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***Research Highlights**

- Park&carsharing services may be a valid transport option for neighbourhood residential users
- the most statically significant attributes are travel cost and travel time.
- Users’ behavior is significantly affected by the user’s socioeconomic characteristics
- EV availability increases the probability of switching to carsharing
- the “pure preference” toward EV is quantified at 1.56 euros per trip

A random utility model for Park&Carsharing services and the pure preference for electric vehicles

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Abstract

Most of the existing Carsharing business models mainly rely on gasoline vehicles and diesel vehicles, but in recent years there has been a significant increase in hybrid electric vehicles (HEVs) and a resurgence in electric vehicles (EVs). Within this framework, this paper investigates and models the choice to switch from a private car trip to a carsharing service available in peripheral parks as well as the propensity to choose an electric vehicle for such a service. In particular, three issues are addressed: (i) investigating and modelling the propensity to choose carsharing as a transport alternative within a neighbourhood residential carsharing business model; (ii) estimating the effect of also having an EV option available; (iii) measuring the "pure preference", if any, in using electric vehicles over traditional ones, in a context excluding factors that may bias such users preference (e.g. purchase price, energy costs, recharging facilities etc). The analyses are based on a stated preferences survey undertaken on 600 car drivers entering the city center of Salerno (Southern Italy), and on the estimation of a binomial Logit model with serial correlation. Results allow an interpretation of the main determinants of the short-term choice of carsharing services (i.e. without any car-ownership changes), give general behavioural insights, make it possible to quantify the "pure preference" for EV and the demand elasticity with regard to different pricing strategies of the carsharing services.

1 Introduction and motivations

Carsharing is an increasingly popular solution for personal mobility in many cities worldwide. As highlighted by Shaheen and Cohen (2013), at the end of 2010 carsharing schemes were operating in more than 1,100 cities in 26 countries on five continents (Asia, Australia, Europe, North America and South America). Although Europe led carsharing activities for two decades (61% of the world's carsharing membership; Shaheen and Cohen, 2007), as from 2010 North America became the largest carsharing region (48% of worldwide carsharing membership), though Europe continues to account for the majority of worldwide fleets deployed in 2010 (53% in contrast to 32% in North America, Shaheen and Cohen, 2013).

Currently, carsharing is most common in urban areas (Shaheen and Cohen, 2013; Shaheen, 1999; Shaheen et al., 2006; Shaheen et al., 2010), and several carsharing business models have been successfully developed: neighbourhood residential; business; government and institutional fleets; transit-based; college and university-based; and personal vehicle sharing (Shaheen and Cohen, 2013). Recently, it has also shown interesting potential in some pilot studies regarding suburban areas (de Luca and Di pace, 2015).

The various business models mainly rely on gasoline vehicles and diesel vehicles, but in recent years there has been a significant increase in hybrid electric vehicles (HEVs) and a resurgence[1] in electric vehicles (EVs).

As pointed out by Bakker and Trip (2013) and Shaheen and Chan (2015b), many governments are attempting to implement EV sharing initiatives by providing financial support, whereas major carsharing providers (e.g. Hertz 24/7™, Car2Go, City CarShare, Zipcar, I-GO CarSharing) and global automakers (BMW, Ford, General Motors, Mitsubishi, Toyota, Daimler, Honda and Suzuki) have begun entering in the market to provide a carsharing service with EVs. Indeed, a significant change in carsharing vehicles propulsion has been recently observed in several countries worldwide: EVs in the USA, Japan, France, Italy, Austria, Australia, Denmark, Norway, the UK, the Netherlands, Switzerland and Portugal; HEVs in Canada, Singapore, the USA, Japan, Italy and Switzerland.

In conclusion, as also indicated by Shaheen and Cohen (2013), the re-emergence of EVs and the integration of plug-in hybrids into carsharing fleets (e-mobility) will be one of the key trends to

[1] Shaheen and Chan (2015) point out that in the early 2000s 60% of all EV carsharing programmes ceased, while by 2006 the majority of EVs had disappeared in favour of gasoline-electric hybrid vehicles.

emerge in the carsharing business over the next five years. As a matter of fact, E-mobility carsharing solutions would allow the following three objectives to be achieved:

(i) making carsharing more environmentally friendly, reducing its environmental impact.
E-solutions might respond to the main criticisms that are often levelled against carsharing, such as the risk of an increase in car use (trips by cars supplied by carsharing and kilometres travelled), and the increase in pollution, congestion and all negative externalities related to the use of conventional cars.

(ii) Improving the appeal of carsharing and increasing user satisfaction due to its possible symbolic, hedonic and environmental significance.
As reported by Shaheen and Chan (2015b), new e-mobility business models have allowed an increase in carsharing membership and greater flexibility.

(iii) Opening up new horizons for EV market penetration.
Since EVs and plug-in hybrid electric vehicles (PHEVs) continue to occupy a niche market, EVs in a carsharing service might be an opportunity for drivers to readily trial new technologies and observe new technologies in use. In particular, embedding e-solutions within carsharing programmes would allow the high capital cost of vehicle batteries to be distributed among several drivers (Shaheen and Chan, 2015a) and reduce the main adoption barriers related to the limited range and to the need to recharge such vehicles (Prem Kumar and Bierlaire, 2012; Wappelhorst et al., 2013; Communauté d'Agglomération de La Rochelle, 2014).

Within the context introduced above, to date few contributions have addressed the potential impacts of EVs in carsharing programmes. As pointed out by Zoepf and Keith (2015) and Shaheen and Chan (2015a), little has been written about the role of vehicle powertrain technologies in the carsharing context and research is still needed to ascertain and quantify e-mobility impacts on vehicle kilometres travelled, household vehicle ownership and modal shift.

Among existing contributions (Nerenberg et al., 1999; Zoepf and Keith, 2015; Firnkorn and Muller, 2015; Wappelhorst et al., 2014; Kim et al., 2015), most consist in descriptive analysis based on real data or stated preference (SP) surveys, and mainly aim to ascertain user satisfaction with e-solutions or the propensity to buy an EV. Only Zoepf and Keith (2015) investigate the choice of powertrain made by carsharing users.

Starting from these considerations, this paper investigates and models the choice to switch from a private car trip to a carsharing service available in peripheral parks as well as the propensity to choose an electric vehicle for such a service. In particular, users may choose whether or not to switch to a car-sharing service which, in turn, may, or may not, contemplate EVs. Therefore, two issues are addressed:

a) the propensity to choose carsharing as a transport alternative within a neighbourhood residential carsharing business model;
b) the effect of also having an electric vehicle option available. Since the respondents faced a binary choice context in which the carsharing service could be supplied by a traditional vehicle or by an electric one, the "pure preference" for an electric solution was directly observed (collected).

In particular, the main determinants are explored, their role is quantified and the "pure preference" for EVs is elicited.

Modelling carsharing behaviour and including EVs is interesting both in methodological and operative terms. First, the carsharing service investigated is a sort of park-and-share service, somewhat overlooked in the literature and in real-world case studies. Thus the proposed models can give interesting insights and/or be transferred to similar case studies. Secondly, the study would allow observation and measurement, using suitable mathematical models, of the "pure preference", if any, of using electric over conventional vehicles without the typical biases that may (positively or negatively) affect EV market behaviour simulation (e.g. price spread, the reliability of battery packs, restricted range, the limited number of charging stations, limited information on the technology and the main features of vehicles on the market). Thirdly, it would help ascertain and quantify whether the use of EVs might be a key factor for carsharing providers, since the availability of an electric vehicle may make the service itself "significantly" more appealing, thus giving useful insights to carsharing operators. Finally, it would indicate whether carsharing could be a niche market for EVs, giving useful insights to automotive manufacturers.

The above issues were addressed through an "ad-hoc" stated preferences survey within a carsharing project in the city of Salerno (Italy), and through specification and calibration of a set of discrete choice models based on the behavioural paradigm of random utility theory. The proposed carsharing service was a one-way service targeting users entering Salerno by car: each user was supposed to leave his/her own car in one of the peripheral parks, pick up the reserved car and continue to travel towards his/her final destination without paying any parking fee and/or without any limitation with respect to restricted traffic zones. Users were intercepted at the main parking lots in central Salerno and were asked whether (and how often) they would choose the carsharing service. Vehicles were assumed always available; electric and traditional technologies were considered and priced at different levels.

The paper is organised as follows. In section 2 an updated literature review is provided, covering both methods to model carsharing behaviour and scientific contributions investigating perceptions of electric vehicles. In section 3 the case study, survey and some descriptive results are presented. In section 4 the modelling framework, estimation results and sensitivity analyses are discussed. Conclusions are drawn in section 5.

2 Modelling carsharing behaviour: literature review

Carsharing has been investigated since the 1970s, but only in the late 1980s did it begin to be considered a viable solution in urban contexts. In-depth overviews and time-lines of carsharing history may be found in the various contributions produced in the last decade by the Transportation Sustainability Research Centre and its co-director Susan Shaheen.

Studies on carsharing are mainly concentrated in North America, and focus primarily on the feasibility of carsharing programmes and on the impact of carsharing on car ownership and vehicle usage (see de Luca and Di Pace, 2015, for an in-depth synopsis). Most of them rely on RP data and mainly develop descriptive analyses. Interesting overviews are proposed by Steininger et al. (2012), Meijkamp (1998), Katzev (2003), Litman (2000), Haefeli et al. (2006), Shaheen et al. (2006), Barth et al. (2007), Shaheen and Cohen (2007), Shaheen et al. (2009), Shaheen and Cohen, (2013), Shaheen et al. (2015a).

With regard to modelling approaches, several models have been proposed to model the usage, the membership behaviour, frequency of usage and other choice dimensions.

With regard to car ownership and vehicle miles travelled daily, the Multinomial Logit model is the most commonly pursued modelling solution (Cervero et al., 2007), whereas in terms of the probability of being an active member, the frequency of usage and/or membership duration has been investigated through regressions or econometric models (Habib et al., 2012; Morency et al., 2012; Stillwater et al., 2008; Shaefers, 2013), through dynamic econometric models (Morency et al., 2009) and, recently, through activity-based micro-simulation methods (Ciari, 2013). The majority of the proposed models are applied to urban contexts, where a reliable transit system is present.

The use of carsharing as an alternative transport mode has been modelled through logistic regressions (Shaheen, 1999; Nobis, 2006), through random utility models (Cervero, 2003; Abraham 2000; Fukuda et al., 2005; Zhou et al., 2011, Zheng et al. 2009; de Luca and Di Pace 2015), and through holding or switching models (de Luca and Di Pace, 2014 and 2015). Finally, the motivations behind carsharing usage have been recently investigated within the previous contributions or explicitly investigated through the hierarchical means-end approach (Shaefers, 2013) or logistic regression analysis (de Lorimier and El-Geneidy, 2013).

In relation to the main operational results, carsharing users emerge as being more concerned with personal utility than social or environmental benefits, and are more motivated by convenience and less by affordability. Moreover, users may be grouped in terms of the frequency of usage (frequent or occasional), favourite period of use (weekday or weekend) and trip length.

The most influential factors are: levels of household ownership, household income, education and professional condition (more likely to join carsharing programmes), neighbourhood and transportation characteristics, familiarity of the project, attitudinal variables (such as sensitivity to congestion, willingness to experiment, concern for the environment), scheduling reliability, convenience and programme cost. Generally, carsharing users focus their mobility habits on public transport, and are sometimes attracted to carsharing because of its positive environmental image.

Previously introduced determinants have been mainly investigated within carsharing programmes supplied by traditional powertrains. Recently, increasing attention towards CS services supplied by electric solutions has generated interest in the impacts that more environmentally friendly technologies could have on carsharing appeal and on users' travel behaviour.

Except for the pioneering work by Neremberg et al. (1999) most of the existing contributions have been concentrated in the last four years. Indeed, Neremberg et al. (1999) were the first to investigate the potential of EV_S within a CS service, and pointed out that environmental and technological aspects are elements of interest in such a technological solution.

In 2014, Wappelhorst et al. (2014) underlined the positive assessment of carsharing schemes including EVs in rural areas, and indicated that users highly appreciate EV driving comfort, the service and system itself and would recommend carsharing with EVs to relatives or friends. In the same year Ruhrort et al. (2014) investigated the potential of carsharing with battery electric vehicles from data derived from the project BeMobility in Berlin. They investigated a multi-modal choice context and observed users' perception, satisfaction and motivations. Overall, the most important motivations in choosing carsharing are of a pragmatic nature. Thus EVs do not increase the propensity to carshare. The main motivations for belonging to an EV carsharing programme lie in an interest in sustainability, taste for innovation and enjoyment of the e-mobility experience. Le Vine et al. (2014) investigated the effect of vehicle type as a choice attribute but did not find it to be statistically significant.

In 2015 three interesting contributions were proposed by the scientific community. Firnkorn and Muller (2015) investigated car2go's potential to reduce private car ownership in urban environments given the ongoing electrification of the system. Their results were based on a randomised controlled trial testing car2go-users' willingness to reduce private car ownership depending on different electrification scenarios. The findings showed that the electric "stimulus" does not increase the propensity of users to forgo an own car purchase. Moreover, the greatest willingness to reduce private car use can be observed for users who have already used EVs and in combinations with electricity generated from renewable energies.

Kim and al. (2015) investigated the factors which affect electric vehicle sharing programme user attitudes to environment-friendly and sustainable travel mode choices just after experiencing EVs. Their results indicated that respondents were rather reluctant to change their car ownership but intended to continue participating in the electric vehicle sharing programme.

Finally, Zoepf and Keith (2015) investigated the willingness to drive hybrid electric vehicles (HEVs), plug-in electric vehicles (PEVs) and battery electric vehicles (BEVs) by calibrating a discrete choice model based on a stated preferences online survey of members of the largest carsharing operator in North America (Zipcar). Estimation results indicated that carsharing users prefer driving a hybrid vehicle but not a plug-in electric vehicle. Furthermore, the utility of PHEV and EV decreases with increasing reservation distance. WTP for vehicle type was quite small, varying from 0.4 dollars/hour for hybrid vehicles to -0.46 for BEVs and 0.5 for PHEVs.

In conclusion, the effect of EVs on carsharing users' behaviour has been mainly investigated through descriptive analyses based on data or surveys collected from actual carsharing users. Most of them focus on whether and in what way users would change their travel behaviour, car purchase or EV purchase. Only Zoepf and Keith (2015) model users' behaviour and quantify the impact of EVs, but they focus on the choice of vehicle type, not on the choice of whether to belong to a carsharing service with an EV available within the introduced framework. No contribution has yet explicitly modelled the effect that an EV vehicle could have on users' propensity to belong to a carsharing service. Such an issue is noteworthy since it may help to understand whether and to what extent an EV may increase/decrease the choice to "take part in" carsharing. Such an effect is of interest for carsharing providers, but also for EV manufacturers.

3 Investigating perceptions of electric vehicles: literature review

Understanding (and quantifying) users' perception of the "electrification" of mobility is one of the most widely investigated, discussed and critical issues in analyses of EV market penetration. As pointed out extensively elsewhere (see the framework in de Luca et al., 2015), the choice phenomenon is quite complex and might not be simply and solely interpreted within a unique theoretical framework. Together with typical instrumental and easily quantifiable attributes (e.g. range, maintenance, driving costs, ownership costs), several other attributes may play a significant role together with the existence of supportive technological, legislative and fiscal policies on both the supply and demand sides.

In particular, eliciting the “preference” for EVs is quite complicated due to several factors. For example, (i) PHEV and EV automotive technologies have only recently been adopted; (ii) sales data are not easily available for validation of any PHEV and EV market model; (iii) consumer evaluation of PHEVs and EVs significantly depends on ownership costs and on the weighting of energy consumption sources, as well as consumer driving habits. Moreover, evaluation of consumer preferences for radically new products is methodologically challenging since any research in which participants have not experienced the new technology may be subject to large uncertainties (Trope and Liberman, 2003).

In general, the decision to install/purchase/adopt an EV depends on several attributes of different types: instrumental, environmental, hedonic and symbolic (e.g. Dittmar, 1992; Voss et al., 2003; Roehrich, 2004; Heffner et al., 2006; Kurani et al., 2007; Skippon and Garwood, 2011; Shepherd et al. 2012; Schuitema et al., 2013; Cascetta and Cartenì, 2014).

In this conceptual framework, “pure preference” for an EV can be defined as “preference” for an EV (technology) independently of its instrumental features. Therefore, it can be assumed that it is mainly affected by environmental, hedonic and symbolic attributes. However, eliciting and quantifying “pure preference” could require simultaneous investigation of all four types of attributes.

Up to now, existing contributions have not addressed all the attributes within a single framework and/or have not quantified the role of each attribute. Indeed, most investigate the intention to adopt EV in terms of instrumental attributes. Founded on random utility theory models, they explore several different choice dimensions regarding EVs: vehicle purchase, ownership decisions and consumer preferences regarding vehicle technology, segment, brand and characteristics.

EVs are usually judged with respect to purchase price, running costs, reliability, performance, driving range and recharging time, performance, convenience, comfort and aesthetics (Beggs et al., 1981; Bunch et al., 1993; Chéron and Zins, 1997; Graham-Rowe et al., 2012; Kurani et al., 2007; Sikes et al., 2010; Skippon and Garwood, 2011; Musti and Kockelman, 2011; Hsu, 2013; de Luca et al., 2015). However, purchase intentions are mainly dependent on EVs meeting such standards at some future date and/or on the existence of supportive policies on both the supply and demand sides (Golob et al., 1997; Kurani et al., 1992, 1996; Brownstone et al., 2000; Dagsvik et al., 2002; Batley et al., 2004; Potoglou and Kanaroglou, 2007; Caulfield et al., 2010).

The role of the perception of environmental benefits has been less widely explored (Graham-Rowe, 2012; Caperello and Kurani, 2012). The above authors showed that the environmental benefits of EVs are not highly valued by most drivers. Rather, the utility of EVs is primarily evaluated in light of whether they could meet personal mobility needs as effectively as internal combustion cars. In particular, Graham-Rowe et al. (2012) found that drivers were not convinced that plug-in EVs would allow them to meet such goals.

Few studies to date (Schuitema et al., 2013) have investigated whether and to what extent the adoption of EVs is influenced by perceptions of hedonic and symbolic attributes. In particular, regarding EVs, Skippon and Garwood (2011) found that people, after an experience with BEVs, attributed clear symbolic meanings to them: agreeableness, conscientiousness and openness to experience. Graham-Rowe et al. (2012) carried out a study in the UK on 40 households using a PHEV or BEV for seven days, and reached two contrasting conclusions. Some of the participants felt good about driving such a vehicle or felt less guilty about driving because of the environmental benefits associated with it. The rest stated they were embarrassed about driving an EV. Further, the results showed that the tested EVs were perceived as uninspiring or "soulless".

Schuitema et al. (2013) investigated the role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles. They interviewed 25 households in the USA and showed that HEV ownership was seen as being symbolic of self-identity, ''making a difference'', of maturity, intelligence and awareness. Furthermore, they indicated that instrumental attributes are important largely because they are associated with other attributes derived from owning and using EVs, including the pleasure of driving (hedonic attributes) and identity derived from owning and using EVs (symbolic attributes).

In conclusion, quantifying the "pure preference" for an EV would require analysis of instrumental attributes and user attitudinal characteristics. However, this is no easy task due to the lack of data, to the many concurring variables and to the immature technology.

While contributions investigating instrumental attributes have not been able to correctly model/interpret the "pure" preference for an electric vehicle, those investigating hedonic and/or symbolic attributes rely on interesting but descriptive analyses, or on a modelling framework which is unable to measure the perception of electric technologies. One possible approach could be based on the observation of user behaviour in a choice context unaffected by the instrumental features that are usually considered a barrier to EV adoption (price, charging, speed, etc.). This could be the case of a carsharing service where EV is an alternative powertrain technology to choose.

4 Case study and descriptive results

The case study for application was the city of Salerno in southern Italy, occupying an area of about 60 km^2 with a population of more than 138,000. A revealed (RP) and stated preferences (SP) survey (*RP&SP survey*) was carried out in the main car parks in Salerno city centre (area bounded by the dashed black line in Figure 1). This congested area concentrates the city's main activities (e.g. courts, banks, shops, workplaces, libraries, museums, schools) and the parking fare is the highest in the city (2.5 Euro/hour against 1.0 Euro/hour or free parking for the other areas in the city). The parking supply in Salerno city centre currently consists of one large car park (park A in Figure 1) with about 870 parking lots over three contiguous areas and three other smaller car parks with about 30-50 car lots each. No park-and-ride scenario is currently available in Salerno, and all the car parks (central) are used as a final trip destination.

Most of the daily travel demand in Salerno consists of car trips (for work) originating from many small peripheral (low-density) municipalities in the province of Salerno while internal car trips account for a small part of travel demand. Due to the relatively small area of the city centre, many trips within Salerno are undertaken on foot. This circumstance does not allow implementation of a traditional carsharing scheme (such as those implemented in many of the world's high-density and/or geographically large cities) to replace the use of private cars and reduce car ownership.

Starting from these considerations, the carsharing service proposed in this study to potential users was a one-way service (*park&share*) from the peripheral interchange car parks (parks B, C and D in Figure 1) in which drivers, also with more than one passenger, may leave their private cars (currently parked in the city centre), take the (traditional or electric) vehicles booked in advance, move within the city and park free of charge (also in the city centre, Figure 1) and freely access the restricted traffic area (area bounded by the continuous blue line in Figure 1). The car travel time from the peripheral interchange parks (*Park&Carsharing* B, C and D in Figure 1) to the city centre is about 6 - 15 minutes according to the car park chosen and the time of day (level of traffic congestion) in which the trip was performed.

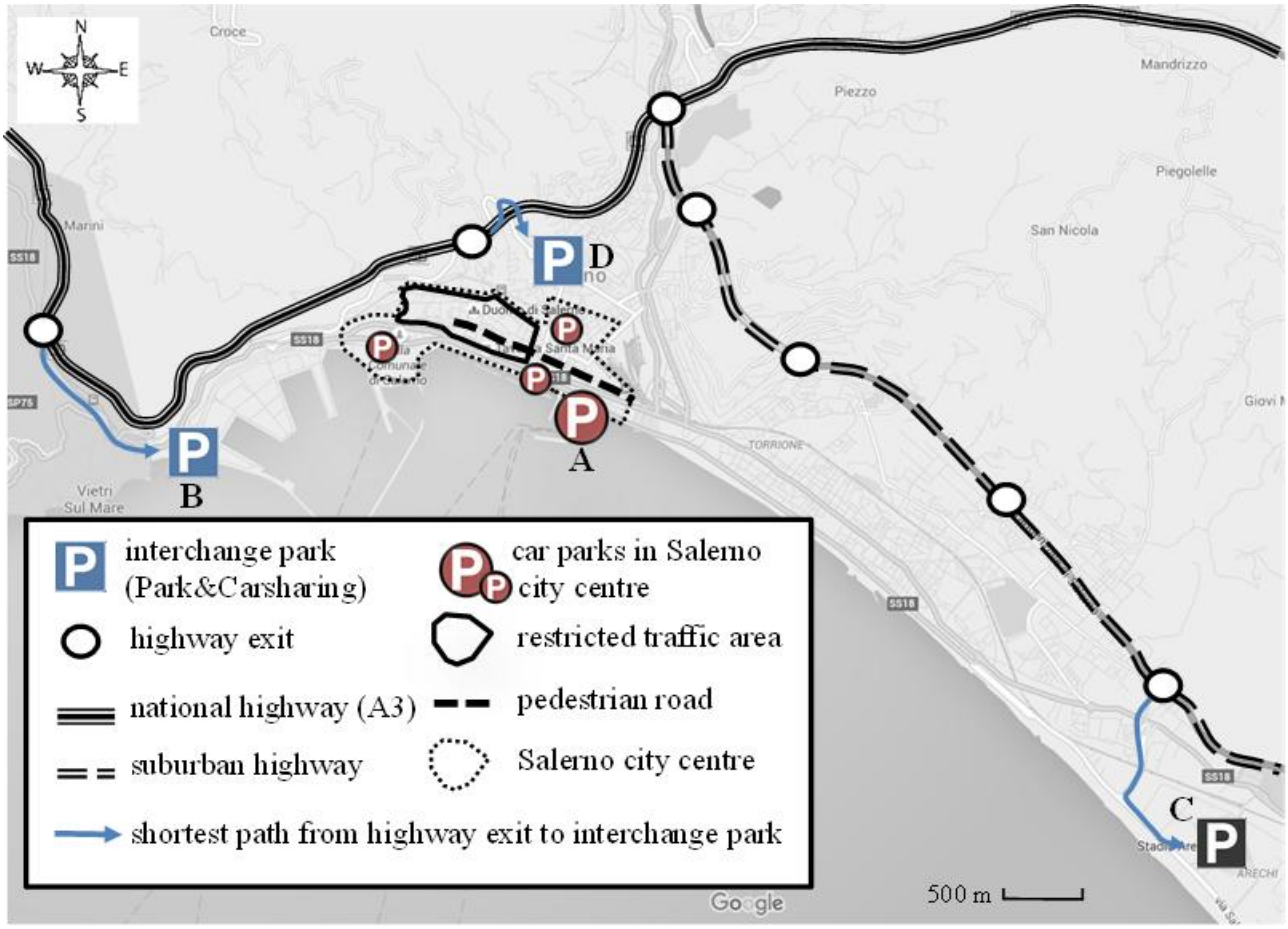

Figure 1 – Salerno municipality road map

In the survey, the investigated travel demand segment was the daily travel demand entering Salerno city centre from the province of Salerno (about 2,700 private cars/day). The *RP&SP survey* consisted in three parts. The first part of the questionnaire (background and *RP* information) aimed to:

- gather information on users' socio-economic characteristics (age, gender, occupation, household composition, number of vehicles in the household) and their residence (address);
- gather information on users' usual travel behaviour (final destination, trip purpose, number of passengers/car, trip frequency to the city centre; average fare spent on parking; average time spent in Salerno);
- introduce the main characteristics of electric and traditional vehicles in the proposed carsharing service (a unique city car model was proposed for both engines to avoid perception bias caused by differences in the model of the vehicles proposed);
- investigate users' general propensity to use electric or traditional vehicles in the proposed carsharing service.

In the second part (*SP*) a carsharing service was proposed and respondents were asked if they would leave their car in a peripheral car park and switch from their usual transport mode (private car) to a carsharing service. The proposed service had to be booked in advance, allowed free parking in the city centre and free access to the traffic restricted area.

Respondents were presented with different choice contexts defined by a set of alternatives. In the proposed choice contexts, the attributes varied between a prefixed number of values, or levels. These levels were defined in absolute terms or as a percentage variation compared to the travel context experienced by the respondent. The SP experiment was conducted on a selection of all the possible scenarios and, starting from the full factorial design scheme, a subset of scenarios was generated with the fractional factorial design technique (Cascetta, 2009). Each respondent faced only eight scenarios in order to limit fatigue effects. Finally, more than 4,800 choices were observed.

In the third and last part of the survey, to recover useful market information to draw up a business plan for the proposed service, a compendium questionnaire (*RP*) was also proposed (not used for model estimations), aiming to:

- investigate preferences for some characteristics of the service like the methods for booking (e.g. smartphone, internet, telephone) and payment (e.g. cash, credit card, dedicated pre-paid card);
- investigate the preference for the carsharing fleet with respect to the brand/model (expensive vs. cheap cars; appealing vs. non-appealing vehicles), the size of vehicle (e.g. two-seater, city car) and the number of seats (2 seats, 4 seats, 5 seats).

The sample rate was about 20% of the total travel demand entering each car park in Salerno city centre (area bounded by the dashed black line in Figure 1), and was stratified with respect both to the total travel demand counted in each car park (to determine the number of interviews per car park) and with respect to census data (to determine the number of interviews of males/females, employed/non-employed, 25-45 year olds/other ages). The overall sample consisted in more than 600 users obtained by sampling one driver every five cars entering the car parks.

The survey results are shown in Tables 2: 63% of the sample was male; 54% of the respondents were 25-45 years old; 75% were employed; 61% of the trips were performed with a very low frequency (less than 1 trip/week); the percentage of trips for work purposes that use the private car are both systematic (commuting) and non-systematic (low frequency work trips, e.g. activities in courts, banks, public/private offices, libraries, museums) and comparable (in number) to those for other purposes (53% against 47%, respectively).

The results describing the users interested in the proposed carsharing service indicate significant differences between working users and non-working users (e.g. leisure, shopping, personal affairs), showing that more than 84% of the users travelling for non-working purposes declared an interest in the carsharing service. This result is interesting since non-working users are those with a greater willingness to pay. Furthermore, 84% of the males interviewed and 80% of those employed were interested in the proposed service. In addition, 85% of the 25-45 year olds were users interested in carsharing. Finally, 77% of the car trips were undertaken with 1 or 2 passengers/car and 73% of the users interested overall parked for an average of 2.5 hours, paying about 6 euros for parking in the city centre.

In conclusion, the average characteristics of a potential carsharing user are: male, employed, 25-45 years old and travelling for non-working purposes. These results are consistent with those obtained in other countries (e.g. Cervero et al., 2002 and 2007; Lane, 2005; Barth et al., 2007; Morency et al., 2008; Firnkorn and Müller, 2011).

Table 2 – Survey results: potential users interested in the use of a carsharing service with respect to socio-economic characteristics and trip purpose

Sample characteristics	*% distribution in the sample*	*% potentially interested in the use of a carsharing service*
males	63%	84%
females	37%	70%
< 25 year olds	9%	75%
25-45 year olds	54%	85%
> 45 year olds	38%	71%
Employed	75%	80%
Not employed	25%	75%
trips for work purposes	53%	74%
trips for other purposes (e.g. leisure, shopping, personal affairs)	47%	84%
trips with frequency lower than 1 trip/week	61%	81%
trips with frequency greater than 1 trip/week	39%	76%

5 The park&carsharing services choice model

5.1 Estimation results

A random utility, discrete choice model was specified and estimated to reproduce respondents' choice behaviour. The decision making process was modelled as the choice between two alternatives: *Private Car (PC* - current choice) and *Carsharing* service (*CS)* using a Binomial Logit choice model taking into account serial correlations among multiple responses given by the generic individual *i* (panel data) over different SP scenarios.

Let:

$V_{i\,CS}^{s}$ and $V_{i\,PC}^{s}$ be the systematic utilities of alternatives *CS* and *PC*, respectively, corresponding to the different choice scenarios *s*, supposed linear in the attribute coefficients (non-linearities were also tested but no improvements were obtained in terms of a validation test);

$\gamma_{i\,CS}^{s}$ and $\gamma_{i\,PC}^{s}$ be the i.i.d. Gumbel random in terms of the respective *CS* and *PC* perceived utilities;

ε_i be the random term (assumed normally distributed with zero mean and standard deviation σ), specific to the individual *i* and invariant over scenarios *s*. The random term was introduced to take into account the serial correlation between responses from the same users. This was introduced in the *CS* perceived utilities, $U_{i\,CS}^{s}$ (e.g. Ben-Akiva and Morikawa, 1990; Cantillo et al., 2007).

The perceived utilities were expressed as:

$$U_{i\,CS}^{s} = V_{i\,CS}^{s} + \gamma_{i\,CS}^{s} + \varepsilon_i$$

$$U_{i\,PC}^{s} = V_{i\,PC}^{s} + \gamma_{i\,PC}^{s}$$

Different systematic utility functions were specified by testing the statistical significance of several attributes; in Table 4 the tested attributes and those statistically significant are reported. A maximum likelihood estimator was used for parameter estimation employing the software BIOGEME (Bierlaire, 2003).

Table 4 - Tested attributes

Category	Description	Statistically significant	In Car Sharing	In Private Car
Level of Service (LoS)	**TTT** - Total Travel Time [2]	YES	✔	✔
	TTT$_{CS}$ - Total Travel Time specific for CS users	NO	✔	
	TTT$_{PC}$ - Total Travel Time specific for Private Car (PC) users	NO		✔
	PCT - Private Car access/egress Time to/from CS car park	NO	✔	
	TVT - Total in-Vehicle Time	NO	✔	✔
	TWT - Total Walking Time from/to CS car park to/from final destination	NO	✔	
	PDT - Pickup and Delivery Time for a CS vehicle	NO	✔	
	TC - Total travel cost [3]	YES	✔	✔
Socio-economic	**Gender** - equal to 1 for male users; 0 otherwise	YES	✔	
	AGE - equal to 1 for 25-45 year-old users; 0 otherwise	YES	✔	
	CarAv - number of household vehicles /number of household members	YES		✔
	TripWeek - number of trips per week;	YES		✔
	Employed - equal to 1 for employed users, 0 otherwise	YES	✔	
	TripPurp - equal to 1 for non-working trips (e.g. leisure, personal affairs, shopping), 0 for working trips (work)	YES	✔	
Electric vehicle preferences	**EV** - equal to 1 for an electric carsharing service; 0 otherwise	YES	✔	
	EV$_{25\text{-}45}$ - for 25-45 year-old users, is equal to 1 for an electric carsharing service; 0 otherwise	YES	✔	
	EV$_{>45}$ - for >45 year-old users, is equal to 1 for an electric carsharing service; 0 otherwise	YES	✔	
ASC	Alternative Specific Constant (ASC)	YES	✔	

As shown in Table 4, different systematic utility functions were statistically significant. Thus different models were proposed for each of the investigated formulations. Overall, the models share most of the attributes, but differ from each other in the following dummy attributes: trip purpose, professional condition and electric vehicle.

The parameters reported in Table 5 are all statistically significant and have the expected signs. The adjusted rho-squares of the model were significantly larger than 0.5, which is consistent with a binomial choice context. The variance for the individual specific random term was statistically different from zero, meaning that a correlation among multiple responses existed and could not be neglected.

[2] Given by the sum of: private car access/egress time to/from CS car park, pickup and delivery time for a CS vehicle, total in-vehicle time, total walking time from/to CS car park to/from final destination.
[3] Given by the sum of: car sharing fare (in the CS alternative) and fuel and parking fare (in the PC alternative)

The estimation results highlight the fact that the total travel time and travel fare/cost were statistically significant, suggesting, for example, that users perceive a sort of trade-off between the time lost in changing vehicle and the parking cost saved at destination. Moreover, the estimated Travel Time Savings – TTS (sometimes referred to as Value Of Travel Time savings - VOT) were about 4€/h (Table 6). This result is consistent with the few papers dealing with similar issues for the south Italy context (e.g. de Luca and Papola, 2002; de Luca and Cantarella, 2005 and 2010; de Luca and Cartenì, 2011; Catalano et al., 2008; Zito and Salerno, 2004).

Other specifications were also tested considering more disaggregated LoS attributes such as: in-vehicle time (TVT), walking time (TWT), car access time (PCT) and pickup and delivery time (PDT). However, these time components were not statistically different from each other according to validation tests (Student T-tests). Furthermore, a model specification with two different total travel time parameters was also tested, one relative to carsharing users (TTT_{CS}) and another to private car users (TTT_{PC}). Yet also in this case calibration results show that these time components did not statistically differ (no difference in perception in total travel time using these two modes).

With respect to socio-economic attributes, the following were statistically significant: age, gender, employed and number of household vehicles /number of household members. Indeed, in line with the carsharing users' profile reported in the previous section, males and respondents younger than 45 years old increased their utility of changing from private car to the carsharing alternative. Moreover, the reciprocal substitution ratio with respect to the travel monetary cost shows a similar incidence (about €1 for 15 minutes of travel time saving) for both attributes in the systematic utility values.

CarAv showed a positive value in the "not-changing" utility function. CarAv measures the level of availability for each individual of the household, but it can also be interpreted as a proxy attribute of household income (de Luca, 2012). Indeed, as the household's income increases, the perception of the financial gain obtainable by using the carsharing service decreases.

As regards the activity-based attributes, only TripWeek was statistically significant and had a positive value in "*Private Car*" systematic utility. As the number of weekly trips increases, travel behaviour (e.g. temporal dimension, destination, parking choice, parking fees, etc.) becomes systematic, inducing a sort of inertia in changing the usual transport mode. Interestingly, for a frequency of 4 trips per week, the effect of trip frequency exceeds €2 (30 minutes of travel time saving).

Other attributes common to all the models were the alternative specific constant (ASC) and the dummy attribute electric vehicle preferences (EV). Estimation results showed that the ASC attribute cannot be neglected, although it has an equivalent monetary value of €1.5 which is dimensionally similar to the relative value of the coefficients introduced above (Table 6). The EV attribute coefficient is probably the most interesting one in this study context, since it makes it possible to measure "*pure preference*" for using an electric vehicle in a carsharing service. Estimation results show that the monetary value of parameter EV is €1.56 (about 20% of the average trip cost). The interpretation is twofold: (*i*) an electric carsharing service is much more appealing than a traditional one because of the novelty effect; (*ii*) users are sensitive to the environmental sustainability of the service itself. It would appear that the model specification does not make it possible to distinguish between the two interpretations even though the car models in the traditional and electric versions were the same, which should reduce the novelty effect. In addition, it is possible to devise a monetary estimate of the possible environmental benefits. Indeed, assuming average CO_2 emissions of 234.5 gr/km for Salerno municipality, the *benefit* is equal to €0.76 per kg of CO_2 saved (Cartenì and de Luca, 2014). This result is similar to that obtained by Gaker and Walker (2013) who estimated a willingness to pay of €0.83 per kg of CO_2 saved through an SP experiment in San Francisco (USA).

If confirmed, these results indicate that the potential of an electric carsharing service is greater than a traditional one and poses interesting new challenges for economic feasibility relative to a private operator (e.g. benefit-cost and revenue-cost analysis and for business plans), because the "*pure preference*" should be considered an explicit design variable for a carsharing service.

As reported in Table 5, Model [1] was specified taking into account a trip purpose dummy variable. As expected, users travelling for working purpose (constrained destinations and constrained time windows) are less willing to switch to a carsharing service. Indeed, even if service availability and reliability have not been explicitly investigated in the survey, workers are usually characterized by a greater inertia to change personal travel habits and to shift to a service which does not guarantee the same reliability of a personal car. At first this result might seem strange, but it should be reminded that most of the working travellers are not commuters (see descriptive analysis). As a matter of fact, in our case study commuters for working purpose mainly use the transit system (not investigated in the paper), whereas the car mode is mainly used for non-systematic working activities (e.g. working activities in courts, banks, public/private offices) with a low weekly frequency.

Model [2] differs from the previous one due to the introduction of the EV attribute in the carsharing alternative, while in Model [3] two different electric vehicle attributes were considered in the carsharing alternative: one for 25-45 year-old users (EV_{25-45}) and another for the others ($EV_{>45}$). These two attributes were statistically significant and different, describing a great propensity among young users to choose an electric vehicle (greater propensity to use new technologies and interest in the environment).

The improvement in terms of adjusted rho-square values (+8%) suggests that EV specific attributes (both in Model [2] and Model [3]) significantly improve the goodness-of-fit of the model. With regard to the latter (Table 5), the likelihood ratio test carried out for models [1], [2] and [3] shows that formulations [2] and [3] are comparable and the best performing.

Table 5 – Estimation results

Parameter	Model[1]	Model[2]	Model[3]	In Car Sharing	In Private Car
TC [euro]	-0.885	-1.020	-1.000	✔	✔
Std Error / T-Test	*0.044 / -20.23*	*0.054 / -18.94*	*0.053 / -18.76*		
TTT [minutes]	-0.061	-0.068	-0.069	✔	✔
Std Error / T-Test	*0.012 / -5.31*	*0.013 / -5.38*	*0.012 / -5.52*		
Gender [binary]	1.070	1.250	0.999	✔	
Std Error / T-Test	*0.378 / 2.83*	*0.439 / 2.84*	*0.423 / 2.36*		
AGE [binary]	1.080	1.210		✔	
Std Error / T-Test	*0.352 / 3.06*	*0.408 / 2.96*			
TripWeek [continuous]	0.542	0.553	0.542		✔
Std Error / T-Test	*0.126 / 4.30*	*0.148 / 3.75*	*0.147 / 3.68*		
CarAv [cont.]	1.460	1.770	1.060		✔
Std Error / T-Test	*0.530 / 2.75*	*0.586 / 3.02*	*0.516 / 2.05*		
TripPurp [binary]	1.021	0.995	-	✔	
Std Error / T-Test	*0.254 / 2.54*	*0.367 / 2.71*			
Employed [binary]	-	-	1.520	✔	
Std Error / T-Test			*0.428 / 3.54*		
EV [binary]	-	1.590	-	✔	
Std Error / T-Test		*0.171 / 9.31*			
EV_{25-45} [binary]	-	-	1.810	✔	
Std Error / T-Test			*0.212 / 8.54*		
$EV_{>45}$ [binary]	-	-	1.240	✔	
Std Error / T-Test			*0.229 / 5.43*		
ASC	2.01	1.490	1.450	✔	
Std Error / T-Test	*0.539 / 4.60*	*0.630 / 2.37*	*0.583 2.49*		

Sample size	4,888	4,888	4,888
Number of individuals	611	611	611
Number of parameters	8	10	10
Null log-likelihood	-1,874	-1,874	-1,874
Final log-likelihood	-910	-853	-849
Adjusted rho-square	0.510	0.551	0.553
Variance of serial correlation	8.65	10.06	10.90
Std Error / T-Test	*1.460 / 5.93*	*1.901 / 5.32*	*1.990 / 5.51*

Table 7 – Coefficient ratios with respect to cost

Parameter	Model[1]	Model[2]	Model[3]
TTT [Euro/hour]	4.14	4.00	4.15
Gender [Euro]	1.21	1.23	0.99
AGE [Euro]	1.22	1.19	-
TripWeek [Euro]	0.61	0.54	0.54
CarAv, [Euro]	1.65	1.74	1.06
TripFreq [Euro]	-	0.98	-
Employed [Euro]	-	-	1.52
EV [Euro]	-	1.56	-
$EV_{25\text{-}45}$ [Euro]	-	-	1.81
$EV_{>45}$ [Euro]	-	-	1.24
ASC [Euro]	2.80	1.46	1.45

5.2 Sensitivity analysis

Starting from the model estimations, a sensitivity analysis was performed estimating both *direct* and *cross elasticity* with respect to the model attributes considered. *Direct elasticity* is defined as the percentage variation of the demand relative to the alternative *j* (in the discussion here, "demand" refers to the carsharing choice probability) divided by the percentage variation of an attribute *k* (*stimulus*) relative to the alternative *j*, X_{kj} (for more details see for example: Cascetta, 2009; Washington, 2003):

$$E_{kj}^{p[j]} = \frac{\Delta p[j]}{p[j]} / \frac{\Delta X_{kj}}{X_{kj}}$$

Analogously, *cross elasticity* is defined as the percentage variation of the demand relative to the alternative *j* divided by the percentage variation of an attribute *k* relative to another alternative *h*, X_{kh}:

$$E_{kh}^{p[j]} = \frac{\Delta p[j]}{p[j]} / \frac{\Delta X_{kh}}{X_{kh}}$$

In the above definitions, the variations of attributes and demand are assumed to be finite. In this case, elasticity is referred to as "arc elasticity", which is calculated as the ratio of incremental ratios over an "arc" of the demand curve.

In Table 8 the results relative to the sensitivity analysis of the Model [2] applied to the calibration sample are reported (similar results were obtained for Model [3] but not reported for brevity). Indeed, a "non-linear" effect can be observed, and it may be noted that elasticity varies with the magnitude and with the sign of attribute percentage variations. For instance, the direct arc elasticity of overall carsharing demand with respect to the CS cost ranges between -0.732 and -0.980. Significant is the estimated CS cross-elasticity with respect to the private car cost that ranges between 0.547 and 0.585 and allows the influence of an increase in private car costs (e.g. raising parking fees in the city centre) on the carsharing demand to be estimated. A similar but less significant consideration can also be carried out for other elasticities. This means that the estimated model is inelastic (elasticity always lower than 1.0).

Table 8 - Direct and cross elasticity with respect to model attributes

	Attributes	$E_{p\,[CS]}$ **Δ(-20%)**	$E_{p\,[CS]}$ **Δ(-10%)**	$E_{p\,[CS]}$ **Δ(10%)**	$E_{p\,[CS]}$ **Δ(20%)**	$E_{p\,[CS]}$ **Average**
Direct elasticity	Fare/Cost	-0.980	-0.906	-0.783	-0.732	-0.850
	TTT	-0.265	-0.266	-0.270	-0.271	-0.268
Cross elasticity	Private car Cost	0.585	0.574	0.557	0.547	0.566
	TripWeek	-0.101	-0.101	-0.102	-0.102	-0.101
	CarAv	-0.149	-0.150	-0.151	-0.151	-0.150

As shown in Table 8, the average direct elasticity with respect to the fare/cost is equal to -0.85. Thus a 10% increase in fare/cost corresponds to a 8.5% decrease in CS demand. Furthermore, the average direct elasticity with respect to travel time is -0.27, which means that a 10% reduction in total travel time (for example due to an efficiency of pickup and delivery time or to a reduction in the in-vehicle time due to a reduction in road congestion) corresponds to a 2.7% increase in carsharing demand.

With respect to the other attributes, the model is less elastic; for example, with respect to trip frequency or number of available household vehicles the cross elasticity is between -0.10 and -0.15.

The results of these sensitivity analyses yield some "key numbers" on demand elasticity with respect to some carsharing attributes. These data could be of use, for example, to estimate the correct carsharing fare in order to maximise the profit for a private operator (business plan) whilst respecting constraints (e.g. the maximum budget; the payback period; the profit rate).

6 Conclusions

This paper investigated the propensity to switch from individual cars to carsharing services including EVs through an SP survey. The non-usual structure of car travel demand affecting Salerno, consisting of car trips originating from many small outlying municipalities and few internal car trips, does not allow implementation of a traditional carsharing scheme to replace the use of private cars and reduce car ownership. Given this consideration, the type of carsharing service proposed in this study was a sort of park&share service, a one-way service for users entering the municipality in question who could leave their car in a peripheral car park and continue by carsharing. The aim of the paper was twofold:

- to interpret and model the potential demand for a carsharing service in which conventional vehicles and EVs are supplied;
- to measure the "pure preference", if any, in using electric vehicles over traditional cars, excluding all other factors including purchase price, energy costs, recharging facilities etc.

The proposed models investigated a quite different carsharing service from those usually adopted in most urban areas. The results validate the adopted modelling approach (switching behaviour) and allow interpretation of the choice phenomenon.

The most statically significant attributes were travel cost and travel time. These findings, albeit expected, show that travel cost is the main determinant in the choice process, whereas differences in travel time, albeit a statistically significant variable, do not modify the choice probabilities. In this case, service providers should pay great attention to service fees, whereas the total travel time supplied by the service is a secondary design issue.

The propensity of changing from car to carsharing is significantly affected by the user's socioeconomic characteristics (age, gender). This result bears out what is already highlighted by the scientific literature and is a further indication that carsharing users belong to specific socioeconomic segments. However, promoting carsharing as an alternative to the use of private cars would require specific policies able to capture different potential socioeconomic segments.

The possibility of using an EV increased the probability of switching to carsharing. Indeed, the models showed a significant preference for EVs which is quantified at 1.56 euros per trip. This indicates that the potential of an electric carsharing service is greater than a traditional one and poses interesting new economic feasibility challenges for a private operator (e.g. benefit-cost and revenue-cost analysis, and business plans) because "*pure preference*" should be considered an explicit design variable for carsharing services.

Finally, model sensitivity analysis yielded some "key numbers" on demand elasticity with respect to the major attributes. As stated above, user behaviour is very sensitive to travel cost, whereas changes in total travel time do not significantly modify switching probabilities.

In conclusions, while our results showed that the proposed carsharing service may be a potential solution of choice, it is nonetheless an unusual type of carsharing service. Therefore, specific analyses should be carried out to ascertain the real cost, the potential benefits, the financial feasibility of the entire programme or the need for subsidy policies.

With regard to the potential effects, short term and medium-long term effects can be expected. In the short term, no significant decrease in vehicle ownership can be expected, but just environmental benefits related to the adoption of EVs. In the medium-long term, car-pooling strategies (within the carsharing service) might help to reduce the number of cars entering the city centre, whereas integration with the transit system might lead to the typical benefits achievable by the adoption of traditional carsharing programmes.

Our findings suggest several future research lines of interest: (*i*) explicit modelling of the frequency of service use; (*ii*) analysis of the hedonic and symbolic determinants in the choice process; (*iii*) interpretation of behaviour within a latent class modelling framework; and (iv) estimation of the potential environmental benefits.

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