users, and 5.4 % of car users), and among single people (44.2 %, but only 36.7 % of all car users). These data suggest a link between train use and fewer family obligations, as revealed by the fact that train users spent 35.4 hours per week on care tasks, while car users spent 40.5 hours.

Logistic regressions

Descriptive statistics identified significant differences between the characteristics

TABLE 5. *Probability of choosing the train to go to work. Logistic regression including all factors*

		B	S.E.	Wald	g.l.	Sig.	Odd ratio
Km. massive transport		0.000	0.000	14.041	1	0.000	1,000
Km. local commuter trains		0.006	0.000	5,552.297	1	0.000	1,006
Trip time (min.)		0.027	0.000	37,514.966	1	0.000	1,027
Vehicles at home (Ref. Yes)	No	2.097	0.018	14,186.266	1	0.000	8,143
Thousands of inhabitants per km2		-0.023	0.002	205,579	1	0.000	0,977
Work municipality (Ref. the same as the residence)	Different from the municipality of residence	1.140	0.024	2,304.165	1	0.000	3,127
Neighborhood poorly connected to transport (Ref. Yes)	No	0.646	0.022	860.906	1	0.000	1,908
Sex (Ref. Male)	Female	0.605	0.011	2,866.615	1	0.000	1,832
Age		-0.004	0.001	64.425	1	0.000	0,996
Disability		-0.042	0.012	12.372	1	0.000	0,958
Country of birth (Ref. Spain)	Distinct from Spain	0.555	0.014	1,520.634	1	0.000	1,742
Education level (Ref. Postgraduate)	Primary school	0.311	0.035	77.357	1	0.000	1,365
	Secondary school	0.243	0.022	120.133	1	0.000	1,275
	Baccalaureate	0.218	0.024	79.296	1	0.000	1,243
	Degree	0.121	0.022	31.623	1	0.000	1,129
Income (Ref. 7500 € and more)	Less than 1,000	0.987	0.062	255.026	1	0.000	2,684
	1,000-1,499	1.321	0.058	523.143	1	0.000	3,746
	1,500-1,999	1.119	0.058	376.290	1	0.000	3,062
	2,000-2,499	1.141	0.057	399.043	1	0.000	3,131
	2,500-2,999	1.351	0.057	562.085	1	0.000	3,863
	3,000-4,999	1.192	0.057	444.935	1	0.000	3,295
	5,000-7,499	1.379	0.059	537.949	1	0.000	3,969
Number of resident children under 25 years of age		-0.186	0.006	1,071.362	1	0.000	0,830
Constant		-10.380	0.078	17,560.768	1	0.000	0,000

Source: Author's own calculations based on the Survey of Essential Characteristics of the Population and Housing, INE.

of train and car users. Various logistic regression models were generated to determine whether these characteristics influenced the likelihood of choosing the train over the car for commuting. The purpose of this work was to identify the differential weight of contextual factors and sociodemographic factors in explaining train use. Therefore, logistic regressions were applied sequentially. The first model, which included the context factors, explained between 6.5 % (Cox and Snell R-squared) and 25.8 % (Nagelkerke R-squared) of the variance in the dependent variable. The model achieved a good level of fit, correctly classifying 96.9 % of the cases, and it was statistically significant $\chi^2(7, N = 23,412) = 100.054$, sig. < 0.001, adequately discriminating train users from car users.

The second model incorporated sociodemographic factors and managed to slightly improve the ability to predict the variance of train selection, which now ranged between 6.7 % (Cox and Snell R squared) and 27.5 % (Nagelkerke R squared), correctly classifying 96.9 % of cases. This second model was statistically significant. $\chi^2 (27, N = 21,112) = 90,851$, sig. < 0.001. The improvement in the predictive capacity of the second model was quite small. It may be pointed out, as another relevant discovery of this work, that contextual factors played a more prominent role in explaining train use than sociodemographic factors.

The greater relevance of contextual factors is also evident in the review of the B coefficients (Table 5). Thus, the previous data confirm the important role played by the lack of access to a car. This condition increased the probability of using the train by a factor of 8.143, confirming what has been indicated by the international literature in works by Combs *et al.* (2016). Another important variable was working in a different municipality

from the individual's place of residence. Those who did so were 3.127 times more likely to travel to work by train, as compared to those who worked in the same municipality as their residence.

Improved accessibility and territorial connectivity were found to encourage greater train use. Thus, each additional kilometer of commuter rail service in the municipality and living in a neighborhood that is well connected to transit, increased the odds of commuting by train by a factor of 1.006 and 1.908, respectively (Table 5). In the case of Spain, these data confirm what has been pointed out in prior literature on how improvements in accessibility and connectivity to trains result in greater use (Mohan, 2008; Gao *et al*., 2019). On the other hand, and contrary to past research (Narsi and Zhang, 2010; Shung *et al*., 2014), living in more densely populated areas did result in greater use of the train as compared to the car. It was found that every thousand additional inhabitants per square kilometer of the municipality reduced the probability of commuting by train by a factor of 0.977.

The analysis of sociodemographic factors reveals that being a woman and having been born outside of Spain significantly increased the probability of using the train to go to work, with factors of 1.832 and 1.742, respectively. Furthermore, the results confirm the inverse relationship between age and train use, with each additional year reducing the probability of its use by a factor of 0.996. This data set on sociodemographic factors confirms what had been previously suggested in the literature for the Spanish case (Oña and Oña, 2022; Matas, Raymond and Roig, 2009; Casado-Díaz *et al*., 2022). Regarding income, train use was favored when the level was below the €7500 threshold (Table 5). This appears to confirm past literature on the use of the train by the less wealthy sectors of the population (Luo, Xiong and

Xiong, 2019). On the other hand, and in line with the descriptive statistics, it was observed that educational levels below postgraduate degrees increased the probability of travelling by train, although the relationship in these lower ranges was variable and did not allow reveal a clear trend. Finally, the presence of children in the home decreased the probability of using the train by a factor of 0.830 for each additional child.

DISCUSSION AND CONCLUSIONS

These results represent one of the first considerations of the extent and conditions necessary for the use of the train as a transport alternative in the major Spanish city suburbs. The following contributions may be identified.

First, it has been found that suburban growth in Spain has been driven by more intensive car use for commuting, compared to the type of travel that takes place in central urban areas. This is predictable and has already been observed in numerous countries, such as the United States (Baum-Snow, 2010), Mexico (Guerra, 2014), France (Aguilera and Mignot, 2004) and Poland (Wolny, 2019). In addition, in Spain, suburbanization is imitating a pattern of building in increased distances and travel times (Delclós-Alió and Miralles-Guasch, 2017; Cervero and Day, 2008), which, in turn, creates greater difficulties in efficiently expanding the public transport network (Wolny, 2019; Alonso, Monzón and Cascajo, 2015). It also encourages the perception that the new residents of these areas need to rely on a car for their daily commutes (Woldeamanuel *et al.*, 2009; Sun and Zacharias, 2020). The dynamics of suburban growth, which involve the consumption of large areas of land and the increasing use of automobiles, require specific monitoring in the

Spanish case, considering the commitments made by the country with regard to the decarbonization of the economy and binding European regulations to reduce greenhouse gas emissions. The encouraging results of the article also revealed an increase in train use to commute to work in suburban municipalities as compared to central ones, confirming the evidence gathered in other contexts (Habib, 2014). Although the percentage of use of suburban trains remained quite low, the promotion of this type of transport may be a good alternative to prevent suburban expansion caused by intensive automobile use.

Second, the article's results revealed the greater relevance of contextual factors in promoting suburban rail use, factors whose regulation is largely under the control of public administrations. Not having a car in the household was an especially relevant factor for suburban train use. In this context, the key policies for achieving rail-supported suburban growth were all of the measures that restrict access to and the use of cars. Although this type of measures requires a meticulous design adapted to the conditions of each city (Hull, 2011), it would have very favorable consequences not only for the reduction of traffic, as examined in the literature (Moavenzadeh and Markow, 2007), but also for the development of suburban train transport (Litman, 2005). This research showed that increasing the number of kilometers of suburban railways and improving public transport connectivity were also important factors in fostering greater use of suburban trains. Thus, these measures should be included in the country's transportation policy agenda in suburban contexts. Complementary measures should also be integrated to encourage sustainable transportation, as repeatedly suggested in the literature (Khan *et*

al., 2016; Topalovic, Tobey and Lotimer, 2008).

Thirdly, the results of this research suggest that certain sociodemographic factors were also relevant (although to a lesser degree) to increased use of suburban trains for commuting to work. This was the case for being female, being born outside of Spain, not having a high income, or being young. However, all of these attributes also correspond to those that some authors have identified as being responsible for transportation disadvantages, including difficulties in accessing essential urban services such as schools, healthcare centers, or work (Shay *et al*., 2016; Kamruzzaman *et al*., 2016). Specifically, the literature has shown that these sociodemographic factors, which encourage increased train use, also define types of individuals having special difficulties in conveniently traveling to the main urban attractions (Hine, 2011; Shay *et al*., 2016). It may be hypothesized that, since the mentioned social conditions imply difficulties in taking advantage of the best transportation and accessibility opportunities, which in suburban contexts would be those provided by car use, these same conditions lead to the obligation to use suburban trains as an alternative for commuting to work. This may be considered a captive audience phenomenon (Jacques, Manaugh and El-Geneidy, 2012) with respect to train use. In other words, the population cannot materialize its transport preferences and has no option but to travel on suburban trains. Given this possibility, it is especially necessary for public administrations to promote policies so that trains become the universal transport option in the suburbs and are not the last available choice for individuals who do not have the resources or possibilities to use a car.

Considering these contributions as a whole, there is clearly a need to develop coordinated and targeted transportation policies that address the travel conditions specific to suburban municipalities. Specifically, the results of this work have highlighted the important role of contextual factors in the selection of trains as a means of transportation in suburban municipalities. This indicates that active policies restricting automobile use in these areas improve the expansion and operation of this transportation type. These policies simultaneously optimize the territorial distribution of the different urban functions that are very likely to reverse the high and unsustainable use of private automobiles in these areas. These specific territorial and transport policies would turn the train into a real travel alternative in suburban contexts, preventing it from being reduced to the last available option for the most vulnerable populations.

The above findings motivate the emergence of future lines of research. Thus, for each of the metropolitan areas considered, it is important to examine how their suburban growth has gone hand in hand with the increasing use of automobiles for commuting, and how the layout of suburban train lines has, to some extent, mitigated this use. Likewise, it is important to investigate the specific characteristics of each of the aforementioned metropolises to facilitate the implementation of transport policies that promote greater use of suburban trains, such as measures restricting the use of automobiles, or those related to the improvement of public transport and railways. Finally, additional work is required to delve deeper into the study of suburban train user populations, in order to confirm the hypothesis of whether these are captive user populations, and to determine the conditions needed for suburban trains to become a universal transportation alternative.

This article has certain limitations arising from the use of a pre-existing survey.

This has made it impossible to use a territorial disaggregation having greater detail than the municipal level. This has prevented the introduction of the specific characteristics of the suburban train network available to each household as explanatory variables. However, it may be hypothesized that a closer connection between train stations and more densely populated areas (such as the metropolitan areas of Madrid and Barcelona) may also be a very important factor to encourage greater train use. Furthermore, the use of a pre-existing survey prevented the consideration of other key variables in explaining suburban train use, such as the costs of different transport modes or user attitudes toward these modes. Finally, this article is based on a cross-sectional study, permitting the identification of initial evidence on suburban travel patterns. However, it cannot accurately establish the determining factors of this type of travel. Longitudinal studies would be needed for this purpose.

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