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The contribution of carsharing to low carbon mobility: complementarity and substitution with other modes

Abstract

This paper analyses both the attributes of carsharing transport modes (station-based and free-floating) and their relationship with other transport modes. Users' and stakeholders' perspectives are synthesized from in-depth interviews in Spain. The elicitation of the comparative advantages of the two carsharing modes with respect to public transport and private vehicles helps identifying factors such as availability of parking, road pricing and convenience that drive the complementary and substitution property of carsharing with other transport modes. Interviews show the limited complementarity of carsharing with public transport, as well as the limited substitutability with private vehicles. Potential policy instruments to make carsharing coexist with public transport are discussed.

Keywords

Car club; Car sharing; Low carbon mobility; CO2 emission; Public transport; in-depth interviews; Urban mobility;

Highlights

- This study highlights the limited complementarity and substitution properties of carsharing with respect to public transport and private vehicles.

- The study is based on in-depth interviews with users and stakeholders of free-floating and station-based carsharing.

- Convenience in use and economic factors play an important role in motivating carsharing use.

- Being considered affordable and cheap, carsharing incurs in the risk of competing with public transport.

- Parking and road pricing, along with policies aimed at connecting carsharing and public transport, are necessary to improve their complementarity.

JEL codes: *R40; L91; O30*

1. Introduction

Carsharing is a short time automobile rental service where the users pay a fee proportional to the use of the vehicle (Shaheen and Cohen, 2013). The service operates mostly in urban areas and rental periods range from a few hours down to a few minutes ride. The mode has attracted interest as an alternative to private vehicle use, and also in areas where other modes are available (Millard-Ball, 2005). The need to decrease dependence on private and conventionally-fuelled vehicles for mobility, which are a primary source of greenhouse gases emissions in Europe (European Commission, 2016) suggests that this mode can potentially play a role in decarbonising the transport sector. The European Commission, in its strategy towards a low emission mobility, considers carsharing services to stand along with the actions that should be promoted by local authorities to reduce congestion and pollution (EC MEMO/16/2497).

Of particular interest is the analysis of how carsharing interacts with other modes, namely public transport and private vehicles, in the urban context. To contribute to lowering transport externalities, apart from substituting private vehicle use, this mode is expected to complement public transport and other mobility alternatives (Shaheen and Chan, 2016). The complementarity property refers to an increase in carsharing use being associated with an increase in public transport use. This implies that those who start using carsharing services should increase their use of public transport. However, as they are both urban travel modes, carsharing can instead substitute public transport use (Martin et al., 2011; Rotaris et al., 2019). Having people shifting away from public transport use towards carsharing instead of doing it from private vehicle use to carsharing, the carsharing's potential contribution to low carbon mobility is marked down.

The overall limited diffusion of carsharing makes it difficult to quantify its impacts on other modes' use. However, a deep understanding of carsharing users' perceptions and preferences towards the mode as well as the elicitation of the comparative advantages and disadvantages with respect to public transport and private vehicle can highlight the aspects that can favour or limit the complementarity with public transport as well as its potential to substitute private vehicle use.

The aim of this paper is hence to contribute to the analysis of the complementarity and substitutability between carsharing services and public and private transport modes. Previous studies focusing on the relation between carsharing and other modes provide mainly quantitative-based evidence and are lacking a thoughtful explanation of the means behind mode substitution. A deeper understanding of the reasons why a mode is preferred to or complements other modes will contribute to highlighting the main drivers of the transport mode decision and providing guidance for low carbon mobility policies.

Qualitative analysis may give important insights into this aspect and enable us to consider the heterogeneity of users' preferences. We use a series of in-depth interviews with carsharing

users, capturing their experiences, opinions and preferences towards this mode and the relation with their use of public transport and private vehicles. To do so, we first gain deeper insights into the motivations for adopting and using carsharing; and then, we analyse how public transport and private vehicles are perceived and how their use has changed with carsharing use. We will then be able to discuss how policy measures can support diffusion of carsharing services and limit the risk of shifting away from public transport rather than shifting away from private vehicle use.

Moreover, this study is accompanied by a series of interviews with stakeholders from administration, business and associations related with carsharing and urban mobility that help picturing the current development of carsharing in Spain as well as highlighting the economic and policy aspects that might influence its diffusion and complementarity with other modes. In our analysis, we focus on the Spanish carsharing system as it offers a market with different carsharing operators in different cities.

The next section introduces the current status of carsharing in Spain. Section 3 reviews previous related works. Section 4 describes the methodology applied in this study. Section 5 presents the findings, which are discussed in section 6. Finally, section 7 draws the main conclusions.

2. Carsharing in Spain

The term carsharing comprises several business models in shared private transport services in urban areas that can differ with respect to the parking system and the type of journey. According to the parking system, business models can be classified in free-floating (FF), where vehicles are freely parked on the streets, and station-based (SB), where these occupy a specific reserved parking lot. The type of journey can be either "one-way", where users take the vehicle from a location and leave it at another within a restricted area, normally the urban centre, or "two-way" (or "round-trip"), where the vehicle must be returned to the same place where it was booked. Different modes are likewise often connected with different rates, with SB carsharing normally charging per-hour rates, whereas FF carsharing charges per-minute rates. Given that in the Spanish case FF carsharing is one-way and SB carsharing is two-way, we will limit to this distinction in the rest of this paper.

At the time we conducted the interviews (2018), seven major companies were offering carsharing services to consumers in Spain. Four of them operated under a SB round-trip model. Users of this mode booked the vehicle by paying a constant rate per hour (ranging between 3-10€), plus an amount per kilometre depending on the vehicle fuel (around 0.30€ per kilometre for the gasoline). The service offered the possibility to pay a monthly fee to have lower prices per use as well as an alternative full day rental tariff. The four carsharing companies using this model (Avancar, Bluemove, Clickar and Respiro) started to operate in the period between 2004 and 2010 in the cities of Barcelona, Bilbao, Madrid, Palencia and Seville.

From 2015 onwards, three other companies began operating in Madrid using a FF one-way model, exclusively based on 100% battery electric vehicles (BEVs). Users of this mode paid a rate of about €0.20 to €0.25 per minute (in 2018), with no specific costs per kilometre.

Madrid had approximately 1,500 FF carsharing vehicles and around 350 vehicles for SB carsharing. Barcelona had the second-largest concentration of vehicles with about 450 shared cars, while Bilbao, Seville and Palencia had a smaller number of vehicles.

From 2018, one new company (Wible) started offering a hybrid FF service in Madrid with an extended area with respect to competitors, while a company in in Barcelona (Avancar) stopped offering the service.

3. Previous research

FF and SB carsharing have been mostly analysed separately in the literature. However, Namazu and Dowlatabadi (2018) explored the impact of both these modes on vehicle ownership reduction. They found round-trip carsharing to be more effective in reducing car ownership, arguing that it directly substituted private car use, while FF carsharing represented an additional mode in multi-modal trips.

Carsharing is found to offer a cheaper alternative to private car use and ownership for households that have an average annual car use below 15,000 kilometres (Litman, 2000) and this could potentially contribute to the transition toward low-carbon mobility by reducing car use (Rabbitt and Ghosh, 2016). In fact, Nijland and van Meerkerk (2017) found carsharing users to reduce their car use by 20% compared with prior conditions, while Martin and Shaheen (2011) found vehicle kilometres travelled decreased by 27%. Carsharing could also reduce the need for owning a vehicle in households, especially with respect to a second and third vehicle (Le Vine and Polak, 2017; Mishra et al., 2015; Nijland and van Meerkerk, 2017).

A previous attempt at analysing carsharing usage motives could be found in Schaefers (2013), although no connection was provided towards the problem of complementarity and substitution with other modes.

In the urban context, carsharing cohabits with public transport. Common to both modes are the concepts of access-based mobility and shared mobility (Smith et al., 2018). The former refers to mobility being independent from the ownership of the vehicle, and whose cost is to a large extent proportional to the use of the mode. While it is ‘shared’, as different people can have access to it at the same time, as in the case of public transport, or in different moments, as in the case of carsharing, this also stands for other forms of shared mobility, such as bike-sharing. Several studies sought to assess the relationship between these modes. Ceccato and Diana (2018) stated that carsharing complemented well with bike-sharing, and to some extent, public transport as well,

finding that carsharing users were more likely to use these modes. However, Martin et al. (2011), surveying carsharing users, found that a large part of them reduced their rail and bus use after joining the service. More recently, Rotaris et al., (2019) have found carsharing to mainly substitute private vehicle use, even though it has also a negative impact on public transport use, especially in the FF model. Furthermore, Tyndall (2019) has studied the effect of a transit outage in Vancouver on FF carsharing demand, finding evidence of an extemporaneous substitution between the two. Hence, shedding light on the relation between these two modes may help us assessing the resulting environmental benefits of carsharing (Jung and Koo, 2018).

4. Methodology

Data were collected with semi-structured interviews applied to two groups: the users and the stakeholders. The user group comprised individuals who regularly used the service during the last year. The stakeholder group included representatives of carsharing companies, public administration and sectorial association. Below, we present the subsampling method and the interview guideline of each group, as well as the method of analysis.

4.1 Sample selection and description

Table 1 reports characteristics of the carsharing user sample. The sample of carsharing users consisted of 15 individuals selected in order to ensure the representation of different gender and age groups. Three age groups were defined: younger than 34 years old, from 34 to 45 and older than 45. The sample also included users with children and without children, as well as living or not living with their partner, given the different needs these groups might have. Each group was represented by at least three interviewees. 10 out of 15 individuals own or have a private car accessible to use in their household. The table also reports the stated use of public transport. Moreover, the study involved users from FF as well as SB carsharing, and covering 5 of the 7 main Business-to-Consumer companies operating in Spain (Car2Go, Emov, Zity, Avancar, Bluemove) in 2018.

Table 1 Carsharing users sample

Interviewee	Gender	Age	Number of children	Living with Partner	Private car	PT use	Carsharing Type*
1	Female	31	2	Yes	Yes	Everyday	SB/FF
2	Male	36	2	Yes	Yes	Occasional	FF
3	Male	31	0	Yes	Yes	1-2/Week	FF
4	Male	46	0	Yes	No	Everyday	FF
5	Male	55	3	Yes	Yes	Occasional	FF
6	Male	45	0	Yes	Yes	Occasional	FF
7	Female	42	0	Yes	Yes	Occasional	FF
8	Male	25	0	No	Yes	Occasional	FF

9	Female	37	0	No	Yes	1-2/Week	FF
10	Female	25	0	Yes	Yes	1-2/Week	FF
11	Male	26	0	Yes	Yes	Occasional	FF
12	Male	35	0	Yes	No	Everyday	SB
13	Male	38	0	Yes	No	Everyday	SB
14	Male	33	0	No	No	1-2/Week	SB
15	Male	44	0	No	No	Everyday	SB

Interviewees were recruited through a survey company (CPS)[1]. Interviews were conducted by the analyst, face-to-face in hotel lobbies or coffee shops at a convenient location for the interviewee and lasted for around one hour. The fifteen in-depth interviews were conducted in the cities of Madrid and Barcelona. A monetary remuneration was given to the interviewees to incentivize their active participation, as it added an additional motivation (Robinson, 2014).

The age of the participants ranged from 25 to 55. Participants between 25 and 45 years old were almost evenly distributed, with at least 3 participants for each 5-year interval. There was a disproportion in gender with a majority of males (11) with respect to females (4). However, this can be considered in line with typical socio-demographic characteristics of carsharing users in Europe (Loose, 2010; Prieto et al., 2017). 11 out of 15 interviewees were living with their partner and 3 of them had children. The sample included representatives of both high school and graduate level education, with two of them currently studying at the university. All the interviewees were working, the majority of them as employees in public or private institutions, while two of them were freelance workers. The sample included 10 FF and 4 SB carsharing users. One interviewee was a recurrent user of both types of carsharing services. In both cities, the sample included people living in and outside the city centre.

Table 2 reports anonymised information on the final stakeholders' sample. Stakeholders were selected in order to represent three groups: the business sector, the public administration and associations. Each of these groups was represented by at least four stakeholders.

Table 2 Stakeholder sample

Business		
Code	**Type of Carsharing**	**Operating in**
B1	SB	Barcelona
B2	SB	Bilbao
B3	SB	Madrid-Barcelona-Seville
B4	SB	Madrid-Palencia
B5	FF	Madrid

[1] www.cps2000.com

Public Administration		
Code	**Area**	**Level**
P1	Bilbao	Province
P2	Barcelona	Province
P3	Madrid	Municipality
P4	Bilbao	Region
Associations/pressure groups		
Code	**Sector**	**Level**
A1	Carsharing	National
A2	Carsharing	Local
A3	Public transport	National
A4	Electric vehicles	National

With respect to the business stakeholders, all carsharing companies operating in Spain in early 2018 were contacted, with the only exception being those businesses working exclusively with companies (company vehicle fleet management). 5 out of 7 operating companies positively answered the call.

With regard to public administration stakeholders, the regional, provincial and municipal authorities for the cities of Madrid, Barcelona and Bilbao were contacted. These three cities were selected because they could cover an area where all the 7 companies active in Spain operated (in Seville and Palencia, the service was provided by companies headquartered and operating mainly in Madrid).

The transport and environment authorities in the areas of Madrid, Barcelona and Bilbao were also contacted. For each of these areas, the institutions at municipal, provincial and regional levels were considered. 4 out of the 9 institutions contacted decided to participate in the study.

With respect to sectoral associations, all major national associations related to urban road transport were contacted: public transport association, car manufacturer association, taxi driver association.[2] Moreover, two carsharing associations were contacted, one operating at a national and the other at a local level; they ranged between a national and a local area of influence. A national company operating in the electric vehicle recharge infrastructure was also included.

The final sample comprised 13 stakeholders: 5 from carsharing businesses, 4 from public administrations and 4 from associations/pressure groups. Companies from both types of carsharing services were represented. All SB carsharing companies and 1 out of 3 FF companies participated in

[2] Taxi driver associations and car manufacturers were contacted but decided not to participate in the study

the study. Stakeholders' contacts were first identified online and then contacted via email to explain the study and its objective.

4.2 Interviewing process and topic guidelines

The users' interviews were semi-structured and based on a common topic guideline. The semi-structured nature of the interviews implied that there was not an explicit list of questions repeated in order in each interview, but rather a list of pieces of information reported in an interview guideline the interviewer made sure to retrieve with each person (Malhotra and Birks, 2007; Symon and Cassell, 2012).

A guideline was elaborated and several blocks were defined in order to gather the information necessary to understand the complementarity and substitutability of carsharing with other modes. The guideline consisted of 5 different blocks. The first block aimed at warming up the conversation, obtaining basic information on the interviewees, specifically their weekly routine and their typical use of the carsharing service. The second block focused on the factors influencing the subscription and the use of the service. Interviewees were asked to tell how they discovered the carsharing service and what made them start using it. The most important attributes affecting their use of carsharing were retrieved mainly in this phase, although the interview allowed for other factors to come up in the discussions. At the end of the interview, users were asked to relist and rank them by order of importance. The third and the fourth blocks were the central block of analysis of complementarity with other modes. The third block focused on the relation with public transport, aiming at understanding how different public transport modes were compared to carsharing and how their use changed after subscribing carsharing services. Users were first asked about the advantages and disadvantages of each public transport mode (metro/tram, bus and taxi) by itself, and then to compare carsharing with each of them. The fourth block focused on the relation with the private vehicle. In particular, they were asked whether their use of the private vehicle changed after joining a carsharing service and how this service could influence their need for a private vehicle. Also in this case, users were asked about the advantages and disadvantages of private cars, and to compare the mode with carsharing directly. The fifth block closed the interview and focused on possible future developments of the service[3]. The complete interview guidelines, which include the full list of pieces of information that were asked, can be found in Appendix I section A.

[3] Users were also asked in this section about advantages and disadvantages of electric vehicles and whether they preferred them compared to conventional ones. Users were specifically asked whether they would have been willing to pay a price premium for the service offered with electric vehicles compared to the conventional one

Topic guidelines for stakeholders' interviews consisted of 5 sections. The first block was aimed at warming up the conversation and gathering information on the stakeholders and the institution they represented as well as their view of the carsharing sector and its development. The second block explored the facilitation of carsharing. In particular, it focused on the motivations to implement and develop this service further, the main policies and social characteristics that could facilitate its success and its contribution to urban mobility. The third block looked at the relation between carsharing and other modes of transport within the urban context and what changes the introduction of carsharing could imply. The fourth section was specific to the stakeholder group. The Business stakeholder group was asked about details on the carsharing market, whether they benefited from any support, whether they targeted a specific group of people and if they had specific aims to provide an environmentally-friendly service. The Public Administration group was asked about measures to combat transport-related problems, how the decisions were made in this context and what role was intended for electric carsharing in urban mobility planning. The pressure groups were asked about the mission and vision of their institutions and about their strategy to achieve it. Finally, all stakeholders were asked how they perceived the relation with the other actors in the field and about their vision regarding the future of the sector. The interviews were conducted in the cities of Barcelona, Bilbao and Madrid, usually at the offices of the companies/institutions.

4.3 Method of analysis

Interviews were digitally recorded and then transcribed. For carsharing users, these were analysed following a *template analysis method* (Symon and Cassell, 2012). This methodology consists of developing an *a priori* and hierarchical set of codes: labels for indexing sections of text related to a specific theme. This set of codes forms an initial template into which the information flows. The template is flexible and can be adapted to include information the analyst did not expect. New codes are added to the template upon the first analysis of the transcripts, then a second analysis ensures the new codes have been considered for each interview. This allows including important themes in the analysis that were not initially considered by the analyst. In our case, the a priori codes were set after the first transcription of interviews with the highest hierarchical level following the topic guidelines structure. After a deeper review of the transcripts more detailed codes were set to better account for heterogeneity of preferences, in particular with respect to alternative travel modes available. A table was developed following the topic guidelines to include all comparable information in the same structure. Each row in the table referred to a single interviewee, while each column was dedicated to collecting information on a specific code. Appendix II reports the final template coding of the interviews.

When discussing the advantages and disadvantages of the different travel modes, as well as motives for carsharing use, interviewees were asked to list a series of attributes. In most cases, interviewees used different wording to express the same attribute. Hence, these went through a homogenisation process and were then categorised into common groups. The homogenisation process is detailed in the Supplementary Material.

Given the different nature of the interviewed stakeholders, topic guidelines were adapted by developing a section with different questions for the three stakeholder types (See Appendix I.B section d.). While for business stakeholders the discussion remained close to the selected topics, the discussions with public administration and associations were highly influenced by the specific area of expertise of the interviewees. Hence, a uniform, data-driven analysis of the interviews, to find similar patterns and concepts, was conducted for stakeholders: main contributions from each transcript of records were summarised and collected into a single document. Then, each contribution was grouped under common topics, keeping track of the stakeholder who mentioned it. The different contributions fed section 3.1 on the current development of carsharing in Spain and contributed to complete insights coming from carsharing users with respect to use, comparison with other modes and electrification of carsharing. The complete topic guidelines for stakeholders can be found in Appendix I section B.

5. Findings

5.1 Carsharing use

FF consumers appeared to be more frequent users of this mode than SB users. 7 out of the 11 FF carsharing interviewees stated they used it around 3 times per week; SB carsharing interviewees used the mode more on a monthly basis and sometimes even more occasionally. Regarding the journey length, most FF users had a normal range of 10 km or 15-30 minutes, normally affected by traffic congestion. SB carsharing instead, was generally booked for 2-3 hours, although in some cases users stated to book it for a full-day or weekend. Some users of both systems also stated their use to be dependent on the period of the year, with a higher frequency during summer or holidays. The higher frequency in these periods was due to the higher number of “out-of-routine” activities, as for normal routine activities most interviewees used other modes. In fact, users stated that they used shared cars especially on weekends, at night when the public transport stops or using the latter when going to locations that were not easy to reach. Other uses mentioned were to replace their own car while it was being repaired and the need to move equipment from one place to another. Some FF carsharing users, given the limited area where this system operates, mainly used the mode to reach the city centre from the periphery, where they could park for free, or to move from one

place to another within the centre. SB users mainly booked vehicles for weekend trips and mainly used the system to reach outer places such as mountains, the seaside or nearby villages.

Age seemed to influence the propensity to use different modes; younger interviewees of both carsharing models used a wider range of modes in their normal routine, mainly due to a higher number of activities and a less structured schedule. It is interesting to note that most young interviewees in Madrid were subscribed to more than one carsharing company, while older ones would normally be subscribed to a single operator. In some cases, this seemed to be due to a higher ability (and willingness) to use smartphones and adopt new technologies by younger generations. However, some older interviewees stated they were registered with a single company because of the higher availability of their vehicles in the area where they lived. Some younger interviewees also stated they registered because they were attracted by the 20€ travel credit incentive upon subscription and the immediacy of the registering process.

5.2 Attributes motivating carsharing use

For many interviewees, the motivation to start using carsharing was either a specific external condition, for instance the unavailability of their own car, or a specific unusual trip they had to do out of their usual routine, or a change in city mobility due to an event or holiday. Some users stated they had also been curious about the type of vehicle and the way the system functioned.

Figure 1 reports the distribution of the importance of homogenised attributes motivating carsharing use, divided by carsharing type. The importance was derived based on the ranking position of the attribute and the times it was cited. That is, the sum of weights of the attributes of each individual was set to one. Moreover, for a single individual, attribute weights were set in order to keep the distance between ranking positions constant. Then, homogenised attributes were summed across interviewees. To make them comparable across types of carsharing users, the sum of the attributes' importance was standardised to 100% for each carsharing type.

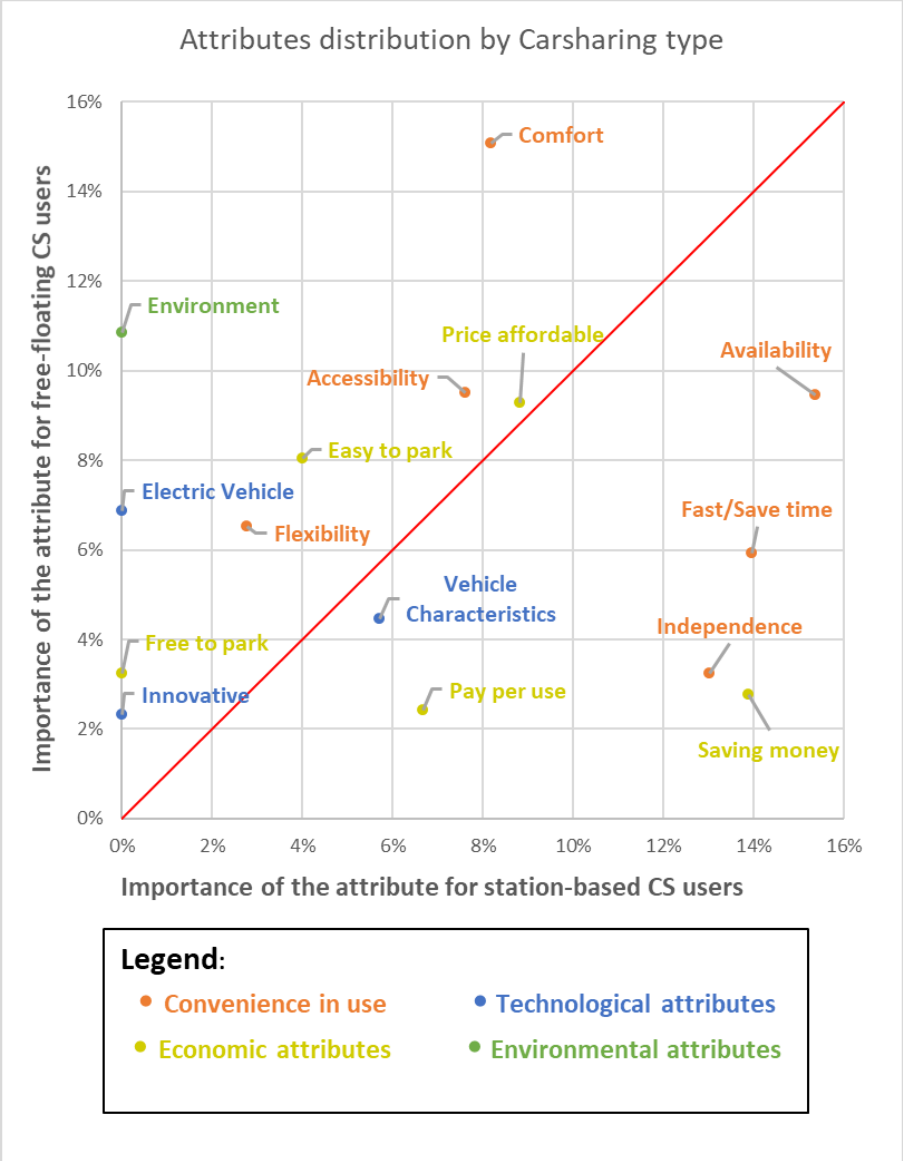

Figure 1: Distribution of the attributes of carsharing use by carsharing (CS) type. The dashed line is the 45º line which separates the FF and the SB prevalence areas.

Based on the interviewees' responses, four main categories were defined, covering the different homogenised attributes: *convenience in use, technological attributes, economic attributes* and *environmental attributes*. *Convenience in use* included factors that identify carsharing as a more practical alternative. This included the comfort feeling, the high availability of vehicles around the city and the possibility of going exactly from and to where you need to go. *Technological factors* included considerations of the type of vehicle, the fact that it is electric, the quality and the small car size. Other attributes mentioned were the possibility to control everything by smartphone and the possibility to pay by card instead of cash. The *economic factors* category dealt with the price, which for most of users was considered as affordable. Some other interviewees mentioned the advantages compared to the costs related to a private vehicle, the possibility to pay according to the use of the mode and the avoidance of purchasing, maintenance and parking costs.

Then, the *environment* category included motivations related to the perception of carsharing as an environmentally-friendly practice.

When looking at how these attributes were distributed in terms of importance, it was clear that aspects related to convenience in use ranked at the top. In particular, comfort was the most important factor for FF carsharing users, whereas availability of vehicles was the most important factor for SB users, followed by saving time and being independent. Economic attributes were also important, especially the possibility of saving money for SB carsharing users and considering the price affordable for FF carsharing users. Only FF electric carsharing users mentioned the advantage of being *environmentally* friendly as a valuable aspect of carsharing. This attribute seemed therefore deeply linked to the type of vehicles involved. In fact, these users believed the service was environmentally-friendly because of the battery electric vehicles. SB carsharing users did not see this aspect of the service because vehicles were not low-carbon fuelled, especially considering that public transport was the main travel alternative for most of them. Also, most SB carsharing users would have preferred to have hybrid or electric vehicles. Only a couple of interviewees expressed indifference in this regard. Regarding technological factors, appreciation for being innovative and based on electric vehicles only came from some FF users, while both types of users valued vehicle characteristics such as size and quality.

5.3 Relation with other modes

Figure 2 reports the distribution of homogenised comparative advantages and disadvantages of carsharing compared to other alternatives modes available to users. Carsharing was valued as more comfortable and flexible, as well as allowing the user to choose the route. Almost 40% of FF users considered carsharing faster than other modes (Fig. 2), while 60% of SB users stated public transport to be faster (as shown in Fig. 3 below). Some young interviewees also mentioned the advantage of having more independence and being able to reach other places, stating that somehow this mode increased their mobility possibilities. One interviewee also mentioned the love of driving rather than being driven as an advantage of carsharing. With respect to the disadvantages of carsharing, users complained about the need to find parking, having to drive and the cost of the service. FF users also mentioned the constraint given by the restricted geographical area, while SB users spoke of the limitation of having to return the vehicle to the station. One user also mentioned the disadvantage of being smartphone-dependent.

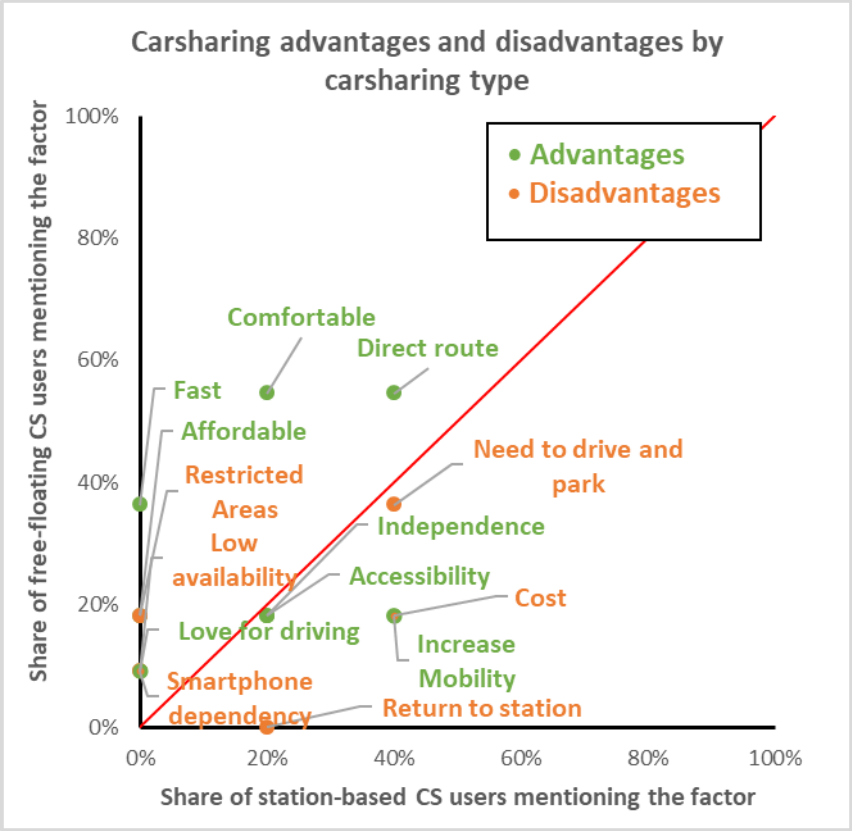

Figure 2: Distribution of advantages and disadvantages of carsharing compared to other modes by type of carsharing(CS) user. The dashed line is the 45º line which separates the FF and the SB prevalence areas

5.3.1 Relation with Public transport

6 out of the 15 interviewees stated they used public transport less than once a month, three interviewees used it around once a week, and 6 used it more often as the main transport mode. It was striking that all 6 users with low public-transport use came from the FF carsharing group, while 4 out of the 5 SB carsharing users stated they used public transport on a daily basis. This is probably related to the fact that the SB carsharing interviewees did not own a car and only one of them had access to it within the household. On the contrary, all FF interviewees either owned or had access to a private vehicle.

Carsharing was competing with some specific public transport modes. Indeed, within public transport modes, the majority of users preferred the metro to the bus. Their opinion regarding the metro was that it was cheap and relatively fast, while the bus was considered too slow. Taxi use was limited to emergencies, occasions where it was not possible to drive and for mobility at night, but it was considered extremely expensive.

Figure 3 reports the distribution of homogenised comparative advantages and disadvantages of public transport. Competitive advantages of public transport were identified as not having to drive, which included not being directly subject to the stress of driving and the possibility of doing something else meanwhile, such as reading or talking. Moreover, some users, mainly from SB

carsharing, stated public transport, in particular the metro, as faster than carsharing, as it was not subject to congestion. Being affordable was also cited by some, and one FF user mentioned having a fixed monthly ticket as an advantage. On the other hand, being crowded, not allowing for direct connection and poor timetables were the most oft-cited disadvantages. Some users also criticised the rigidity of route, the payment method and limits for animal access.

When asked how their use of public transport changed after subscribing to carsharing, all FF carsharing users except one stated that their use decreased. Those of them using public transport as their main mode said that it fell slightly on occasions where many transit changes were needed, when not knowing about when they would have to return, or in case of emergencies. Moreover, most of them also stated that this mode increased their mobility possibilities. Conversely, all SB carsharing users said that, given the occasional use, it did not greatly influence their behaviour with respect to public transport. Indeed, a couple of them said they rather completed each other, leading to greater independence because an alternative mode existed.

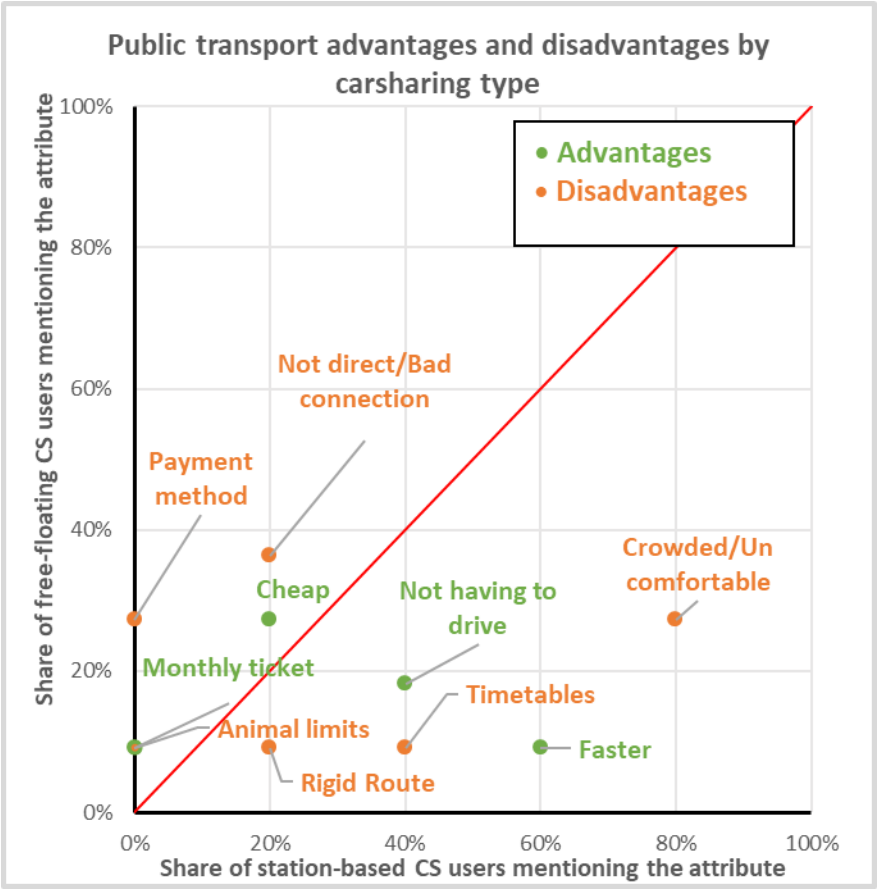

Figure 3: Distribution of advantages and disadvantages of public transport compared to other modes by type of carsharing(CS) user. The dashed line is the 45º line which separates the FF and the SB prevalence areas.

5.3.2 Relation with private vehicle

Among carsharing users, most FF carsharing users owned at least a car, a motorbike or had access to a vehicle within their household, or through their parents. However, the majority of them

only had one vehicle in their household. None out of the five SB carsharing users personally owned a car, although one of them owned and mostly used a motorbike and another one could have access to his/her partner's vehicle. Most owners of a private vehicle used it to go to work every day, while preferring to take a shared car when needing to go to the city centre. Some of them also expressed the need for a vehicle when going on a longer journey for holidays or during weekends.

Figure 4 reports the advantages and disadvantages of private vehicles compared to carsharing. The first noticeable aspect is the difference between the perception of FF and SB users. Most of the private vehicle's advantages were mentioned exclusively by FF users. In particular, they acknowledged the advantage of being always available, not having a limited area, facilitating household needs, being useful for emergencies, love for the car and growing affordable with frequent use. The only exception was the increased independence, which was indeed in the SB prevalence area. Conversely, all private vehicle disadvantages fell in the SB users' prevalence area, meaning they had a more critical view with respect to the mode. This might depend on the fact that SB users did not own private vehicles. Both types of users cited the disadvantages of maintenance and the purchase cost, as well as the struggle to find and pay for parking. SB users also cited cars to be stressful and inefficient in urban areas compared to public transport, due to traffic congestion and parking costs.

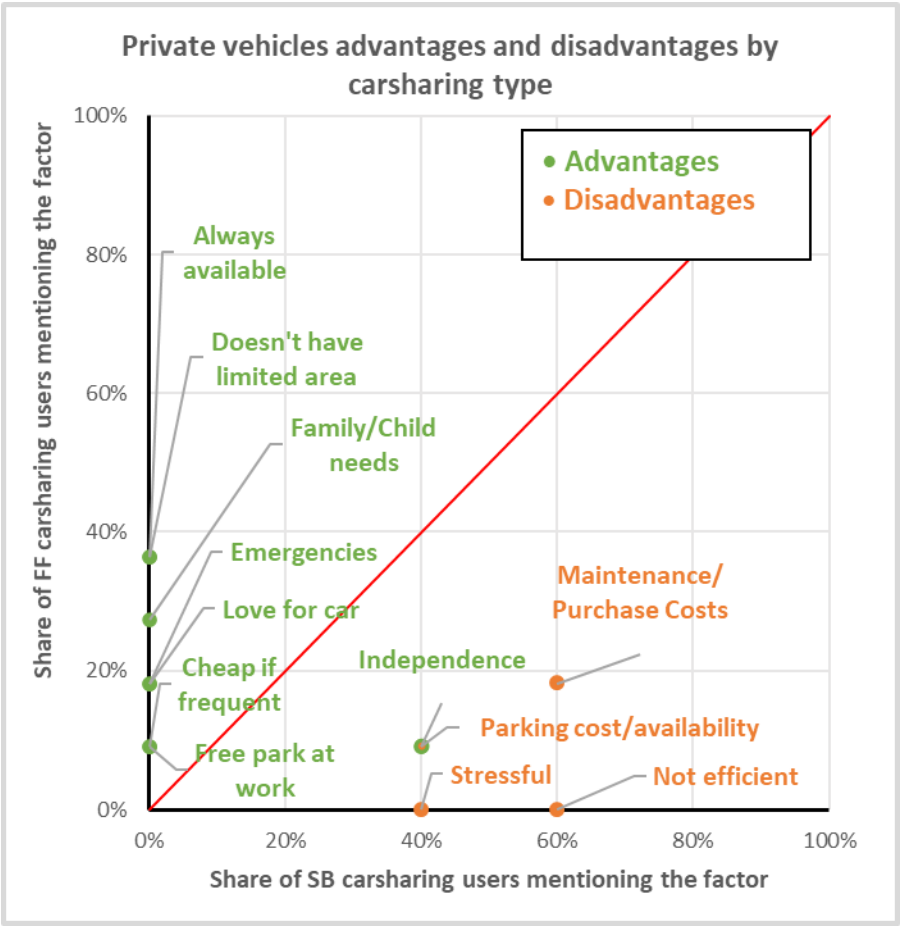

Figure 4: Distribution of advantages and disadvantages of private vehicles compared to other modes by type of carsharing(CS) user. The dashed line is the 45º line which separates the FF and the SB prevalence areas.

Most of the interviewees stated they had partially reduced the use of their private vehicle since using carsharing, although they normally had different uses. Some users living in suburbs stated that when they needed to go to the city centre they used their own car to the closest point where they could park for free, and then changed to a shared car as it would be more expensive to pay for several hours' parking than to pay for a shared car.

Finally, the vast majority of the respondents who owned a car were open to at least reducing the number of cars to one for the whole household, and directly connected this possibility to the existence of the carsharing service. This was mainly because of its high availability in the urban area, the immediateness of reservation and the possibility of free access and parking in the city centre. Most of them related the decision of whether or not to own a vehicle to the change in daily routine, to the area where they lived or to having children. Most of the interviewees stated they had had the car since before discovering carsharing, and a couple of them stated they would not have bought one if they had known about carsharing before. A barrier to reducing the number of cars cited by some of the respondents was the low market value of their vehicle, while the disposal of the vehicle through scrappage programs was connected to the purchase of a new one. Hence, some of the

interviewees said they were waiting for the car to stop working to scrap it. All interviewees who did not own a private car stated they would not buy one if their routine at the time or living place did not change.

5.4 Considerations from Stakeholders

Carsharing providers considered that the market was emerging and a large share of users could be captured. They considered the level of 15,000 kilometres per year to be the cut-off point above which private vehicles were more cost-efficient than carsharing. This level is also reflected in literature (Litman, 2000). They argued that carsharing, in exchange for a higher price per kilometre, gave door-to-door solutions that facilitated citizen independence from private vehicles. They also stated that the vast majority of citizens living in urban areas drove their car for less than that amount and were hence potential carsharing users. Most of the stakeholders said carsharing helped users to avoid buying a car, or at least to reduce the number of cars per household. They were also convinced that the private vehicle was losing its symbolic value (i.e., vehicle as a mean to express identity or social position), especially among young people who were given new ways of gaining their independence, one of which was access to a shared vehicle.

With respect to economic aspects of the service, carsharing providers highlighted the importance of having a mix of private users and companies as their demand covered different hours during the day and private users mainly used carsharing for leisure activities. For SB carsharing this implied that they were most interested in having the station in mixed neighbourhoods accessible by both type of users. FF carsharing users needed instead to have a capillary distribution of vehicles, so that over the whole area of service users could find a vehicle within 5 minutes walking. FF carsharing hence incurred in other costs due to relocations of vehicles over the service area. Some stakeholders expressed that profitability of the service was on average guaranteed by a 5 hours daily use per vehicle.

Looking at the location aspects and relation with local institutions, providers mentioned the importance of parking availability and car access restrictions as main tools driving the existence of this type of service. Especially, providers believed that for FF carsharing the possibility of freely parking on the streets and access over the whole area of service was a pre-condition for economic viability, since the vehicles might be parked on a spot for several hours between uses. FF providers noted that in Madrid this pre-conditions were met not because of being a carsharing service but because this was guaranteed to all electric vehicles. In fact, this seemed to be the main reason why they decided to offer only electric vehicles. SB carsharing, instead, was typically paying for the parking spaces they occupied in the stations and would benefit from a lower price due to a

441 recognition of the benefits linked to their service. They stated that electric vehicles were not a viable
442 option for their service given the large range of their trips.
443 An important area for policy intervention highlighted by both carsharing providers and the
444 public administration authorities was to improve the connection of carsharing services with public
445 transport. For most stakeholders, public transport and carsharing were deeply interconnected and
446 should be considered part of one same service, even if managed by different operators.
447 Stakeholders of different groups agreed that carsharing's main contribution to low-carbon mobility
448 depended on the positive impact it could have on exploiting synergies with public transport in order
449 to reduce the need to own a private vehicle.
450 The Public Administration group considered public transport to be the main tool to deal with
451 mobility and congestion, availability of parking space and preservation of air quality, because of the
452 size of its impact on urban mobility. They believed that the relative impact of carsharing was limited,
453 as it serviced a lower number of users than public transport, but it was considered to contribute to
454 the transition to low-carbon mobility.
455 According to different stakeholders, SB and FF carsharing could supplement the supply of public
456 transport, especially when a vehicle was needed to carry packages, when the public transport
457 timetables did not cover the journey or when the location was poorly connected. The connection
458 between the services could be improved, according to providers, by the joint development of hubs,
459 stations where it was possible to switch between public transport and shared modes, bicycle and
460 car. Also, it would be important for carsharing companies to rely on the same public transport card
461 and a unique app that could show public transit routes and position of shared vehicles. This view
462 supported the need for a Mobility-as-a-Service (MaaS) type of offer (Jittrapirom et al., 2017) which
463 would increase visibility of the mode and facilitate complementarity between carsharing and other
464 collective and shared modes (Ambrosino et al., 2016; Smith et al., 2018).

465 ## 6. Discussion
466
467 What can be drawn from how the interviewed households described their use of carsharing is
468 that those cases where carsharing could be considered a complement to public transport are rather
469 limited. None of the users stated that their use of public transport increased upon joining the
470 carsharing service. In fact, most of the FF users stated, in line with the findings of Martin et al.
471 (2011), that their use of public transport had decreased instead. It is also true that SB users stated
472 that their use of public transport did not change much due to their occasional use of the shared cars.
473 However, it has to be noted that for most of them public transport was the only alternative travel

mode, and carsharing ended up being used for trips that were formerly conducted with public transport.

Both SB and FF business stakeholders argued that users of carsharing services had a higher use of public transport compared to other people. However, this does not necessarily prove complementarity between carsharing and public transport as this could merely be interpreted as a sign of reverse causality, i.e., people with higher public transport use are more likely to start using carsharing. In our interviews, this seemed to be the case, especially for SB carsharing. Some recent studies are also finding difficulties when trying to shed some light on the connection between carsharing and public transport use. Thus, Clewlow and Mishra (2017) and Mishra et al. (2017) reach the conclusion that connecting carsharing use with higher public transport use may be affected by self-selection and simultaneity biases of carsharing users.

Ceccato and Diana (2018) recognize the difficulty to prove complementarity between public transport and car sharing when comparing public transport use before and after subscribing carsharing services because beginning to use carsharing could be connected to changes in mobility needs, or so-called «life events» (e.g. marriage, birth of a child).

Overall, the interviewees cited motivations for using carsharing in line with the previsions made by stakeholders. In particular, most of the SB carsharing users moved mainly by public transport and used the shared car on a monthly basis to reach outside leisure locations or furniture stores. This is in line with the stakeholders' view and findings by Rotaris and Danielis (2018). However, most FF users had a low use of public transport and this did not increase after joining the service. Conversely, some of them stated that they reduced public transport use. Given that shared vehicles could be parked for free in the city centre, some of them used the service as a "park and ride" solution, in substitution of public transport. For some interviewees, carsharing somehow increased their mobility rather than substituting other modes. This allowed them to perform trips which they would otherwise avoid because they "couldn't be bothered," the "complexity of using other modes" or external conditions (e.g., weather, time of the day). In this sense, carsharing created more mobility in cases where public transport was considered inefficient. However, the majority of car owners interviewed stated that they have also reduced private vehicle use, substituting it with carsharing.

Since both carsharing models were perceived as a more comfortable and more direct solution than public transport, increasing user independence and possibilities, they should have implied a price premium with respect to public transport. However, FF carsharing was considered affordable and even cheaper when sharing the price between more people. Hence, in order for a complementarity between this mode and public transport to exist, policies might ensure this price premium for carsharing use, or incentivize complementarity through policies aimed at connecting

508 the two modes. SB carsharing incurred less in the risk of competing with public transport in urban
509 areas. Indeed, the interviewed users of this mode were using this service occasionally,
510 complementing a public-transport and active mode-based mobility. However, this mode might
511 compete with medium-distance trips by bus or train if it did not imply a sufficiently high price
512 premium.
513 The complementarity between carsharing and public transport could benefit from joining effort
514 with public transport, developing a network to facilitate use and connection between both modes.
515 This could be done by using a common payment method, by including stations and car parks in the
516 public transport information system and by involving carsharing to serve urban areas without a
517 critical mass of public transport users. This aspect was primarily raised by carsharing operators and
518 seemed to be reflected in public administration and sectoral pressure group opinions. This could be
519 done through MaaS type of service with integrated offer of different mobility alternatives
520 (Jittrapirom et al., 2017). This includes developing a higher level service, which can be provided by
521 public administration or private entities that facilitate a seamless mobility by allowing users to
522 purchase a trip with different modes at once with a single subscription. Services of this type have
523 been already developed in some European cities and they have been proved effective in improving
524 the complementarity between carsharing and public transport (Ambrosino et al., 2016; Smith et al.,
525 2018). Facilitating multimodality and the specific places where modal shifts are possible might hence
526 make it easier to avoid private vehicle use. According to users, the most valued factors of carsharing
527 were in fact related to its simplicity and immediateness, making it more convenient compared to its
528 alternatives, rather than economic or other advantages. In the same way, access-based mobility was
529 likely to be more successful than private vehicle-based mobility only if it was seen as more
530 convenient in these terms.
531 Parking and road pricing are important factors, as they seem to be a deterrent for car use in
532 urban areas (Garling and Schuitema, 2007). Certainly, carsharing diffusion would benefit from being
533 exempt from such restrictions, but this might also trigger competition between carsharing and public
534 transport if the difference in prices between the two trips is marginal and if there is no connection
535 between carsharing and public transport offerings. Especially in areas as the city centres, where
536 public transport offer is more capillary, allowing free parking and access to carsharing vehicles might
537 favour this competition and lead to substitution. Conversely, carsharing would play a
538 complementary role in outer urban areas where public transport might be sparser.
539 As envisaged by business stakeholders and expressed by users, both modes seemed to reduce
540 the stated need for private vehicle use and ownership. SB users were found to have a more negative
541 opinion of private vehicles, and most of them did not use a car in their daily routine. Moreover,

users owning cars stated that the service could help them reducing the number of vehicles in their household, in line with findings by Nijland and van Meerkerk (2017). A policy that might incentivise the switch from private car to carsharing might be to provide stronger incentives to get rid of old vehicles and use carsharing than to the purchase of a new one. This could also add qualitative insights to the findings of Namazu and Dowlatabadi (2018), who discovered that round-trip carsharing was more effective in reducing ownership. The switch from private car to carsharing might be encouraged by enforcing restrictions to private vehicle use and parking.

7. Conclusion

This paper sought to understand how carsharing systems could contribute to low-carbon mobility. It particularly focused on understanding its complementarity or substitutability with its alternatives in the urban context. For this we have carried out a qualitative analysis based on semi-structured interviews with users and stakeholders in Spain. The analysis gathered a total of 28 in-depth interviews with carsharing users, experts from all the Spanish carsharing companies, public administration and associations.

Currently carsharing covers mainly users' journeys in the evening and at the weekend for leisure. Factors influencing its use appeared to be primarily related to its convenience with respect to other modes, in particular, the possibility of easily travelling directly to the desired destination, independence and the comfort during the journey. Economic attributes, such as the cost of the service and savings related to the avoidance of private vehicle purchase and maintenance costs, were also shown to be relevant, in particular with respect to avoiding private car maintenance costs and the generally affordable price of the service. To a lesser extent, technological aspects related to vehicle quality and the functioning of the entire carsharing service were also cited. Moreover, environmental friendliness of the use of electric vehicles was also cited as a motivating factor by FF carsharing users.

These attribute groups can be connected to the ones found in Schaefers (2013)[4], namely, value-seeking (economic attributes), convenience (convenience in use), and environmentalism (environmental attributes). In our study, we provided a strategy to assess their relative importance by aggregating interviewees' ranked motives for carsharing use. This analysis also allowed us to highlight differences between carsharing modes.

In principle, carsharing can supplement the supply of public transport both for urban and extra-urban areas. SB carsharing often serves as an occasional alternative to public transport for people

[4] The only exception would be "lifestyle", although within our technological attributes considerations on the service being innovative were also included.

574 who do not own vehicles and mainly move by public transport and active modes. FF carsharing is an
575 urban mode which can complete public transport supply in poorly-serviced areas, at night and for
576 multi-destination trips.
577 However, this complementarity seems to be rather limited at the moment. Carsharing, especially
578 the FF type, is likely to compete with public transport instead, as it is considered more comfortable,
579 flexible and direct. These features should be reflected in a price premium. However, this did not
580 seem to be the case in our study as many interviewees considered it affordable, and by some, even
581 cheaper when shared between multiple passengers. SB carsharing seems to be mainly directed to
582 those who do not own and use a private car. Moreover, there is also evidence that in some cases
583 carsharing generates new demand for mobility.
584 Thus, additional policies seem to be necessary to ensure the complementarity of these two
585 modes in order to successfully provide an alternative to private-car use, which should be the main
586 mode substituted by carsharing. Measures aimed at connecting carsharing with public transport
587 services can play a role in facilitating this process. For instance, the complementarity could benefit
588 by an integrated MaaS offer facilitating a seamless trip planning. Moreover, restrictions on private
589 car use in urban areas could also contribute to the development of this alternative.
590 This approach allowed us to consider heterogeneity of preferences and experiences and
591 highlight motivations which would otherwise be overlooked by quantitative studies. Nonetheless,
592 our findings could be complemented and supported by a quantitative based analysis which could
593 evaluate at a larger scale some of the policy instruments we discussed.
594

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Appendix I - Interviews Guidelines

A. Households

a. Introduction

- Aim of this section: Warm-up for the conversation, obtain basic information on the interviewee, on the specific shared mobility scheme and on the use the user makes of it.

- Outcome: □ Introduce the interviewee to the ENABLE.EU project (not with excessive detail, to avoid influencing interviewee answers)

□ Collect basic information on the interviewee (Age, education, work, leisure, routine, household size, travel needs)

□ Describe a normal day from beginning to end where they use this mode.

□ How does the mode work?

□ How often do they use the mode?

□ How long have they been using the mode?

□ How did they learn about the mode?

□ What are the destinations and the occasions to use it?

□ For how many kilometres do they normally use the mode?

b. Factors and Lifestyle

- Aim of this section: Obtain insights into which factors possibly influence propensity to subscribe to a shared mobility scheme.

- Outcome: □ What habits s-/he had before using this mode?

□ Why did they start using carsharing?

□ In which aspects do they see carsharing fits with their travel needs?

□ What were the motivations to switch to using this mode?

Possible motivations:

- Economic reasons
- Environmental attitude
- Propensity for new technologies
- Personal emotions (e.g., satisfaction from being a user, doing something good)

- Other

Extra: high presence of vehicles, low price, etc.

□ What do you think would convince more people to join the group?

c. <u>Relation with other modes</u>

- Aim of this section: Obtain insights into how the scheme relates to other modes, in particular public transport. Are they complementary or rivals?

- Outcome: □ What are the complementary modes they use to meet their transport needs?

□ How do these other modes compare to carsharing?

□ How did their use of public transport change after joining the carsharing scheme? (Did it reduce or increase?)

d. <u>Personal vehicle</u>

- Aim of this section: Obtain insights into car-use history and future willingness to buy a car for carsharing users.

- Outcome: □ Do they own a car? Did they ever own a car?

□ Which factors affected their decision of not having, or not using, a personal car?

□ Do they plan to own a car in the future? Which factors would affect this decision?

□ If they plan to buy a car in the future, what could make them rethink this decision?

e. <u>Evaluation and Electric carsharing focus</u>

- Aim of this section: Understand possibilities for improvement or implementation of an electric carsharing scheme.
- Outcome
    i. Electric carsharing users
- Outcome: □ How could be the service improved?

□ Do they prefer the service to be provided by electric vehicles?

□ What are the advantages of using electric carsharing?

- compared to conventional carsharing?

- compared to other transport modes?

□ What are the barriers/limits and disadvantages of electric carsharing?

□ Would they be willing to pay more, less or the same if the service was provided with conventional cars?

ii. Other users

- Outcome: □ How could be their service improved?

□ What are the advantages and disadvantages of using carsharing?

□ Would they be willing to use the service if it were provided by electric vehicles?

□ What would be the advantages of having an electric carsharing service compared to a conventional service?

□ Would there be barriers/limits and inconveniences to it?

□ Would they prefer it?

□ Would they be willing to pay more, less or the same as conventional carsharing?

B. Stakeholders

a. <u>Common introduction</u>

- Aim of this section: Warm-up the conversation, obtain basic information on the interviewee.
- Outcome: □ Introduce the interviewee to the ENABLE.EU project.

□ Collect basic information on the interviewee (Time at the company/administration, role as stakeholder).

□ What is the current development of the electric carsharing system?

b. <u>Facilitation of Electric Carsharing</u>

- Aim of this section: Understand what factors and measures can facilitate the development and implementation of an electric carsharing scheme.
- Outcome: □ What are (or would be) the motivations to implement and foster an electric carsharing system?

□ What are the main measures to develop in order to facilitate the implementation of an electric carsharing system? Or to improve it?

□ Do they think it is worth it to have this mode? Why or why not?

□ What are the features that can determine the success or failure of this system?

□ What is the contribution that this system provides (or could provide) in urban areas?

c. Relation with other urban modes

- Aim of this section: Obtain insights into how electric carsharing relates to alternative transport modes
- Outcome: □ How does this mode relate to private car ownership? What does (or would) it imply?

□ How does this system relate to public transport? Did it increase or reduce public transport use?

□ How did (or would) urban transport change with the implementation of this system?

d. Stakeholders' specific questions

- Aim of this section: Obtain further insights into the topic through the point of view of the specific actor.

i. Policymakers

- Outcome:

□ Apart from the electric carsharing system, which measures have been developed to reduce the carbon intensity of urban mobility? Which measures are planned to be developed?

□ What are the costs and the benefits of an electric carsharing scheme?

□ On which basis were decisions made on this topic? (Convenience, environmental concern, financial balance)

□ What would be the direct and indirect benefits (e.g., health, congestion, etc.) of having a low-carbon city/region/country (depending on the PM area of influence)?

□ In their view, what are the positions of pressure groups and service providers? What are the synergies and the contrasts with them?

□ What is their vision on the future of electric carsharing? (will it increase, reduce?)

□ What is their vision on the future of low-carbon mobility in general?

ii. Pressure groups

- Outcome: □ What are the groups you usually target?

□ What are the results they aim to achieve and the strategy to pursue them?

□ What is lacking in the current situation of electric carsharing scheme?

□ In their view, what are the positions of policymakers and service providers? What are the synergies and the contrasts with them?

□ What is their vision on the future of electric carsharing? And regarding low-carbon mobility in general?

iii. Industry stakeholders

- Outcome:

□ Is the mode working completely on a commercial basis, or it is partially financed from other sources? (public support, private sponsorship, etc.)

□ Are there specific categories of people particularly targeted by the company offer? How? Why?

□ Does the company have any measure planned to provide a “Low Carbon” service? If not, why? (only for non-electric carsharing providers)

□ Does your service compete with another? Who? Does it occupy a niche in the sector?

□ In their view, what are the positions of policymakers and pressure groups? What are the synergies and the contrasts with them?

□ What is their vision on the future of electric carsharing?

Appendix II – Carsharing users Template Coding

1. TRAVEL ROUTINE AND CARSHARING USE

1.1. Carsharing

1.1.1. Frequency of use

1.1.2. Usual distance/time

1.1.3. Means of use

1.2. Traditional travel modes

1.2.1. Foot

1.2.2. Bicycle

1.2.3. Public transport

1.2.4. Private car

1.2.5. Others

1.3. The routine

1.3.1. Leisure activities

1.3.2. Work time

2. FACILITATION OF CARSHARING

2.1. Personal experience

2.1.1. When started

2.1.2. Previous modes

2.1.3. Motivation to start

2.1.4. How was the mode discovered?

2.2. Opinion

2.2.1. Attributes motivating its use

2.2.1.1. Ranking

2.2.2. Barriers to its use

2.2.3. Other possible motivations people might have

3. RELATION WITH OTHER MODES

3.1. Public Transport (PT)

3.1.1. Current frequency of PT use

3.1.2.PT Use

3.1.2.1. Bus use

3.1.2.2. Metro use

3.1.2.3. Other modes use

3.1.3. PT Opinion

3.1.3.1. Bus opinion

3.1.3.2. Metro opinion

3.1.3.3. Other modes opinion

3.2. Private Vehicle (PV)

3.2.1. PV Ownership (Yes/No)

3.2.1.1. Motivation

3.2.1.2. Number of vehicles

3.2.2. Current frequency of PV use

3.2.3. PV Use

3.2.4. PV Opinion

3.3. Relation with Carsharing

3.3.1. Comparative advantages

3.3.1.1. Advantages Public Transport

3.3.1.2. Advantages Carsharing

3.3.1.3. Advantages Private Vehicle

3.3.2. Comparative advantages

3.3.2.1. Disadvantages Public Transport

3.3.2.2. Disadvantages Carsharing

3.3.2.3. Disadvantages Private Vehicle

3.3.3. Influence of carsharing on other modes use

3.3.3.1. Change in use of Public transport

3.3.3.2. Change in use of private vehicle

3.3.3.3. Change in PV purchasing intention

3.3.3.4. New demand for mobility

4. CONSIDERATIONS ON ELECTRIC CARSHARING

4.1. Type of carsharing vehicle used (Electric or Conventional)

4.1.1. Knowledge of different models of carsharing end vehicles' type

4.2. Experience with BEV electric vehicle

4.2.1. Previous experience with electric

4.2.2. Opinion on electric technology

4.3. Value of being electric

4.3.1. Willingness to pay for electric carsharing

4.3.2. Pros and Cons of the Electric vehicles

4.3.3. Influence on the intention to buy