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Behavioral factors impacting adoption and frequency of use of carsharing: A tale of two European cities

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ABSTRACT

Innovative mobility services have emerged in many urban areas, causing a notable change in transport supply. Particularly, free-floating carsharing has allowed gaining short-term access to cars on an as-needed basis. In Europe, carsharing has experienced remarkable growth in the past few years and is often perceived as a shift towards sustainable mobility. While an increasing number of studies have analyzed individuals' behavior, most authors analyze carsharing in contexts where this service is not available yet. Furthermore, little attention has been given to exploring the role played by psychosocial aspects. This study aims to fill this gap in the literature by exploring carsharing usage in two European cities (Madrid and Munich), cities with a different timespan implementation. Based on the individual-level dataset from a survey campaign conducted in 2019, we develop a Generalized Structural Equation Model (GSEM) that estimates how sociodemographic characteristics, mobility-related attributes, and psychological attitudes affect carsharing usage. The research identifies a higher use of free-floating carsharing among males, young, wealthy, well-educated individuals, and those who reside in inner and denser districts. Interestingly, the model results suggest that people with a high sharing propensity, variety-seeking lifestyle, and preference for driving have a significantly higher familiarity with carsharing services, while pro-environmental behaviors reduce carsharing usage. This research shows the importance of the background and sociodemographic context on carsharing usage by comparing the results obtained for each city. Finally, the paper provides interesting policy implications, helpful for planners and policymakers to better understand the factors impacting carsharing usage and its potential effects on travel behavior and sustainability.

1. Introduction

In the context of strengthening and promoting sustainable mobility, more attention is being devoted to the design, operation, and management of urban mobility systems in the planning agendas (Banister, 2008). In the past few years, emergent technologies on the Internet of Things, connectivity, wireless communications, and big data, along with the widespread use of smartphone technology, have fostered an important development of app-based mobility solutions in many urban areas. These innovative mobility services have changed the traditional way of planning, modeling, and doing business in urban transportation (Smith and Hensher, 2020). From the citizens' point of view, they have also allowed gaining short-term access to vehicles (car, moped, bicycle, scooter, etc.) on an on-demand basis. This is the case for shared mobility systems launched in the past few years, such as scooter sharing, bikesharing or free-floating carsharing.

Carsharing services allow users for a car short-term access on an as-needed basis, generally subject to payment for the use of the vehicle (Shaheen and Cohen, 2013; Münzel et al., 2018). Shared vehicles are owned by a platform company so this service promotes new forms of car use, in which drivers do not necessarily need to bear car ownership-related costs. These mobility services have increased markedly in the past few years worldwide, particularly in Europe, as is the case of free-floating services operating within a defined area (Münzel et al., 2020). Carsharing has brought great changes in, e.g., car ownership or how individuals plan and make their trips, thus the implications for cities, urban mobility, and the automobility business model are deep. Free-floating carsharing, also referred to as point-to-point or one-way carsharing, is often viewed as a shift towards more sustainable mobility. Many authors have pointed out the positive impacts of

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carsharing in e.g., reducing vehicle ownership (Firnkorn and Müller, 2015; Liao et al., 2020), promoting public transport (Martin and Shaheen, 2011b; Münzel et al., 2018), decreasing air pollution (Martin and Shaheen, 2011a; Firnkorn and Müller, 2015) or relieving road congestion (Shaheen and Cohen, 2013; Perboli et al., 2018). However, some of the impacts of carsharing on urban transportation and sustainability still remain uncertain (Wielinski et al., 2016; Wen et al., 2021).

Understanding individuals' travel behavior is essential to identify important elements of transportation planning and policy analysis, especially as innovative mobility systems emerge and interact with traditional ones. Previous contributions on carsharing from the user behavioral perspective have mainly analyzed the influence of individuals' sociodemographic characteristics and mobility patterns on carsharing usage (see e.g., Kopp et al., 2015; Wielinski et al., 2016; Efthymiou and Antoniou, 2016; Dias et al., 2017; Jochem et al., 2020). However, further important aspects have gained little attention in the existing literature up to date. For instance, in spite of the increasing number of studies applying the psychological dimension in travel behavior models, scarce efforts have been devoted to exploring the role played by psychological and behavioral aspects on carsharing usage. Furthermore, most authors analyze carsharing in contexts where these services are not available yet, while there is a need to investigate adoption and frequency of use in cities where carsharing is already in operation. As noted by Le Vine and Polak (2019) and Hjorteset and Böcker (2020), carsharing research urgently requires more case-study contexts, since the population is increasing the use of these services in recent years to meet their mobility needs. Furthermore, public authorities need to be updated about the carsharing sector with the aim of being aware of their implications and impacts, promoting new legislation, or removing existing barriers.

Within the above context, the purpose of this paper is to explore the key factors at the individual level (i.e., socioeconomic, demographic, and mobility-related attributes, or psychological attitudes of the individuals) determining the usage of carsharing in the European context. For this purpose, a survey campaign was conducted in two European cities with carsharing services available: Madrid (Spain) and Munich (Germany). The information collected was used to estimate a Generalized Structural Equation Model (GSEM) aimed at identifying people's behavior towards the adoption and frequency of use of free-floating carsharing systems. Therefore, this paper expands the scientific knowledge on carsharing by analyzing its usage in two European cities with different timespan implementation.

The remainder of the paper is structured as follows. After this introductory chapter, Section 2 displays a review of the main literature relevant to this study. Section 3 presents the case study analyzed, the survey conducted, and the dataset collected for the analysis. Section 4 outlines the methodology adopted for this research. Section 5 presents some details on the latent constructs approach employed. Section 6 presents and discusses the main model estimation results and the policy implications of the findings. Finally, Section 7 sets out the main conclusions and suggests further research needs.

2. Evaluating travel behavior on carsharing: literature review

Most studies on the carsharing literature are focused on exploring the effects on urban sustainability coming from the implementation of these services and generally agree about their positive impacts. For instance, carsharing has been found to offer some degrees of flexibility as could decrease individuals' dependence on private vehicles (Martin and Shaheen, 2011b, Ter Schure et al., 2012; Becker et al., 2018; Hjorteset and Böcker, 2020), resulting in a higher share of active modes and public transit (Münzel et al., 2018), along with mitigation of congestion and lack of public space (Shaheen and Cohen, 2013; Perboli et al., 2018). Second, some authors such as Liao et al. (2020) indicate that carsharing providers are playing a role in decarbonizing the transport sector since they generally use zero-emission vehicles (ZEVs). This can subsequently result in reducing pollutants and greenhouse gas emissions in urban areas (Martin and Shaheen, 2011a; Baptista et al., 2014; Firnkorn and Müller, 2015). In fact, unlike total sales of the automotive industry, carsharing companies include a much higher proportion of ZEVs in their fleets (Ferrero et al., 2018; Shaheen et al., 2019; Liao et al., 2020), such as battery-electric vehicles (BEVs) or plug-in hybrid electric vehicles (PHEVs). In short, as pointed out by Firnkorn and Müller (2015), carsharing reduces both the individual costs of owning a car as well as other social costs such as air pollution, noise, energy use, parking shortage, and road congestion.

Some researchers have investigated carsharing from a travel behavior viewpoint, although most of them explored the intention to use carsharing in contexts where this transportation mode was not available yet. Interestingly, these studies have identified some consistent individual socioeconomic characteristics with a higher usage or intention to use carsharing systems. According to the literature, these individuals are commonly males (Velázquez Romera, 2019; Hjorteset and Böcker, 2020), young (Martin and Shaheen, 2011b; Habib et al., 2012; Dias et al., 2017), wealthy (Clewlow, 2016; Efthymiou and Antoniou, 2016; Dias et al., 2017; Le Vine and Polak, 2019; Hjorteset and Böcker, 2020), and well-educated people (Kopp et al., 2015; Clewlow, 2016; Becker et al., 2017; Dias et al., 2017; Hjorteset and Böcker, 2020), Furthermore, Kopp et al. (2015), Dias et al. (2017), and Hjorteset and Böcker (2020) found that living in denser urban areas significantly influences the usage of carsharing services. Overall, this field of the scientific literature has been particularly helpful for defining the early adopter profiles of this emerging service.

Other studies have focused on the substitution and complementary effects on the transportation system. For instance, Nobis (2006), Martin and Shaheen (2011b), Becker et al. (2017), and Wielinski et al. (2017) have noted that carsharing members are also frequent users of sustainable transport modes, and Kopp et al. (2015) and Frank et al. (2021) concluded that overall carsharing users show a higher trip frequency and are more multimodal and intermodal in their behavior. Accordingly, Shaheen and Chan (2016) point out that carsharing is expected to complement more environmentally friendly mobility services such as public transport, so an increase in the use of carsharing could be associated with an increase in public transit use. Furthermore, carsharing is also related to vehicle ownership decisions in the sense that carsharing adopters generally tend to own fewer vehicles than non-users (Ter Schure et al., 2012; Giesel and Nobis, 2016; Hjorteset and Böcker, 2020; Jochem et al., 2020). However, in the case of London, Le Vine and Polak (2019) found similar levels of car ownership amongst carsharing adopters and the general population, and significantly higher levels of car ownership for well-educated, wealthier carsharing users.

As pointed out by Hjorteset and Böcker (2020), few studies have investigated the psychological and behavioral aspects on carsharing usage (e.g., environmental consciousness or the symbolic value of driving), or the relationships found are weak or nonsignificant. It is worth noticing that most of these studies have examined individuals' intention to adopt carsharing in urban areas where these mobility services are not in operation. For instance, environmental concerns appear to have a significant effect, either positive or negative, on the intention to join carsharing (see e.g., Efthymiou and Antoniou, 2016 for young people aged between 20 and 35 in Greece; Kim et al., 2017 for the Netherlands; Acheampong and Siiba, 2020 for young people aged between 18 and 35 in Ghana; Jin et al., 2020 for Beijing), or the intention to continue using free-floating carsharing services (see e.g., Mattia et al., 2019 for a sample of 300 carsharing users from Italia). Kim et al. (2017) have also concluded a strong relationship between the intention to use carsharing and the intrinsic preference for driving. Reasonably, evidence from a previous study in a developing country shows that tech-savvy individuals reported a higher intention to adopt carsharing (Acheampong and Siiba, 2020).

Finally, Velazquez (2019) and Hjorteset and Böcker (2020) are among the few studies investigating the causal relationship between carsharing adoption and different latent variables in urban contexts with the availability of these mobility services. Velázquez Romera (2019) showed that openness to data sharing, familiarity with the sharing economy, and social norms have positive impacts on the adoption of carsharing in Madrid (Spain), while community resilience and environmental concerns do not seem to have a significant effect. In the case of Norwegian urban areas, Hjorteset and Böcker (2020) found that carsharing enrolment has a positive connection with environmental concerns while it is negatively related to financial awareness.

As can be observed, further contributions should continue exploring the factors motivating individuals' usage of carsharing in the travel behavior literature. The need is even greater given the fact that many of the current studies are based on stated preference questionnaires that explore the intention to adopt carsharing in urban areas where these services are not available. This point is particularly relevant since only individuals having real experience with carsharing will be able to: i) consider the main characteristics of the service, as well as its operation and performance-related issues; and ii) evaluate more fairly the advantages and disadvantages coming from carsharing. Thus, it is important to deeply explore the determinants influencing carsharing usage –particularly, the role of behavioral/psychological aspects– in urban areas where shared cars are already in operation. In addition, more in-depth modeling approaches are needed to understand the adoption and use of carsharing and, especially, explore the influence of latent psychological variables when choosing these services, as indicated by Kim et al. (2017) and Hjorteset and Böcker (2020).

This research paper aims to fill this gap in the literature by exploring carsharing adoption and frequency of use in two cities with carsharing services in operation: Madrid and Munich. These cities are worth investigating since they represent case studies with a different timespan implementation of carsharing. Therefore, the research could lead to a better acquaintance with carsharing dynamics in European cities, the role played by timespan implementation and the importance of psychological/behavioral aspects for real users of the system.

3. The data: a survey campaign in two European cities

3.1. Case-study contexts: the cities of Madrid and Munich

Madrid (Spain) and Munich (Germany) are the case studies selected for this research as they represent quite different cities within the European context (see Table 1). On the one hand, Madrid is the capital and most populous city of Spain, and the second-largest city in the European Union, with approximately 3.3 million inhabitants. The municipality covers 605 km^2 and has an effective population density of around 9,000 inhabitants/km^2, with higher densities in the inner neighborhoods. The city has experienced an intense process of urban sprawl in the last decades and presents a strong interdependency with its surrounding suburbs. Its metropolitan area is the second-largest in the European Union with a population of 6.5 million, only surpassed by Paris. Munich, in its turn, has a population of around 1.5 million inhabitants and is the third-largest city in Germany, after Berlin and Hamburg. The total area of Munich is about half of Madrid, while the average population density is significantly lower (around 5,000 inhabitants/km^2). Its metropolitan region, home to 6 million people, is of the same size as that of Madrid.

Regarding sociodemographic characteristics, some important differences can be observed between the cities. For instance, Munich has a wealthier and more dynamic economic environment, with a higher GDP per capita compared to Madrid (75,200 vs. 43,600 Euro). According to census data, the proportion of young adults (residents aged between 20 and 40) is particularly high in Munich (32.9%) compared to Madrid (25.7%). Likely partly as a result of that, Munich has a higher percentage of people living alone and a lower ratio of children per household than Madrid. Concerning the level of education, it is worth noting that both cities are above their national averages. Nevertheless, we can observe that Munich presents a noticeable percentage of people with vocational/professional qualifications, while the percentage of people with lower education levels (lower secondary education, incomplete primary education, and no education) is lower than in Madrid. All these differences could be particularly relevant to this research since, according to the literature, young, well-educated, wealthier people are the segments of the population with the highest propensity to adopt carsharing services. Additionally, it is worth noticing that car ownership rates in Madrid (0.46 vehicles/inhabitant) and Munich (0.47 vehicles/inhabitant) are similar, while the moto ownership rate is significantly lower in the German city (Consorcio Regional de Transportes de Madrid [CRTM], 2020; Observatorio de la Movilidad Metropolitana, 2020; Bundesministeriums für Verkehr und digitale Infrastruktur [BMVI], 2019).

The road networks in Madrid and Munich include several radial motorways at different distances from the city center. The inner ring roads in both Madrid (M-30) and Munich (Mittlerer Ring, also known as Middle Ring) are the backbones of urban road traffic and the fastest connections to all major traffic corridors in their cities. Additionally, these ring roads typically define, in practice, the boundaries between inner, dense districts, and outer neighborhoods.

As it happens in many other European cities, the existing public transport networks in Madrid and Munich lie on a dense integrated system, including buses, metro, trams (or light rail transit), and suburban rail services. As can be observed in Table 1, Madrid has a supply of metro and bus services significantly higher than Munich, but this is counterbalanced by a more extensive tram network in the German city. Furthermore, in Munich, the urban rail network (both metro and tram) is concentrated in dense areas, so these services cover a lower share of the territory and population compared to Madrid. In the Spanish city, the metro network serves the whole municipal area in a fairly homogeneous way and even connects some towns within the metropolitan

Table 1
Summary of characteristics and comparison between case-study cities.

VARIABLES	Subgroup	Madrid	Munich
General information	Population	3,334,730	1,542,211
	Municipal area[a] (km^2)	364.8	310.0
	Population density[a] (inhab./km^2)	9,141	4,975
	GDP per capita (€)	43,622	75,186
Motorization rate	Cars/1000 inhabitants	461	472
	Motorcycles/1000 inhabitants	59	41
Modal share (%)	Private vehicles	25.4	34.0
	Public transport	34.4	24.0
	Active modes (walking and cycling)	38.8	42.0
Public transport network (km)	Metro	288	95
	Light rail/tram	36	82
	Bus	3,076	511

[a] It does not take into account the area free of buildings, defined as specially protected natural land that cannot be developed.

Table 2
Comparison of free-floating carsharing services in Madrid and Munich (2019).

	Madrid	Munich
No. Operators	4	3
No. Vehicles	2,600	2,150
Fleet/1000 inhab.	0.8	1.4
Year of implementation	2015	2011
Area coverage (km^2)	75–104	88–92
Engine type	Battery-electric vehicles or plug-in hybrid electric vehicles	Mostly conventional fuel vehicles and less than 15% are electric
Payment scheme	Based on time (mainly per min, but also per hour, and per day)	Based on time (mainly per min, but also per hour, and per day) and/or kilometers driven
Parking	Free on-street parking and specific parking lots	Free on-street parking. Parking spaces for carsharing are reserved in pilot areas

area.

According to the latest mobility survey in Madrid (CRTM, 2020), the modal share in this city is well balanced towards sustainable modes. Trips within Madrid city have a notable share of public transport (34.4%) and active modes (38.8%), significantly higher than the use of private vehicles (25.4%). Modal shares for sustainable modes are even higher in inner districts. By contrast, the modal split in Munich shows a higher presence of private vehicles (34.0%) compared to public transport (24.0%), as stated in BMVI (2019). Modal shares of active modes as a whole (walking and cycling) are fairly similar in both cities.

Overall, Madrid and Munich represent very interesting and active cases worldwide regarding carsharing. While station-based carsharing has been traditionally available in both cities, mainly for interurban mobility, free-floating carsharing services have been launched in these cities in the last decade. Free-floating carsharing started to operate in Munich in 2011, while these services were launched in Madrid some years later (2015). Since then, the number of vehicles and registered users has grown rapidly in both cities. The shared car features and service conditions rapidly change over time and vary across operators. Table 2 displays a brief general overview of the free-floating carsharing services available in Madrid and Munich at the time of the survey campaign. This information on service availability is essential to better understand the factors that impact carsharing usage in each city.

In 2019, there was a fleet of more than 2,600 and 2,100 shared cars in Madrid and Munich, respectively. As a result, the average fleet per inhabitant in Madrid is 44% lower than in Munich. Another difference to be pointed out is that all shared cars in Madrid are BEVs or PHEVs. This is particularly relevant in the case of Madrid since these vehicles do not have restrictions to access the city center and generally benefit from free on-street parking (Lagadic et al., 2019), thus providing an accessible and flexible alternative for getting around and parking inside the inner districts. In Munich, there are different pricing structures (generally based on the time of use, but also in the kilometers driven), while in Madrid the payment scheme is based on the time of use, mainly per minute. Furthermore, carsharing services in both cities coexist with other shared mobility alternatives, which are also based on a per-use payment and are mainly available in the most densely populated areas. For instance, Madrid is the city with the largest fleet of shared e-mopeds in operation worldwide after Bangalore, and both Madrid and Munich have an extensive network of public electric bikesharing in the city center and some surrounding districts around it.

3.2. Data collection and survey description

A survey campaign was conducted to collect the dataset in order to investigate carsharing adoption and frequency of use in the cities selected, for several reasons. Firstly, there is limited availability of publicly accessible empirical data in Europe for shared mobility services, and only aggregate information is commonly shown in technical or professional reports. Secondly, scarce insight about carsharing usage is provided in the latest mobility surveys, particularly for the cities selected. This is due to the fact that few carsharing users were identified in the latest surveys (see e.g., CRTM, 2020 for the case of Madrid and BMVI, 2019 for the case of Munich) and the majority of mobility surveys available were carried out before the boom of carsharing services. Therefore, already available information was not appropriate for the purpose of this research.

The dataset used in this study was collected through survey questionnaires conducted in Madrid (Spain) and Munich (Germany). Both questionnaires were specifically designed for this research to deeply compare the main factors (sociodemographic, mobility-related variables, along with behavioral and psychological aspects) motivating individuals' usage of carsharing in two different European contexts. The target population is whoever resides in and/or commutes to Madrid or Munich. It is worth noticing that the questionnaire was ascertained after reviewing other research studies exploring individuals' intention to join and/or adoption of carsharing services through surveys (e.g., Efthymiou and Antoniou, 2016; Kim et al., 2017; Dias et al., 2017). Additional aspects that might influence the use of carsharing services were included, e.g., factors capturing the tendency of individuals to have a variety-seeking lifestyle (see more details below).

Two different survey waves were conducted in the same time period to collect the information for this research. The first wave, common for both cities, was fully managed –under the supervision of the authors– by a renowned company with extensive know-how in conducting surveys. This wave was specifically addressed to obtain a heterogeneous set of respondents in terms of individual sociodemographic characteristics. To that end, two types of surveying methods were implemented: (i) in-person on-street interviews conducted 7 days a week during the morning, afternoon, and evening, throughout different areas of the cities that were selected based on their geographical location, land-use patterns, and neighborhood characteristics (e.g., socioeconomic status); and (ii) paid online research panel. The second wave, fully managed by the authors, comprised: (iii) handing out flyers –with the link to access the online questionnaire and explaining the purpose of the research– in the street, throughout different areas of Madrid; and (iv) dissemination of the online questionnaire throughout electronic mailing lists, messaging apps, and social media platforms. This surveying method was only carried out in the city of Madrid, as some restrictions of the German legislation hindered the replication of this procedure in Munich.

The randomness of the sample population was tested in terms of gender and age, along with heterogeneity for income levels and carsharing usage. Additionally, as noted above, a particular effort was made to disseminate the survey in different districts (covering both the city center and suburbs) and at different times of the day and days of the week. Finally, in order to identify any potential bias coming from survey methods, the subsamples of both waves were checked and analyzed.

The data collection took place from June to October 2019. Given the lower representativeness of August in terms of mobility patterns when compared with the rest of the months, we focused both survey waves on neutral months (i.e., neither summer breaks nor containing too many holidays or special events), so they were not conducted during August. After conducting data cleaning and validation and excluding incomplete answers, a total of 1,246 and 619 valid responses were kept for Madrid and Munich, respectively. Concerning the content of the survey, respondents were asked about four main aspects:

- *General sociodemographic information*: gender, age, household annual income, level of education, occupation, household structure, and residential location (including zip code).

- *Urban mobility patterns:* availability of a motorized vehicle for personal use, and the number of trips made in both the last weekday and non-weekday (excluding trips on foot shorter than 15 min).
- *Lifestyle and attitudes statements*: respondents were asked to rate on a 5-level Likert scale their level of agreement towards 18 different statements. This information represents the indicators employed to later build the five unobserved latent variables included in the GSEM aimed at capturing the psychological preferences of individuals that may impact carsharing usage (see more details in Section 5). The indicators covered the following behaviors:
  i) Propensity to adopt a Variety-Seeking Lifestyle (VSL). Several indicators, adapted from Schwartz et al. (2001), capture the tendency of the individual to have a varied lifestyle full of new experiences and risks, as well as the inclination to try or purchase new products, goods, or services. This latent variable has been previously used in the field of shared mobility, specifically for ridesourcing services (see e.g., Alemi et al., 2018; Lavieri and Bhat, 2019; Gomez et al., 2021). The inclusion of the VSL construct is sound since carsharing can still be considered a trendy urban transportation mode, particularly in Madrid. Furthermore, the individuals who follow a more VSL may present higher mobility rates, in the sense that they tend to be more outgoing.
  ii) Tech-savviness. A set of indicators capture the tech-savviness of the individual through the adoption and daily use of social media and mobile apps for daily tasks. This latent variable has been widely used in previous research on the use of emerging urban transportation modes (see e.g., Astroza et al., 2017; Velázquez Romera, 2019; Acheampong and Siiba, 2020; Aguilera-García et al., 2022). It seems reasonable to include this construct given that carsharing is a new form of technology-enabled mobility. Therefore, familiarity with new technologies, particularly mobile applications and internet services, is essential for using carsharing since vehicles can only be booked via app.
  iii) Environmental consciousness. Several indicators capture pro-environmental attitudes through perceptions of sustainable transportation systems, recycling behavior at home, and preferences for environmentally friendly goods and services. In this regard, pro-environmental behaviors may lead to reducing private vehicle use and increasing environmentally friendly transportation modes. This variable may potentially impact carsharing usage, as suggested in the literature (see e.g., Costain et al., 2012; Efthymiou and Antoniou, 2016; Mattia et al., 2019; Acheampong and Siiba, 2020; Jin et al., 2020; Hjorteset and Böcker, 2020). Moreover, Kim et al. (2017) found that people who have a greater preference towards a green lifestyle are less likely to use shared cars in the Netherlands. In addition, this latent variable has been broadly used in previous literature on travel behavior for other new mobility systems such as ride-hailing (Astroza et al., 2017; Lavieri and Bhat, 2019; Gomez et al., 2021).
  iv) Propensity to use shared goods. Several indicators capture individuals' willingness to purchase second-hand products, tendency to use shared products/services (as is the case of carsharing), and inclination to avoid shared spaces with strangers. Therefore, this latent construct also reflects the privacy sensitivity of the individuals. Both privacy sensitivity and sharing propensity have been shown to influence shared mobility use (Lavieri and Bhat, 2019; Gomez et al., 2021) such as carsharing (Velázquez Romera, 2019).
  v) Intrinsic preference for driving. A set of indicators capture the personal pleasure or preference for driving a car. This latent construct has been also used by Kim et al. (2017). The inclusion of this construct is reasonable since individuals' attitude toward driving a car may potentially impact their carsharing usage.
- *Use of carsharing services:* adoption and frequency of use of free-floating carsharing systems.[1] These are the main variables of interest for this research. They will be explained in detail in Section 3.4. Further information was collected concerning carsharing mobility but has not been exploited in this research.

We should note that the questionnaire has been presented in defined blocks in this section to provide a clearer understanding to the readers. As recommended in the survey design literature, the socioeconomic and demographic information was collected at the end of the questionnaire, and the attitude statements were mixed throughout the questionnaire.

3.3. Sample description: socioeconomic and demographic characteristics

Basic descriptive analysis shows a fairly heterogeneous distribution of individual sociodemographic characteristics across the subsamples in both cities (see Table 3). This aspect is needed for the present research purpose, which is estimating causal effects between exogenous and outcome endogenous variables. Overall, the survey campaign has sufficiently captured those specific sociodemographic segments of the population that may be less likely to use carsharing, such as low-income or elderly people (see e.g., Martin and Shaheen, 2011b; Clewlow, 2016; Efthymiou and Antoniou, 2016; Dias et al., 2017).

Compared to census data, the subsamples present a higher proportion of males in Madrid as well as individuals aged under 35 in both cities, while the level of annual household income is somehow consistently distributed for both Madrid and Munich. It is worth clarifying that annual household income was re-categorized into five levels for Munich, with one more category than in the case of Madrid, due to the higher income level in the German city. In both urban areas, employees make up the majority of the sample (70% and 83% of respondents from Madrid and Munich, respectively). There is a noticeable presence of students and part-time employees in Madrid (22.2%) compared to Munich (8.2%).

Because of the specificities of the education system in each country, the variable capturing the level of education of individuals has been adapted accordingly. For the case of Munich, the levels were merged into three categories: (1) lower secondary education or below, including no schooling, elementary school, primary schooling, and lower secondary education; (2) upper secondary school and post-secondary education; and (3) university and postgraduate degrees. For Madrid, the education level was recoded into two levels: (1) without university studies; and (2) with university studies completed. While education statistics can be considered fully representative in Munich, the Madrid subsample shows an over-representation of respondents with high education levels, since 69.3% of the subsample finished university studies. This could be driven by the fact that this particular demographic subgroup may have a higher propensity to respond to questionnaires, especially concerning the second wave, as indicated by Efthymiou et al. (2013). As for household structure, people living alone are considerably more common in Munich (28.8%) than in Madrid (14.0%), while there is a noticeably higher proportion of families with children in the Madrid subsample (46.2%) compared to Munich (27.6%).

Finally, we explain the sample characteristics for the residential location variable. As indicated in Table 3, the sample distribution is similar in the two cities, with the large majority of respondents living in the city center (47.1% inside the M30 Ring of Madrid, and 53.6% inside

[1] For the case of Madrid, this part of the questionnaire also captured individuals' usage of a ride-hailing, another new mobility service in the city. This further information has been exploited in detail in Gomez et al. (2021) and is out of the scope of this paper.

Table 3
Summary of the socioeconomic and demographic characteristics of the sample.

VARIABLES	Subgroup	Madrid		Munich	
		Respondents	% Sample	Respondents	% Sample
Gender	Male	688	55.2	302	48.8
	Female	558	44.8	317	51.2
Age	Under 25	254	20.4	100	16.2
	25 to 34	383	30.7	155	25.0
	35 to 49	356	28.6	208	33.6
	50 to 59	186	14.9	92	14.9
	Above 59	67	5.4	64	10.3
Annual HH income[a]	Rank 1	189	15.2	86	13.9
	Rank 2	277	22.2	144	23.3
	Rank 3	314	25.2	128	20.7
	Rank 4	141	11.3	110	17.8
	Rank 5	n/a	n/a	53	8.6
	DN/DWA[b]	325	26.1	98	15.8
Education	Lower secondary education or below	383	30.7	221	35.7
	Upper secondary education			188	30.4
	University studies	863	69.3	201	32.5
	DN/DWA[b]	0	0.0	9	1.5
Occupation	Employed	863	69.3	513	82.9
	Student and part-time employee/student	277	22.2	51	8.2
	Other: housework, unemployed or retired	106	8.5	55	8.9
Household structure	Living alone	175	14.0	178	28.8
	Living with flatmates	150	12.0	121	19.5
	Couple without children	237	19.0	147	23.7
	Couple with children below 24	457	36.7	155	25.0
	Couple with all children above 25	118	9.5	16	2.6
	Other	109	8.7	2	0.3
Residential location	City center	587	47.1	332	53.6
	City suburbs	473	38.0	192	31.0
	Metropolitan area	186	14.9	95	15.3

[a] *Annual HH income in Munich*: Below 21,000 Euro (Rank 1); 21,000 to 41,000 Euro (Rank 2); 41,000 to 60,000 Euro (Rank 3); 60,000 to 100,000 Euro (Rank 4); Above 100,000 Euro (Rank 5). *Annual HH income in Madrid*: Below 18,000 Euro (Rank 1); 18,000 to 30,000 Euro (Rank 2); 30,000 to 60,000 Euro (Rank 3); Above 60,000 Euro (Rank 4).
[b] *DN/DWA*: Do not know/do not want to answer.

the Mittlerer Ring of Munich) and in the city suburbs (38.0% and 31.0% in Madrid and Munich, respectively). In both cases, around 15% of respondents live in the metropolitan area (beyond the municipal limits of each city).

3.4. *Sample description: transportation-related factors and frequency of use of carsharing*

Concerning mobility patterns, the sample distribution is quite similar in both cities, with a few differences being worth noting (see Table 4). First, ownership or access to a private vehicle presents a similar share in the Madrid and Munich subsamples. This variable was obtained by asking individuals whether they have access to a motorized private vehicle at home for their personal use. As for weekday and weekend mobility rates, Madrid residents reported a slightly higher intensity in their out-of-home activity. It is important to mention that two trips per day were set as the threshold value for these two variables given that it would usually indicate a pattern in which a single out-of-home activity was carried out on that certain day.

Table 4 also shows the distribution of the sample characteristics

Table 4
Summary of the transportation-related characteristics of the sample.

VARIABLES	Subgroup		Madrid		Munich	
			Respondents	% Sample	Respondents	% Sample
Vehicle availability	Yes		861	69.1	409	66.1
	No		385	30.9	210	33.9
Weekday mobility	Zero trips		109	8.7	103	16.6
	1 to 2 trips		681	54.7	412	66.6
	3 or more trips		456	36.6	104	16.8
Weekend mobility	Zero trips		248	19.9	127	20.5
	1 to2 trips		583	46.8	302	48.8
	3 or more trips		415	33.3	190	30.7
Carsharing use	Never used		825	66.2	396	64.0
	Used but not in the last 6 months		67	5.4	39	6.3
	Used but not in the last month		98	7.9	8	1.3
	Used in the last month	1-4 trips	157	12.6	98	15.8
		5-10 trips	60	4.8	48	7.8
		>10 trips	39	3.1	30	4.8

according to the usage of carsharing systems. These data have been subsequently employed to build the two main variables of interest in the modeling methodology: adoption and frequency of use of carsharing. *Carsharing adoption* indicates whether the individual has ever used this mobility option, and it is represented as a binary variable. As can be observed, the adoption of carsharing systems in Munich (36.0%) is slightly higher compared to the Madrid sample (33.8%), where carsharing can still be considered a new mobility service. Additionally, those respondents having adopted carsharing also reported their frequency of use of carsharing. This variable was built with the following five categories: (1) used, but not in the past 6 months, (2) used, but not in the past month, (3) used 1 to 4 times in the past month, (4) used 5 to 10 times in the past month; and (5) used more than 10 times in the past month. Again, Munich respondents seem to make more intensive use of carsharing compared to Madrid, as can be observed in Table 4. For instance, people making more than 10 trips by carsharing in the last month represent 4.8% of the Munich subsample, while this percentage is lower for the case of Madrid (3.1%). The same trend is observed for respondents making between 4 and 10 trips by carsharing in the last month since the share for Munich (7.8%) is again higher than the case of Madrid (4.8%). In this regard, the higher presence of intensive carsharing users in the Munich subsample may be a result of the longer timespan after the carsharing implementation, as well as the greater number of shared cars per inhabitant, in the German city compared to the Spanish one (see more details in Table 2).

4. Methodology

In order to explore people's behavior towards the adoption and frequency of use of carsharing, this paper estimates a choice model at the individual level based on a Generalized Structural Equation Model (GSEM). This modeling methodology provides a flexible tool to study the sequential relationships between multiple variables and accommodate cause-effect structures (see Section 4.2). This approach, increasingly adopted in transport research studies (see e.g., Yin et al., 2020; Aguilera-García et al., 2022), also allows us to integrate the latent behavioral constructs into discrete choice models based on the utility-maximizing framework (Ben-Akiva et al., 2002). To this end, before building the choice model, the underlying latent constructs were identified through the factor analysis (see Section 4.1).

4.1. Latent psychological constructs

As noted in Section 3.2, surveyed people were asked about 18 behavioral/psychological statements on different topics. This information was employed to build the unobserved latent variables, which capture different psychological and behavioral aspects of individuals in Madrid and Munich that may impact carsharing usage. For this purpose, an EFA was conducted to find hypothetical relationships between the underlying latent attitudes (factors) and the observed indicators that adequately account for the patterns of covariance among them. The correlation structure across observed indicators and latent variables obtained with the EFA was then validated through a Structural Equation Modeling (SEM) developed as CFA. The reader is referred to Bollen (1989) for an extensive discussion. The results of this process are presented in detail in Section 5 due to their inherent interest.

4.2. Analytical approach: Generalized Structural Equation Model (GSEM)

The GSEM-based approach enables us to represent a joint estimation of multi-stage interrelations between numerous endogenous variables of interest at the individual level, as well as the incorporation of exogenous and latent psychological variables. Hence, these models are not limited to studying the effect of explanatory exogenous variables on a single dependent endogenous variable. Additionally, unlike traditional SEM, GSEM allows for the joint estimation of nominal, ordinal, and continuous variables (Rabe-Hesketh et al., 2004). The GSEM approach can include link functions $g(\cdot)$ of different nature such as logit, probit, or linear regressions, and statistical distributions F such as Bernoulli, binomial, gamma, Gaussian, multinomial, or ordinal. Then, the link functions $g(\cdot)$ specify how the response variable y_i is related to a linear equation of the explanatory variables, $x_i\beta$, and the family F specifies the distribution of y_i:

$$g\{E(y_i)\} = x_i\beta, \quad y_i \sim F \tag{1}$$

Our investigation of people's behavior towards the adoption and frequency of use of carsharing comprises a joint estimation of both variables of interest at the individual level as functions of exogenous sociodemographic and latent psychological variables, along with additional endogenous variables by employing a discrete choice framework in a sequential manner. The model equation can be written as

$$\boldsymbol{Y} = \boldsymbol{\alpha} + \boldsymbol{BY} + \boldsymbol{\Gamma X} + \boldsymbol{\zeta} \tag{2}$$

where $\mathbf{Y}$ is the vector of all endogenous variables, $\boldsymbol{\alpha}$ is the vector of intercepts for the endogenous variables, $\mathbf{B}$ is the matrix of coefficients on endogenous variables, $\boldsymbol{\Gamma}$ is the matrix of coefficients on exogenous variables, $\mathbf{X}$ is the vector of all exogenous variables, and $\boldsymbol{\zeta}$ is the vector of all error variables. The standard calibration method is the maximum likelihood estimation. For further details on GSEM, as well as its estimation process and likelihood expressions, the reader is referred to Rabe-Hesketh et al. (2004) and Bartus (2017).

Fig. 1 shows an overview of the proposed model adopted. The five latent psychological constructs previously identified in the CFA were defined as functions of exogenous sociodemographic variables and an unobserved error term. It is important to mention that this model relationship is not directly estimable but is estimated through observations on the latent construct indicators. The stochastic latent constructs, along with the exogenous sociodemographic variables, serve as determinants of the latent utilities of the observed outcomes characterizing the endogenous variables of interest. To sum up, this part of the analysis enables us to simultaneously analyze i) the links between the latent constructs and their corresponding indicators, ii) the correlation between the latent constructs, and iii) the relationships of dependence between the latent constructs and both exogenous sociodemographic variables and the main outcome variables of interest. The latent construct indicators are not shown in Fig. 1 to avoid clutter but see Table 5 later and Section 5 for a discussion of these indicators.

Simultaneously, the six endogenous outcome variables of interest (residential location, vehicle availability, weekday mobility rates, weekend mobility rates, carsharing adoption, and frequency of use of carsharing) are jointly modeled as functions of both exogenous and latent variables by employing a discrete choice framework in a sequential manner. In our case, we have specified that $g(\cdot)$ is the logit function and F the binomial, multinomial, or ordinal distribution, depending on the nature of the dependent endogenous variable. The following sequential structure is adopted (see Fig. 1): residential location influencing both weekday and weekend mobility rates, and these three variables impacting, in turn, vehicle availability. Furthermore, these four variables are assumed to have an impact on carsharing adoption. Finally, the frequency of use of carsharing is considered as a function of the other five endogenous variables. It is worth noting that carsharing adoption enables us to control the potential self-selection effect coming from people who have not used these services yet. This

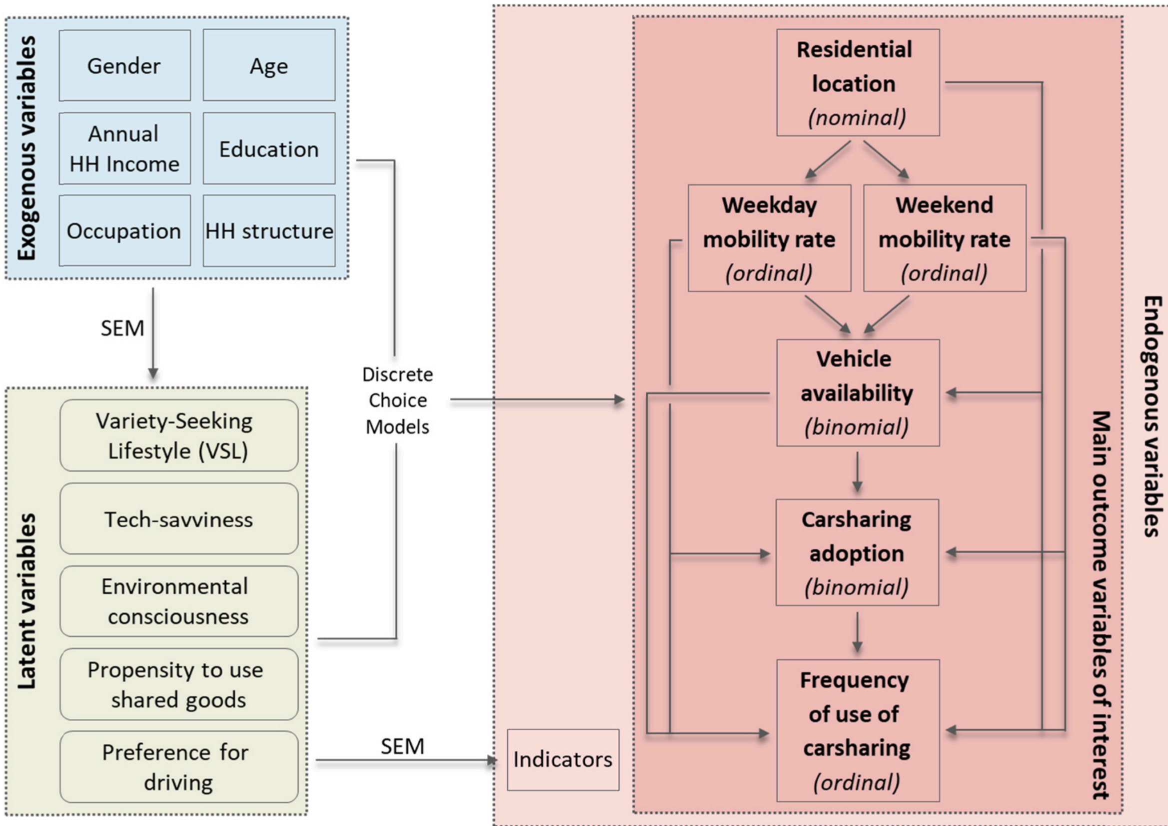

Fig. 1. Path diagram of the GSEM adopted to explain carsharing adoption and frequency of use.

Table 5
Attitude statements of indicators in the survey questions, constructs, and factor loadings obtained in the EFA.

Indicator codes	Attitude statements in the survey	Madrid					Munich				
		F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
VSL1	I think it is important to have all kinds of experiences and I am always trying new things	0.810	–	–	–	–	0.583	–	–	–	–
VSL2	I love to try new products before anyone else	0.728	–	–	–	–	0.665	–	–	–	–
VSL3	Looking for adventures and taking risks is important to me	0.852	–	–	–	–	0.789	–	–	–	–
VSL4	I regularly use sharing economy apps or websites: Airbnb, Wallapop, Couchsurfing, etc.	–	–	–	–	–	0.741	–	–	–	–
TEC1	I frequently use online social media (e.g., Facebook, Twitter, Instagram, or Snapchat)	–	0.651	–	–	–	–	0.733	–	–	–
TEC2	I regularly use internet services or mobile applications to facilitate my daily life: banking services, online purchases, GPS navigation, email, etc.	–	0.847	–	–	–	–	0.881	–	–	–
TEC3	Learning how to use new smartphone apps and testing them is easy for me	–	0.817	–	–	–	–	0.805	–	–	–
ENV1	When choosing my transportation mode, I try to be environmentally friendly	–	–	0.762	–	–	–	–	0.790	–	–
ENV2	I recycle at home	–	–	0.810	–	–	–	–	0.827	–	–
ENV3	Generally, I am willing to pay more for a product that is more environmentally friendly	–	–	0.762	–	–	–	–	0.708	–	–
SHA1	I am willing to purchase second-hand products	–	–	–	0.736	–	–	–	–	0.735	–
SHA2	I am willing to use/put on objects that have been used by many people before me	–	–	–	0.811	–	–	–	–	0.803	–
SHA3	I feel comfortable traveling with strangers	–	–	–	0.620	–	–	–	–	0.594	–
SHA4	I am willing to share a ride with strangers if it reduces my costs	–	–	–	–	–	–	–	–	–	–
DRI1	I like driving	–	–	–	–	0.747	–	–	–	–	0.820
DRI2	I prefer driving in my own vehicle even if I waste time looking for parking	–	–	–	–	0.759	–	–	–	–	0.764
DRI3	I don't mind using a mode of transport which doesn't allow me to take advantage of the time: reading, studying, working, using my mobile, watching movies, etc.	–	–	–	–	0.614	–	–	–	–	–
DRI4	I usually feel stressed when driving in heavy traffic/jams	–	–	–	–	–	–	–	–	–	–

enables us to better explore the frequency of use of carsharing since this variable only considers users of these services. Therefore, 421 and 223 individuals make up the subsamples for modeling carsharing frequency of use in Madrid and Munich, respectively. The Stata 15 software was employed for conducting the modeling analysis.

5. Latent variables constructs

As already noted in Section 3.2, respondents were requested to rate on a 5-level Likert scale their level of agreement towards different statements concerning: proneness to technology, environmental consciousness, preferences for driving, etc. Statements included in the questionnaire were the same for both cities, and the scoring system employed to measure individuals' attitudinal behavior ranged from 1 (unidentified/unlikely) to 5 (highly identified/likely). These data have been subsequently employed to capture the five unobserved latent constructs of our model, aimed at capturing different psychological and behavioral aspects of individuals that may impact carsharing usage. In order to include adequate heterogeneity in each latent/psychological variable and mitigate the yes-saying effect, the attitudinal statements were mixed throughout the questionnaire, and they were not designed in a homogeneous way. We should note that these statements were later redrafted in a homogeneous direction and presented in defined blocks in this article to provide a clearer understanding to the readers (see Table 5).

Firstly, EFA with orthogonal varimax rotation was developed to analyze the underlying theoretical structure of the constructs and the internal consistency of the indicators. A factor loading of 0.50 was selected as the threshold value to keep the indicators within a factor. Factor loadings reveal the direction and strength of an attitude statement on a factor. Table 5 shows the attitudinal items finally used to construct each latent psychological variable, as well as their factor loadings, which were all as expected.

Factor 1 is associated with statements that capture individuals' tendency to have a varied lifestyle in terms of experiences, as well as the inclination to try or purchase new products, goods, or services. As can be observed in Table 5, this first factor includes three indicators for the case of Madrid and four indicators for the case of Munich. Factor 2 captures the tech-savviness of the individuals through three statements in both cities. Factor 3 is associated with three indicators reflecting pro-environmental attitudes. Factor 4 is associated with the same three indicators in both cities and refers to individuals' propensity to share and privacy sensitivity. Finally, three indicators in Madrid and two in Munich characterize Factor 5, which measures the personal preference toward driving a car. As can be observed, two attitude statements obtained a factor loading lower than 0.50, thus they were removed from the analysis. Based on these results, we built 5 latent variables named "Propensity to adopt a Variety-Seeking Lifestyle (VSL)", "Tech-savviness", "Environmental consciousness", "Propensity to use shared goods", and "Intrinsic preference for driving".

Then the Kaiser-Meyer-Olkin (KMO) test was calculated. KMO measures sampling adequacy for each variable and the whole model, and thus determines the proportion of variance in the variables that might be caused by the underlying factors. KMO indicated the adequacy of the subsamples of Madrid and Munich (obtained values of 0.756 and 0.795 respectively) and the suitability of the factor analysis technique for this dataset. In addition, Bartlett's test of sphericity was assessed, and null values of the significance level were obtained, which also upholds the use of the Factor Analysis technique in this research.

Finally, SEM is used as CFA to determine the extent to which the hypothesized structure is consistent with the EFA results, as well as to test whether the data fit a postulated latent variable measurement model. After fitting the models, a set of overall goodness-of-fit statistics were performed, and the following results were obtained for the case of Madrid and Munich, respectively: Root Mean Square Error of Approximation (RMSEA) = 0.066 and 0.070, Comparative Fit Index (CFI) = 0.897 and 0.913, Tucker Lewis Index (TLI) = 0.864 and 0.885, Standardized Root Mean Square Residual (SRMR) = 0.067 and 0.054, and Coefficient of Determination (CD) = 0.998 and 0.999. These statistics uphold the validity of the latent variables according to the recommended cutoff values in the literature (see e.g., Akaike, 1987; Hu and Bentler, 1999; Kline, 2016).

6. Modeling results and discussion

The GSEM estimation results are presented in the following subsections. Section 6.1 explains the structural relationships between sociodemographic and latent psychological variables. Section 6.2 briefly shows the modeling results for the first block of endogenous outcome variables. Section 6.3 presents and discusses the findings from the models explaining the main variables of interest in this research: adoption of carsharing (see Section 6.3.1), and frequency of use of carsharing (see Section 6.3.2). Finally, Section 6.4 sets out the policy implications from this research.

It is important to mention that the final model specification is the result of a process of testing alternative combinations of variables. Furthermore, non-statistically significant variables were subsequently phased out to get parsimonious specifications, although some of them have been preserved since they provide intuitive interpretations and insights (see Tables 6 and 7, and Appendix A and B). Furthermore, these effects may provide input to specifications in future research with larger sample sizes.

6.1. Sociodemographic determinants of latent variables

Table 6 presents the model estimation results for the structural relationships between sociodemographic and latent variables. Regarding the propensity to adopt a VSL, it should be noted that age is the only statistically significant variable in both Madrid and Munich. In line with many findings in the social psychology literature (see e.g., McCrae et al., 2000; González Gutiérrez et al., 2005), the results suggest a lower VSL as people age increases. The analysis also indicates that, for the case of Madrid, females are associated with a lower propensity to adopt a VSL. This result has been explained in the literature on human values and consumer behavior since men are generally more open to new changes and experiences (McAlister and Pessemier, 1982; Schwartz and Rubel, 2005). In the case of Munich, the modeling results suggest a significantly higher propensity to a VSL for individuals with higher incomes. This can be a direct result of having higher purchasing power to pursue a wider variety of different activities, as noted by Lavieri and Bhat (2019).

The SEM results also find that the tech-savviness of the individuals from both cities differs significantly with age and educational level. Some previous research (see e.g., Garrido-Lora et al., 2016; Lavieri et al., 2017; Rogers et al., 2017) indicated that the use of smartphones and familiarity with new technologies is strongly related to high education levels. Furthermore, tech-savviness is lower as age increases, because of lower exposure to new technologies. Nevertheless, this result differs for the two samples. In Madrid, this effect is observed for all age categories, while in Munich it is only statistically significant for people aged 50 and over. Strong connections are also found between tech-savviness and level of income, in the sense that respondents with higher levels of income in Madrid are more likely to be tech-savvy than low-income

Table 6
Sociodemographic determinants of latent variables.

VARIABLES (base category)	STRUCTURAL EQUATIONS MODEL COMPONENT RESULTS									
	VSL		TECHY		ENVIRONMENT		SHARER		DRIVER	
	Madrid	Munich	Madrid	Munich	Madrid	Munich	Madrid	Munich	Madrid	Munich
Gender (male)										
Female	−0.137***	–	–	–	–	0.187***	−0.112**	–	−0.269***	–
Age (under 25)										
25 to 34	−0.131	–	−0.141**	–	0.135*	–	–	–	–	–
35 to 49	−0.424***	−0.133**	−0.343***	–	0.205**	–	–	–	–	–
50 to 59	−0.538***	−0.414***	−0.616***	−0.297***	0.290***	–	−0.194***	–	–	–
Above 59	−0.769***	−0.456***	−0.830***	−0.812***	0.264**	–	−0.304***	−0.259**	–	–
Annual HH income [a] (Rank 1)										
Rank 2	–	0.221***	0.201***	–	0.278***	0.208**	–	–	0.221**	0.239*
Rank 3	–	0.411***	0.220***	–	0.264***	0.260***	–	−0.270***	0.275***	0.328**
Rank 4	–	0.141	0.311***	–	–	0.238**	−0.227**	−0.165	0.273**	0.256*
Rank 5	n/a	0.300***	n/a	–	n/a	0.447***	n/a	–	n/a	0.317*
Education (lower secondary education)										
Upper secondary education	n/a	–	n/a	0.260***	n/a	–	n/a	–	n/a	–
University studies	–	–	0.123**	0.132	–	0.147**	–	–	0.161**	–
Occupation (employed)										
Student or part/student	–	–	–	–	–	–	–	0.409***	–	−0.595***
Other: housework, unemployed or retired	−0.387***	−0.494***	−0.271***	−0.562***	–	–	–	–	–	−0.275**
Household structure (living alone)										
Living with flatmates	–	–	0.188***	–	–	–	–	0.298***	−0.204**	–
Couple without children	−0.151**	–	–	–	–	–	–	–	–	–
Couple with children below 24	–	–	–	–	–	–	–	0.148	0.131**	0.241***
Couple with all children above 25	–	–	−0.131*	–	–	–	–	0.442*	–	0.502**
Other	–	–	–	–	–	–	−0.174*	–	–	–
Correlations between latent variables										
VSL	1.000	1.000								
TECHY	0.288***	0.402***	1.000	1.000						
ENV. CONSCIOUSNESS	0.315***	0.310***	0.199***	0.308***	1.000	1.000				
SHARER	−0.065**	−0.143***	−0.149***	−0.191***	–	−0.105***	1.000	1.000		
DRIVER	0.156***	0.193***	0.117***	0.226***	−0.178***	0.121***	−0.148***	−0.217***	1.000	1.000

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.
[a] Annual HH income in Munich: Below 21,000 Euro (Rank 1); 21,000 to 41,000 Euro (Rank 2); 41,000 to 60,000 Euro (Rank 3); 60,000 to 100,000 Euro (Rank 4); Above 100,000 Euro (Rank 5). Annual HH income in Madrid: Below 18,000 Euro (Rank 1); 18,000 to 30,000 Euro (Rank 2); 30,000 to 60,000 Euro (Rank 3); Above 60,000 Euro (Rank 4).

individuals. In general, these findings are in line with previous studies analyzing tech-savviness and purchasing capacity to buy technological services and accessories (see e.g., Carey, 1989; Berkowsky et al., 2017; Astroza et al., 2017; Lavieri and Bhat, 2019).

Regarding environmental consciousness, the demographics-related factors associated with this latent construct differ for the two cities analyzed. In the case of Madrid, the modeling results indicate a higher pro-environmental attitude as age increases. Interestingly, in this city, the effect of income suggests a kind of inverted U-shaped relationship, in the sense that people with a moderate level of income (between 18,000 and 60,000 Euro) have a higher environmental consciousness than low and high-income individuals. For the case of Munich, it is found that those respondents who reported a greater preference towards a green lifestyle were mainly females, highly educated people, and belonged to high-income groups. It is worth noting that these findings are consistent with many others reported in the social psychology literature (see e.g., Sundblad et al., 2007; McCright, 2010; Franzen and Vogl, 2013), in which some differences can also be noted depending on the tradition and culture of the specific country analyzed.

As for sharing propensity, similar results are found in both case-study contexts. The model identifies lower sharing attitudes among older respondents. As pointed out by Kim et al. (2017), aged individuals are more prone to avoid shared spaces with strangers. Furthermore, as respondents have a higher level of income, they show a statistically significant lower propensity to use shared products and services. This clearly reflects the higher accessibility to private goods and services of wealthy individuals, in line with Chevalier and Gutsatz (2012). Some modeling results differ among contexts. In the case of Madrid, females are significantly less likely to have sharing attitudes. For the case of Munich, a statistically significant higher propensity to use shared goods and services is observed among students, individuals living with flatmates, and those with grown-up children (see Table 6).

The last latent construct captured the intrinsic preference for driving. As can be observed in Table 6, some findings are similar for both Madrid and Munich. As expected, the modeling results indicate an increasing tendency to drive for individuals with higher incomes and living with children, compared to other household structures. The results suggest that these sociodemographic characteristics generate a greater reliance on using the private vehicle to fulfill travel needs. In fact, the scientific literature has noted that age, presence of children, and employment have a significant impact on car use (see, for example, Buehler, 2010). Other modeling results significantly vary between the two cities. For instance, the model indicates that females are less prone to drive than males in the case of Madrid, similarly to Kim et al. (2017) in the Netherlands. Furthermore, statistically significant relationships are obtained between individuals' preference for driving and higher levels of education. By contrast, in the case of Munich, individuals' occupation influences the preference for driving, in the sense that employees are significantly more prone to drive, which could also be linked to access to company cars.

Finally, we comment on relationships found between latent constructs in the model. As can be observed in Table 6, all correlations are statistically significant, except for the relationship between sharing propensity and environmental consciousness in the Madrid case study.

The large majority of the statistically significant correlations are positive, while only a few of them are negative. For instance, the correlations between the propensity to use shared goods and the other latent variables are negative in both Madrid and Munich. In the case of Madrid, the correlation between the intrinsic preference for driving and environmental consciousness is negative, while the opposite effect is obtained in Munich. This result is important to be highlighted because it suggests different behavior in both cities regarding the preference for driving and pro-environmental attitudes. It might be explained by the lower supply of public transport network in Munich, which generates a greater reliance on the private vehicle to travel, despite the personal environmental consciousness. One may also consider the strength of the German automobile industry as a factor indirectly leading to higher driving rates in Munich. In fact, modal share in the Bavarian capital shows a higher presence of private vehicles, as commented in Section 3.1, despite policy efforts, practices, and innovation, and citizens with pro-environmental behaviors (City of Munich, 2010; Tölkes and Butzmann, 2018).

6.2. Model estimation results for the co-endogenous variables

This section summarizes the GSEM-based analysis results for residential location, weekday/weekend mobility rates, and vehicle availability, including the influence of both sociodemographic and latent variables on these co-endogenous variables. To save space, the results obtained from the Madrid and Munich subsamples are included in Appendix A and B, respectively. Below, we emphasize the most relevant aspects of each variable.

As seems reasonable, residing outside the city center is positively correlated with the intrinsic preference for driving, while the opposite appears to be with the propensity to adopt a VSL. This result may reflect that people with a high VSL tend to live where they can easily find diverse kinds of leisure and cultural activities. Furthermore, given that the use of private vehicles is higher in less dense urban areas with a scarce presence of public transit, this finding may be consistent with higher pleasure in driving a car in these areas. The modeling results for the residential location also identify strong relationships with sociodemographic variables, with significant expected results in both Madrid and Munich.

As for weekday and weekend mobility rates, we can observe higher mobility ratios in both cities among individuals with high levels of VSL construct (i.e., people more open to conducting a variety of activities over the weekends, or before or after their work shift). Interestingly, we can also observe that age and residential location significantly influence weekend mobility rates. In this regard, aged individuals are more likely to have lower mobility rates during weekends. Additionally, people residing outside the city center show lower weekend mobility ratios, indicating the lesser variety of activities available outside the city center.

Finally, the model presents sound results related to vehicle availability. In both cities, this variable is positively correlated with the pleasure or preference for driving a car, as could be expected. Other variables, such as annual HH income and educational level, influence vehicle availability for both Madrid and Munich similarly, with high income and highly educated respondents being more likely than their counterparts to have access to a motorized vehicle at home for their personal use. Regarding household structure, families with young children in both cities are also more likely to have a vehicle available. Finally, residents living in the metropolitan area of both cities (beyond the municipal limits of each city) are more likely to own or have access to a private vehicle to fulfill their travel needs. This result is also consistent with the higher preference for driving a car obtained among people residing outside the city center and the lower supply of transit services in these areas.

6.3. Model estimation results for adoption and frequency of use of carsharing

The variables explained in Section 6.2 (residential location, weekday/weekend mobility rates, and vehicle availability) are modeled as co-endogenous so that we can control for self-selection effects when analyzing their influence on carsharing behavior. The modeling estimation results for the adoption and frequency of use of carsharing systems in both cities are presented in Table 7 (see more details in Appendix A and B). The model shows interesting findings related to carsharing usage when comparing both Madrid and Munich cities, as discussed below.

Table 7
Results of carsharing adoption and frequency model components.

VARIABLES		Carsharing adoption (base: never used)		Frequency of use of carsharing (ordinal)	
		Madrid	Munich	Madrid	Munich
LATENT VARIABLES	VSL	0.204*	–	0.380***	0.649**
	TECHY	0.623***	–	–	–
	ENV. CONSCIOUSNESS	−0.398***	–	–	−0.485*
	SHARER	0.338***	0.269*	–	–
	DRIVER	–	0.411**	0.365**	–
EXOGENOUS VARIABLES	*Gender (male)*				
	Female	−0.370***	–	–	−0.382
	Age (under 25)				
	25 to 34	–	–	−0.410**	–
	35 to 49	−0.326**	0.424**	–	–
	50 to 59	−0.494**	–	–	–
	Above 59	−0.494**	–	–	–
	Annual HH income [a] *(Rank 1)*				
	Rank 2	0.335*	0.350	1.094***	1.035**
	Rank 3	0.534***	0.350	–	0.859*
	Rank 4	0.632***	0.458*	–	1.054**
	Rank 5	n/a	0.744**	n/a	1.564**
	Education (lower secondary education)				
	Upper secondary education	n/a	0.575***	n/a	–
	University studies	0.448***	0.445**	–	–
	Occupation (employed)				
	Student or part/student	–	–	−0.813***	–
	Other: housework, unemployed or retired	–	–	–	–
	Household structure (living alone)				
	Living with flatmates	–	–	–	–

(continued on next page)

Table 7 (*continued*)

VARIABLES		Carsharing adoption (base: never used)		Frequency of use of carsharing (ordinal)	
		Madrid	Munich	Madrid	Munich
	Couple without children	–	–	–	–
	Couple with children below 24	–	–	–	–
	Couple with all children above 25	–	–	–	–
	Other	–	–	–	–
ENDOGENOUS VARIABLES	*Residential location (inside the innermost ring road)*				
	Inside city boundary (outside the innermost ring road)	−0.553***	–	–	–
	Outside city boundary	−1.370***	−0.720***	–	–
	Weekday mobility (zero trips)				
	1 to 2 trips	–	–	–	0.623
	3 or more trips	–	0.488**	–	0.879*
	Weekend mobility (zero trips)				
	1 to 2 trips	–	–	0.567**	–
	3 or more trips	–	0.370*	0.483*	–
	Vehicle availability (no availability)				
	Availability	0.611***	−0.522**	–	−0.603**

***p < 0.01; **p < 0.05; *p < 0.1.

[a] Annual HH income in Munich: Below 21,000 Euro (Rank 1); 21,000 to 41,000 Euro (Rank 2); 41,000 to 60,000 Euro (Rank 3); 60,000 to 100,000 Euro (Rank 4); Above 100,000 Euro (Rank 5). Annual HH income in Madrid: Below 18,000 Euro (Rank 1); 18,000 to 30,000 Euro (Rank 2); 30,000 to 60,000 Euro (Rank 3); Above 60,000 Euro (Rank 4).

6.3.1. Carsharing adoption

The model results for the adoption of carsharing are shown in the first numeric column of Table 7. Statistically significant results are found for some latent variables, with a clear effect of individuals' sharing propensity on the adoption of carsharing in both cities. As expected, individuals with a high sharing propensity have a significantly higher likelihood of adopting carsharing services. This relationship has been also cited by Velázquez Romera (2019) and seems reasonable given that vehicles used in this mobility service are shared successively by people registered in the system.

The results for Madrid point out the crucial role of psychological constructs in carsharing adoption. First, unlike in Munich, a positive statistically significant relationship is found between the VSL construct and carsharing adoption. At this point, we should remind that carsharing was introduced in Madrid later than in Munich (see more details in Section 3.1). This result may indicate that this service is still considered a fairly new and trendy transportation mode in the Spanish city. Supporting this finding, Lavieri and Bhat (2019) pointed out that individuals with a high VSL may be more prone to adopt different transportation modes. In Madrid, we also observe a higher carsharing adoption among people with high levels of the tech-savviness construct. This relationship is reasonable given that people only can access shared cars via a mobile application. Accordingly, Acheampong and Siiba (2020) indicate that tech-savvy people are more likely to adopt carsharing. In the case of Munich, however, a technological gap cannot be concluded between users and non-users of carsharing services.

Furthermore, environmental consciousness significantly affects the adoption of carsharing in Madrid. In this regard, pro-environmental behaviors may lead to reducing the use of shared cars, as already pointed out by Kim et al. (2017) for the Netherlands and Mattia et al. (2019) for Italia. This result for Madrid contrasts with some previous research on the intention to join carsharing (see e.g., Efthymiou and Antoniou, 2016 for Greece; Acheampong and Siiba, 2020 for Ghana; Jin et al., 2020 for China; Hjorteset and Böcker, 2020 for Norway). However, it should be noted that these studies were conducted in cities where carsharing services were not yet implemented. Our results appear to suggest that people with pro-environmental attitudes tend to prefer using more typical environmentally friendly transportation modes (such as active modes or public transport) rather than shared cars for their urban trips. The same is not found for the Munich case, maybe due to the relationship observed between environmental consciousness and preference for driving in the German city (see the correlations between latent variables in Table 6).

As expected, the preference for driving a car is positively related to carsharing adoption in Munich. This means that individuals who generally find driving a car pleasurable are more likely to adopt carsharing services. This effect is also present in the context of Madrid when explaining the frequency of use of shared cars (see comments below). Similar results are obtained by Kim et al. (2017) for people's intention to use carsharing and the intrinsic preference for driving. As can be observed, in Munich once sharing propensity and the intrinsic preference for driving are accounted for, there are no statistically significant remaining effects of VSL, environmental consciousness, and even tech-savviness on carsharing adoption.

Some sociodemographic factors were found statistically significant when explaining carsharing adoption in both Madrid and Munich. As can be observed, people with a higher income and education levels are more likely to be carsharing adopters, which has been cited throughout the literature in other case studies (see e.g., Efthymiou and Antoniou, 2016; Clewlow, 2016; Becker et al., 2017; Dias et al., 2017; Hjorteset and Böcker, 2020). Furthermore, higher education may increase familiarity with carsharing due to greater information exchange and extensive knowledge about new transportation modes.

Table 7 also indicates that men and younger individuals (below 34) are more likely to adopt carsharing in Madrid, which is also consistent with the higher propensity found for these individuals to use shared goods and services and adopt a VSL. Although the model did not find differences in terms of gender in the case of carsharing adoption in Munich, this effect is observed when exploring the frequency of use of shared cars. These findings are also in line with many others reported in the scientific literature on new urban mobility services such as Martin and Shaheen (2011b), Habib et al. (2012), Dias et al. (2017), Velázquez Romera (2019), and Hjorteset and Böcker (2020). However, age has a different outcome on carsharing adoption in Munich, where middle-aged individuals (from 35 to 49 years old) are more likely to adopt carsharing.

Concerning endogenous variables, individuals residing in inner and denser districts are more likely to adopt carsharing compared to individuals living in the outskirts. This finding is not surprising, since carsharing supply is concentrated in highly dense areas, and similar results were obtained in previous investigations conducted on the carsharing literature (see e.g., Kopp et al., 2015; Dias et al., 2017; Hjorteset and Böcker, 2020). Interestingly, the results also show a positive and significant relationship between higher mobility rates (both on weekdays and weekends) and carsharing adoption in the case of Munich. For the case of Madrid, the role played by mobility rates on carsharing usage seems to be captured instead by the variable 'frequency of use' (see comments below). Finally, regarding the role played by vehicle availability, opposite results are obtained in Madrid and Munich. For the case of Madrid, the model indicates a higher likelihood of adopting carsharing among individuals who have access to a motorized private vehicle for their personal use. This result contrasts with the one obtained in Munich, as with many findings usually reported in the carsharing research literature (see e.g., Ter Schure et al., 2012; Giesel and Nobis, 2016; Hjorteset and Böcker, 2020; Jochem et al., 2020).

6.3.2. Frequency of use of carsharing

The results for the frequency of use of carsharing, which was only reported by individuals who claimed to have ever used this service, are presented in the right-hand columns of Table 7 once controlling for carsharing adoption. Interestingly, the GSEM-based approach used in this research reinforced the importance of certain latent/psychological constructs on carsharing usage. Taking advantage of the latent variables results, some indirect socio-demographic effects are also discussed.

The only latent construct with a statistically significant influence on the frequency of use of carsharing in both cities is the VSL construct. Again, this finding suggests that carsharing is more frequently used by people with higher VSL, who are mostly young (under 35) in both cities and also men in Madrid. In Madrid, carsharing is more frequently used by individuals who enjoy driving a car, which is related to males, higher incomes, and higher levels of education. As commented above, similar effects are obtained in the context of Munich for carsharing adoption, as well as by Kim et al. (2017) when explaining the willingness to use carsharing for the Netherlands.

As with the case of carsharing adoption in Madrid, pro-environmental behaviors have negative effects on the frequency of use of carsharing in Munich, so certainly this transportation mode is not perceived as green mobility in Munich either. Although respondents with a green lifestyle may be willing to join a carsharing system, they tend to prefer using more environmentally friendly mobility services such as collective/public transport or active modes (walking or cycling), as pointed out by Kim et al. (2017). These results show the importance of pro-environmental behaviors on carsharing use when analyzing a case study of a real implementation of this service.

Statistically significant results are also found for the effect of demographics-related factors on the frequency of use of carsharing, but none is coincident for the two case studies. For instance, women present a lower frequency of use of carsharing in Munich. In Madrid, this effect may be obtained from the indirect influence through two latent constructs, VSL and intrinsic preference for driving a car. In this regard, other research papers, such as Velázquez Romera (2019) and Hjorteset and Böcker (2020), already pointed out such differences in terms of gender in carsharing adoption.

Once controlling for carsharing adoption, the model presents interesting findings related to the level of income when explaining the frequency of use of carsharing, with differing findings among cities. In Madrid, middle-income individuals (with annual household income from 18,000 to 30,000 Euro) present a higher frequency of use of carsharing. According to this result, the relationship between the level of income and frequency of use of carsharing responds to an inverted U-shaped curve. The modeling results indicate that carsharing use is significantly lower between both low-income groups (it may be due to the well-known 'income effect') and high-income groups (who may prefer driving their privately-owned luxury vehicles or using ride-hailing services). By contrast, in the case of Munich, the frequency of use of carsharing increases with the level of income. Additionally, in Madrid, students, part-time employees, and those individuals from 25 to 34 show less intensive use of carsharing compared to their counterparts.

Mobility patterns also play a major role when exploring the frequency of use of carsharing, and some differences can be also observed between the two cities that are worth noting. For the case of Madrid, respondents with higher mobility rates during the weekend show a higher frequency of using carsharing services. This finding may indirectly indicate that young and people with high levels for VSL construct are more likely to use carsharing more frequently. Therefore, there may be higher carsharing demand during the weekends to conduct out-of-home leisure activities or errands, as previously outlined by Wielinski et al. (2016). By contrast, this effect is not observed in Munich, where a higher frequency of use of carsharing is obtained for individuals with higher weekday mobility rates. Differences between both cities in this respect may be a reflection of different outgoing behaviors between Mediterranean and Central Europe societies, or different segments of the population (young adults vs. middle-aged adults) using more intensively carsharing in each city. Finally, it is worth noting that carsharing usage in Munich is higher among respondents who do not have access to a vehicle for their personal use.

6.4. Discussion and policy implications

Free-floating carsharing can currently be considered a new player within the transport system of medium and large cities. This research found both common and diverging trends between Madrid and Munich, thereby suggesting that the performance of carsharing systems may depend on a large number of factors that vary from city to city (see more details in Section 3.1, and Table 2). Therefore, the design of an effective carsharing system needs to rely not only on general trends, but also on their interaction with specific characteristics of the urban form, the existing transportation network, and mobility dynamics, as well as the sociodemographic context of each city.

6.4.1. Implications coming from individuals' characteristics and lifestyle attitudes

This research shows that different attitudes and lifestyles of individuals due to cultural characteristics explain variations in the use of carsharing. For example, the technological gap seems to be greater in Madrid than in Munich, significantly impacting carsharing use. In fact, while younger individuals (below 34) are more likely to adopt carsharing in Madrid, in Munich this service appears to be used by broader segments of the population, such as middle-aged individuals (from 35 to 49 years old). Another explanation for that fact may be that carsharing in Munich was implemented four years earlier than in Madrid. As a result, the Munich respondents appear to be more familiar with carsharing services compared to the Spanish city. It should be also taken into account that the number of shared cars per inhabitant in the city of Munich is higher than in Madrid (see Table 2). Anyway, insofar as mobility gets back to pre-COVID19 standards, it is expected that carsharing use will increase in Madrid as tech-savviness penetrates older segments of the population and carsharing is better known.

Interestingly, our results also demonstrate the importance of environmental awareness in the use of carsharing. As could be observed, carsharing is not perceived as a green transport mode, since higher environmental consciousness reduces individuals' carsharing usage. In the case of Madrid, pro-environmental attitudes negatively impact the adoption of carsharing, despite having a fully electric or plug-in hybrid shared car fleet. Therefore, carsharing operators in Madrid should strive to show and demonstrate the environmental advantages of the service compared with less environmentally friendly mobility options such as private vehicles powered by fossil fuels. Thus, operators may improve general perception towards the adoption/usage of shared ZEVs when the private car is less attractive (e.g. to access the city center or areas with private car restrictions). Additionally, this would in turn help in reducing the levels of car ownership, as previously mentioned by Ter Schure et al. (2012), Firnkorn and Müller (2015), Giesel and Nobis (2016), Jochem et al. (2020), or Liao et al. (2020). This result contrasts with Munich, where there is not a significant result on carsharing adoption depending on environmental behavior, even though the carsharing fleet in this city is mostly made up of conventional fossil fuel vehicles (less than 15% are electric shared cars). This may be due to different social and mobility dynamics (e.g., the strength of the German automobile industry may lead to greater reliance on the private vehicle to travel, despite the personal environmental consciousness). However, once controlling for adoption, pro-environmental attitudes do have negative effects on the frequency of use of carsharing in Munich. In other words, people with a high environmental awareness would use greener mobility options (public transport, walking, or cycling) than a shared car for their urban trips despite having adopted carsharing. Again, the insights obtained from our research may better explain the increased adoption and intensive use of carsharing observed in Munich compared to Madrid.

Growing environmental concerns observed among the population (see e.g., Kachaner et al., 2020) may lead to the implementation of measures to improve air quality in urban areas. These can include restrictions to the use of private vehicles (urban pricing, low emission zones, on-street parking regulation, etc.) in e.g., city centers according to the environmental label of vehicles. Under this scenario, electric shared cars may become a more appealing and competitive option when traveling in the city. Furthermore, both growing environmental concerns and the implementation of car restrictions are powerful drivers to change carsharing fleets from fossil-fuel to ZEVs in cities like Munich.

6.4.2. *Implications coming from mobility patterns*

This research also found interesting relationships between mobility patterns and carsharing usage, with some differences between the two cities. The positive relationship found in Madrid between carsharing adopters, and the availability of a personal vehicle might be explained by the fact that people who use their private vehicle more frequently may be more used to making door-to-door trips. Those people may find free-floating carsharing a convenient alternative when another household member needs to use the private car, when restrictions are applied to polluting vehicles in certain areas of the city, or when parking is very expensive. These results contrast with the ones obtained in Munich, where carsharing use seems to be related to people who do not have access to a private vehicle for their personal use but need a car for their urban trips. Furthermore, the results suggest that carsharing usage in Madrid can be mainly associated with weekend mobility, which usually is related to occasional leisure trips. As the supply of public transport services is noticeably lower during weekends, carsharing can represent a relevant mobility option in this context, as also outlined by Ampudia-Renuncio et al. (2020) when exploring frequent trips profiles in Madrid. Carsharing thus appears to provide further mobility opportunities when other transport options are scarce or not available, thereby covering certain service gaps.

The overall impact of carsharing on sustainability is highly dependent on the modes of transport substituted. According to data collected in this survey, transit is the most affected mode since 50% of carsharing users declared that they would have used public transport for their trips if carsharing had not been available. This trend has been also cited throughout the literature in other case studies (see e.g., Wielinski et al., 2016), and undoubtedly has negative impacts on road congestion, particularly when shared cars are used in dense areas during peak hours. To improve sustainability, schemes to integrate carsharing with public transport should be explored, so that these services complement rather than compete with sustainable modes. An interesting option may be to use carsharing as a feeder of public transport for neighborhoods, usually far from the city center, with a low supply of public transport. One of the main obstacles to implementing this approach is that carsharing firms usually do not serve peripheral areas (Mattia et al., 2019; Lagadic et al., 2019). To avoid this problem, carsharing companies and transport authorities should find ways of collaboration to integrate public transport and carsharing services for certain trips. For that integration to be effective, it would be crucial to have a single fare for the combined trips. This would in turn help in achieving a more sustainable modal shift, decreasing individuals' dependence on private vehicles, reducing pollutants and greenhouse gas emissions as well as reducing other social costs in urban/metropolitan areas.

The methodology of this research (including the survey instrument, but also the modeling and analysis approach) can be used by policymakers to explore carsharing dynamics in other cities. Enriching the results of this research with those from additional cities is expected to provide a better overview of the spectrum of possible outcomes. Finally, the paper reveals the importance of studying new mobility services once they are in operation (*ex-post*), since adoption and usage patterns may significantly differ compared to stated preference from citizens declared before their implementation (*ex-ante*).

7. Conclusions and further research

In this study, we calibrated a multi-dimensional model to investigate the usage of free-floating carsharing, taking two European cities with a different timespan implementation (Madrid and Munich) as case studies. The results of this paper are particularly useful for carsharing operators to sharpen and refine the system design and operation, and for planners and policymakers to better understand the factors impacting adoption and frequency of use of these emerging mobility services and their potential effects on travel behavior and sustainability.

From this paper, some interesting conclusions can be drawn. As previously seen in other case studies of carsharing services in the US and Europe, this research identifies a higher use of carsharing systems among males, young, wealthy, well-educated individuals, and those who reside in inner and denser districts. However, age has a different effect on carsharing adoption in Munich, since individuals from 35 to 49 years old are more likely than their counterparts to adopt that service. This is probably due to the role played by the tech-savviness of individuals, as well as the longer life of carsharing services in the German city compared to Madrid. In this regard, Munich respondents seem to be more familiar with carsharing services compared to Madrid, which is reasonable given that free-floating carsharing services were launched in the Spanish city some years later.

Additionally, the GSEM results obtained in this research reinforce the importance of several latent/psychological constructs on carsharing usage. The results suggest that people with a high preference for driving, variety-seeking lifestyle, and sharing propensity have a significantly higher familiarity with carsharing. However, people with a pro-environmental attitude tend to show lower levels of adoption and frequency of use. Our results also emphasize the importance of explicitly including transportation habits as explanatory variables when modeling carsharing usage. Actually, those variables could help understand adoption and frequency of use in other cities where mobility and social dynamics are different.

Some aspects emerge for further research. First, studies like this one are needed in other cities where mobility and social dynamics are different to provide a better overview of the spectrum of possible outcomes. For this purpose, the survey instruments, modeling, and analysis approach employed in this research can be used by scholars and policymakers to extract their specific insights. Second, further contributions should address how heavier restrictions to the use of private vehicles in urban areas may impact carsharing usage. Third, due to the changes in people's habits and travel behavior patterns, exploring the use of carsharing in post-COVID-19 times seems necessary. In this respect, key aspects such as fear of contagion in shared vehicles and potential sanitizing measures to be adopted are worth exploring. Finally, competition between carsharing and traditional transportation modes should be investigated more deeply, due to its relevance for understanding the future and current role of these emerging mobility services in achieving urban sustainability.

CRediT authorship contribution statement

Álvaro Aguilera-García: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Project administration. **Juan Gomez:** Conceptualization, Methodology, Software, Validation, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Funding acquisition. **Constantinos Antoniou:** Validation, Investigation, Resources, Writing - Review & Editing.

José Manuel Vassallo: Conceptualization, Validation, Investigation, Resources, Writing - Review & Editing, Supervision, Funding acquisition.

Declaration of competing interest

None.

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Appendix A. Results for the GSEM model (case of Madrid)

VARIABLES (base category)		Residential location (base: inside the M30 Ring)				Weekday mobility rate (ordinal)		Weekend mobility rate (ordinal)		Vehicle availability (base: no availability)		Carsharing adoption (base: never used)		Carsharing frequency (ordinal)	
		Outside the M30 Ring		Outside Madrid city											
		Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
LATENT VARIABLES	VSL	−0.186	0.018	−0.172	0.107	0.263	0.000	0.184	0.006	–	–	0.204	0.056	0.380	0.001
	TECHY	–	–	–	–	–	–	–	–	–	–	0.623	0.000	–	–
	ENV. CONSCIOUSNESS	–	–	–	–	–	–	–	–	–	–	−0.398	0.000	–	–
	SHARER	–	–	–	–	–	–	–	–	–	–	0.338	0.010	–	–
	DRIVER	0.271	0.006	0.319	0.016	–	–	–	–	1.650	0.000	–	–	0.365	0.013
EXOGENOUS VARIABLES	*Gender (male)*														
	Female	–	–	–	–	–	–	–	–	0.672	0.000	−0.370	0.007	–	–
	Age (under 25)														
	25 to 34	−0.240	0.107	−0.375	0.062	–	–	−0.533	0.001	–	–	–	–	−0.410	0.027
	35 to 49	–	–	–	–	−0.244	0.050	−0.658	0.000	–	–	−0.326	0.049	–	–
	50 to 59	–	–	–	–	–	–	−0.707	0.000	0.541	0.043	−0.494	0.027	–	–
	Above 59	–	–	–	–	–	–	−1.140	0.000	1.256	0.002	−0.494	0.027	–	–
	Annual HH income (below 18,000 Euro)														
	18,000 to 30,000 Euro	–	–	0.486	0.122	–	–	–	–	–	–	0.335	0.065	1.094	0.000
	30,000 to 60,000 Euro	–	–	0.676	0.028	−0.278	0.033	–	–	0.882	0.000	0.534	0.003	–	–
	Above 60,000 Euro	–	–	0.808	0.023	–	–	–	–	0.876	0.009	0.632	0.007	–	–
	Education (non-university)														
	University studies	−0.573	0.000	−0.657	0.001	–	–	–	–	0.979	0.000	0.448	0.005	–	–
	Occupation (employed)														
	Student or part/student	−0.288	0.065	–	–	–	–	–	–	–	–	–	–	−0.813	0.000
	Other: housework. unemployed or retired	–	–	−1.009	0.014	–	–	–	–	–	–	–	–	–	–
	Household structure (living alone)														
	Living with flatmates	–	–	–	–	–	–	–	–	−1.125	0.000	–	–	–	–
	Couple without children	0.285	0.128	–	–	−0.401	0.006	–	–	–	–	–	–	–	–
	Couple with children below 24	0.316	0.054	–	–	–	–	−0.256	0.031	0.768	0.000	–	–	–	–
	Couple with all children above 25	0.990	0.000	0.660	0.033	–	–	–	–	–	–	–	–	–	–
	Other	0.521	0.043	0.707	0.012	–	–	–	–	–	–	–	–	–	–
ENDOGENOUS VARIABLES	*Residential location (inside the M30 Ring)*														
	Madrid city (outside the M30 Ring)	n/a	n/a	n/a	n/a	−0.377	0.002	−0.243	0.038	0.210	0.267	−0.553	0.000	–	–
	Outside Madrid city	n/a	n/a	n/a	n/a	−0.335	0.043	−0.839	0.000	0.499	0.061	−1.370	0.000	–	–
	Weekday mobility (zero trips)														
	1 to 2 trips	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	−0.738	0.022	–	–	–	–
	3 or more trips	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	−1.316	0.000	–	–	–	–
	Weekend mobility (zero trips)														
	1 to 2 trips	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	–	–	–	–	0.567	0.024
	3 or more trips	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	–	–	–	–	0.483	0.064
	Vehicle availability (no availability)														
	Availability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.611	0.000	–	–
	Constant	−0.122	0.496	−1.315	0.000	n/a	n/a	n/a	n/a	0.053	0.888	−0.789	0.000	n/a	n/a
	Thresholds														
	Threshold1	n/a	n/a	n/a	n/a	−2.934	0.000	−2.362	0.000	n/a	n/a	n/a	n/a	−1.492	0.000
	Threshold2	n/a	n/a	n/a	n/a	0.053	0.000	−0.172	0.000	n/a	n/a	n/a	n/a	−0.158	0.000
	Threshold3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.666	0.000
	Threshold4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.869	0.000

Appendix B. Results for the GSEM model (case of Munich)

VARIABLES (base category)		Residential location (base: inside the Mittlerer Ring)				Weekday mobility rate (ordinal)		Weekend mobility rate (ordinal)		Vehicle availability (base: no availability)		Carsharing adoption (base: never used)		Carsharing frequency (ordinal)	
		Outside the Mittlerer Ring		Outside Munich city											
		Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
LATENT VARIABLES	VSL	−0.454	0.004	−0.446	0.030	0.669	0.004	0.153	0.252	−0.571	0.065	–	–	0.649	0.016
	TECHY	–	–	–	–	−0.311	0.045	–	–	−0.351	0.094	–	–	–	–
	ENV. CONSCIOUSNESS	–	–	–	–	−0.391	0.028	–	–	0.511	0.029	–	–	−0.485	0.059
	SHARER	–	–	–	–	–	–	–	–	0.627	0.003	0.269	0.071	–	–
	DRIVER	0.265	0.057	0.484	0.011	–	–	0.275	0.020	1.620	0.000	0.411	0.011	–	–
EXOGENOUS VARIABLES	*Gender (male)*														
	Female	–	–	0.458	0.057	−0.365	0.044	–	–	–	–	–	–	−0.382	0.147
	Age (under 25)														
	25 to 34	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	35 to 49	–	–	–	–	–	–	−0.540	0.004	–	–	0.424	0.025	–	–
	50 to 59	–	–	–	–	–	–	−0.547	0.027	–	–	–	–	–	–
	Above 59	–	–	−0.957	0.057	–	–	−0.740	0.008	−1.013	0.015	–	–	–	–
	Annual HH income (below 21,000 Euro)														
	21,000 to 41,000 Euro	–	–	0.546	0.040	0.410	0.096	0.596	0.006	0.322	0.296	0.350	0.115	1.035	0.041
	41,000 to 60,000 Euro	–	–	–	–	0.289	0.265	0.449	0.053	0.465	0.161	0.350	0.115	0.859	0.092
	60,000 to 100,000 Euro	–	–	–	–	0.518	0.050	0.527	0.028	0.729	0.040	0.458	0.099	1.054	0.047
	Above 100,000 Euro	–	–	0.644	0.088	0.672	0.061	0.612	0.046	1.003	0.060	0.744	0.035	1.564	0.012
	Education (lower secondary education)														
	Upper secondary education	–	–	–	–	–	–	–	–	–	–	0.575	0.009	–	–
	University studies	0.309	0.098	–	–	–	–	–	–	0.382	0.124	0.445	0.044	–	–
	Occupation (employed)														
	Student or part/student	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Other: housework, unemployed or retired	0.672	0.056	1.361	0.004	−2.077	0.000	–	–	–	–	–	–	–	–
	Household structure (living alone)														
	Living with flatmates	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Couple without children	–	–	–	–	–	–	–	–	0.452	0.101	–	–	–	–
	Couple with children below 24	0.418	0.056	0.788	0.003	–	–	–	–	1.029	0.001	–	–	–	–
	Couple with all children above 25	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Other	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ENDOGENOUS VARIABLES	*Residential location (inside the Mittlerer Ring)*														
	Munich city (outside the Mittlerer Ring)	n/a	n/a	n/a	n/a	–	–	–	–	–	–	–	–	–	–
	Outside Munich city	n/a	n/a	n/a	n/a	–	–	−0.698	0.002	1.340	0.001	−0.720	0.008	–	–
	Weekday mobility (zero trips)														
	1 to 2 trips	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	−0.648	0.010	–	–	0.623	0.134
	3 or more trips	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	–	–	0.488	0.036	0.879	0.069
	Weekend mobility (zero trips)														
	1 to 2 trips	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	–	–	–	–	–	–
	3 or more trips	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	–	–	0.370	0.055	–	–
	Vehicle availability (no availability)														
	Availability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	−0.522	0.021	−0.603	0.038
	Constant	−0.871	0.000	−2.121	0.000	n/a	n/a	n/a	n/a	−0.057	0.860	−1.226	0.000	n/a	n/a
	Thresholds														
	Threshold1	n/a	n/a	n/a	n/a	−1.988	0.000	−1.450	0.000	n/a	n/a	n/a	n/a	−0.827	0.000
	Threshold2	n/a	n/a	n/a	n/a	1.608	0.000	0.860	0.000	n/a	n/a	n/a	n/a	−0.578	0.000
	Threshold3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.556	0.000
	Threshold4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.896	0.000

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