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Title: Modelling users' behaviour in inter-urban carsharing program: a stated preference approach

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Abstract: In this paper, the effects of a inter-urban carsharing program on users' mode choice behaviour were investigated and modelled through specification, calibration and validation of different modelling approaches founded on the behavioural paradigm of the random utility theory. To this end, switching models conditional on the usually chosen transport mode, unconditional switching models and holding models were investigated and compared. The aim was threefold: (i) to analyse the feasibility of a inter-urban carsharing program; (ii) to investigate the main determinants of the choice behaviour; (iii) to compare different approaches (switching vs. holding; conditional vs. unconditional); (iv) to investigate different modelling solutions within the random utility framework (homoscedastic, heteroscedastic and cross-correlated closed-form solutions). The set of models was calibrated on a stated preferences survey carried out on users commuting within the metropolitan area of Salerno, in particular with regard to the home-to-work trips from /to Salerno (the capital city of the Salerno province) to/from the three main municipalities belonging to the metropolitan area of Salerno. All of the involved municipalities significantly interact each other, the average trip length is about 30 Km a day and all are served by public transport. The proposed carsharing program was a one-way service, working alongside public transport, with the possibility of sharing the same car among different users, with free parking slots and free access to the existent restricted traffic areas.Results indicated that the inter-urban carsharing service may be a substitute of the car transport mode, but also it could be a complementary alternative to the transit system in those time periods in which the service is not guaranteed or efficient. Estimation results highlighted that the conditional switching approach is the most effective one, whereas travel monetary cost, access time to carsharing parking slots, gender, age, trip frequency, car availability and the type of trip (home-based) were the most significant attributes. Elasticity results showed that access time to the parking slots predominantly influences choice probability for bus and carpool users; change in carsharing travel costs mainly affects carpool users; change

***Research Highlights**

[1] Inter-urban carsharing program may be a valid transport alternative for systematic users

[2] Conditional switching approach is the most effective modeling solution

[3] The transport mode usually chosen considerably affect carsharing choice determinants

[4] Access time to parking slots is the most important design attribute

[5] Users’ socio-economic characteristics considerably affect carsharing choice probabilities

1 Introduction and motivations

The carsharing industry has grown significantly over recent years throughout the world and it has shown great potential as well as becoming a sustainable transport solution, which in turn implies significant business opportunities.

As shown by the Transportation Sustainability Research Center at the University of California (Shaheen and Cohen, 2013) carsharing operates in 27 countries and on 5 continents, accounting for an estimated 1,788,000 members sharing over 43,550 vehicles. North America remains the largest carsharing region, with Europe and North America accounting for 38.7% and 50.8% of worldwide carsharing membership, respectively. Currently, Europe accounts for the majority of fleets deployed in 2012: 47.0% in contrast to 36.2% in North America. Furthermore, as highlighted by a report from Navigant Research[*] (2013), worldwide membership in carsharing programs will grow from 2.3 million in 2013 to more than 12 million by 2020, and global carsharing services revenue will approach $1 billion in 2013 and grow to $6.2 billion by 2020.

The rapid growth of carsharing derives from two different but complementary reasons.

Firstly, carsharing has become an alternative mode of urban transportation and makes it possible to accomplish several transportation planning goals while contributing to sustainable urban development. Overall, carsharing represents a significant potential for reducing car ownership as well as the total amount of car trips made in urban areas. Moreover, it allows cars to be used properly, it makes it possible to use the appropriate mode of transport for each journey, it favours trip-chaining and reduces impulsive trips.

Secondly, as stated by Huwer (2004), carsharing is a sort of ‘carrot’ given to the car users, unlike most of the transport policies that aim to offer only ‘sticks’ against cars. Indeed, transportation users can benefit from the car’s flexibility without having to bear all its inherent costs.

Currently, carsharing has been mainly implemented in urban contexts, and in particular in highly populated cities, with significant congestion and parking problems. The present trend indicates that the carsharing business is battling to obtain profitability even as membership increases over time. In fact, many of the existing carsharing programs have been (and are) financially sustained by communities and governments through tax incentives, starting investments, free parking spaces, marketing, etc. At the same time alternative approaches to make carsharing more profitable are focusing on the increase the number of members (with fee) but decrease the frequency of use.

In this context, the most critical issues depend on the fixed costs of the service, but also on the overestimated (or underestimated) revenues, mainly determined by the misunderstanding of users’

[*] http://www.navigantresearch.com/research/carsharing-programs

behaviour (Wagner and Shaheen, 1998). Indeed, although carsharing may rely on several case studies and it is already relatively established in many cities, it should be noted that not many attempts to model choice behaviours exist in literature.

The majority of studies are mainly concentrated in North America, in urban contexts and they have most frequently been addressed through focus groups and/or analyses of real data or through revealed preferences (ex-post). Among modelling approaches, different solutions have been applied in order to predict changes in individual car ownership, mode choice and carsharing usage. Most of them are based on ex-post revealed preferences surveys and have usually interpreted carsharing as an alternative to the car transportation mode. Those which are less investigated are carsharing programs on an inter-urban scale where different municipalities significantly interact each other (e.g. bidirectional commuting flows) and carsharing may be an alternative to car, carpool and might become a potentially complementary alternative to public transport.

Indeed, as also highlighted by Shaheen et al. (2006), there are five major demographic markets for which carsharing may be a valid transport alternative: neighbourhood, business, college, low-income and commuter. Among them, it is the authors' opinion that the inter-urban travel demand may be an interesting potential market, especially between municipalities that significantly interact each other.

First of all, the household's car ownership rate for inter-urban systematic travellers is usually greater than the rate of urban systematic users, thus the fixed travel costs with which they have to deal are much greater than the costs perceived by urban travellers. In this context, car users may be more inclined to reduce the number of owned cars.

At the same time, inter-urban public transport users may be significantly attracted by a carsharing service. Indeed, if the involved municipalities are not served by a frequent and continuous (spatially and temporally) transit system (e.g. schedule based with few stops/stations within each municipality), carsharing could be a complementary alternative to the transit system in those time periods in which the service is not guaranteed, efficient or not accessible. Moreover, carpooling users may be interested (captive) in (to) the service, since they already take part in a sort of "self-organized" carsharing. In this case, carsharing would allow a more flexible solution.

From an operational point of view, if some doubts may arise on the effective feasibility of an inter-urban carsharing program, on the other hand it can be pointed out that the travel distances between municipalities daily interacting each other are comparable to those occurring in most typical contexts (intra-urban scale) in which carsharing has been already developed. Moreover, if the involved municipalities significantly interact with each other and the travel demand is bidirectional, the demand for shared cars will redistribute the cars during the day. Furthermore, users might share the car with other people, thus facing travel costs which are comparable to public transport and smaller than those faced travelling by car.

Based on said motivations, in this paper an ex-ante analysis of the acceptability of an inter-urban (short-distance) carsharing program, and its effects on mode choice behaviour were investigated and modelled.

The analysis was carried out through the specification, calibration and validation of different modelling solutions which were founded on the behavioural paradigm of the random utility theory. The aim was fourfold.

(i) To understand if an inter-urban carsharing program would have been perceived and chosen.

(ii) To compare different modelling approaches and to establish the most effective one. In particular, switching models conditional on the transport mode which is usually chosen (public transport, car and carpool), unconditional switching models and holding models were investigated and compared.

(iii) To investigate different modelling solutions within each modelling approach: homoscedastic, heteroscedastic and cross-correlated closed-form solution.

(iv) To investigate the main determinants of the choice process.

The considered case study was the metropolitan area of Salerno, in particular with regard to the home-to-work trips from /to Salerno (the capital city of the Salerno province) to/from the three main municipalities belonging to the metropolitan area of Salerno. All of the involved municipalities significantly interact each other and the average trip length is about 30 Km a day. The study area is served by the transit system, is connected by highways, and commuting flows among each origin-destination pair may choose among three transport alternatives: car, carpool or bus/train. The proposed carsharing program was a one-way service, working alongside public transport, with the possibility of sharing the same car among different users, with free and/or dedicated parking slots and free access to the existent restricted traffic areas.

The survey data were collected from a sample of 500 individuals who were asked to state their switching behaviour depending on the transport mode used to reach the usual destination. The carsharing program was common to all of the respondents, it was introduced in terms of the main features (the access time to parking sites, the travel time to the destination, the service fare) without details on the specific parking locations and/or on the type of fare (distance-based or time-based).

The paper is organised as follows: the state of play is discussed in section 2; the methodological framework is proposed in section 3; the case study, the survey and some descriptive results are described in section 4; estimation results and cross comparison are discussed in sections 5 and 6. In section 7 the main conclusions are drawn up.

2 State of play

Carsharing has been investigated since the 70’s, but only towards the end of the 80’s did it begin to be a viable solution in urban contexts.

Currently, Carsharing attracts new users by presenting a less expensive option than private car ownership in that a driver only pays for vehicle use as needed, he/she does not need to pay for or worry about parking, and he/she may be somewhat protected from rising operating costs. For these reasons, carsharing services have predominantly been implemented on urban contexts, in the presence of good public transport, cycling and other mobility organizations. Moreover, the market segment has consisted mainly of non-systematic users.

Against this background, the literature proposes a wide variety of analyses that may be classified according to the pursued analysis approaches (descriptive ex-post or modelling), the investigated impacts (car ownership and vehicle usage), the geographical contexts (North America or Europe) and the type of available data (Stated preferences - SP vs. Revealed Preferences - RP).

Studies on carsharing are mainly concentrated in North America, and are focussed primarily on the feasibility of carsharing programs and on the impact of carsharing on car ownership and vehicle usage. Most of them rely on RP data and mainly develop descriptive analyses. Interesting overviews are proposed by Meijkamp (1998), Katzev (1999), Litman (2000), Haefeli et al. (2006), Shaheen et al. (2006), Barth et al. (2006), Shaheen and Cohen (2007), Shaheen et al. (2009), Shaheen (2013).

One of the first contributions on carsharing is by Walb and Loudon (1986) and by Doherty et al. (1987). The former investigated the influence of a short-term car rental project on reducing car ownership and increasing transit usage in San Francisco (data analysis) and the latter investigated a combination of carsharing and carpooling services. In 1996, Steininger et al. analysed a controlled experiment of voluntary members and carried out a descriptive analysis investigating pre-membership and membership trip structure and modal split. Shaheen (1999) investigated the impact of information and communication technology in making carsharing popular in US cities and influencing user behaviour. In the same year, Shaheen et al. (1999) presented a systematic investigation of commuters’ attitudes towards a carsharing concept over time. Findings of a pilot study on a commuter-based carsharing program are investigated in Shaheen and Wright (2001) and carsharing user behaviour based on a survey conducted among carsharing users is dealt in Katzev (2003) and Lane (2005). Huwer (2004) investigated the benefits of the cooperation of public transport and carsharing and the study shows that new customer groups for public transport can be reached. Shaheen and Rodier (2005) assert that carsharing may have significant effects on transit modal share, reducing drive-alone modal share and total vehicle-mile travel in suburban areas. Burkhardt and Millard-Ball (2006) advance that user attitudes towards sustainability and economic growth are the most important factors influencing the success of carsharing programs. Celsor and Millard-Ball (2007) analyse GIS-based carsharing user profiles and discover that household car ownership is highly correlated to carsharing frequency of usage.

Several contributions investigate the impact of carsharing on urban travel demand. The most interesting have been proposed by Sacramento (Rodier and Shaheen; 2004), Seattle (Vance et al., 2005), Montreal (Morency et al., 2007) and the University of Los Angeles (Zhou, 2012).

Unlike the previous descriptive approaches, different modelling approaches have been investigated to model membership behaviours, frequency of usage and other choice dimensions. Most of them are ex-post analyses based on revealed preferences or on real observed behaviours (service data-set), addressing medium-long term predictions and predicting changes in individual car ownership, mode choice and carsharing usage.

Logistic regressions were explored (Shaheen, 1999), followed by binary Logit models (Cervero, 2003) to predict the use of carsharing; the Multinomial Logit model was used to predict the likelihood of choosing carsharing as a travel model among other travel modes and the Probit model was considered to examine factors influencing people’s acceptance of carsharing (Zhou et al., 2008). Cervero et al. (2007) investigated the relative success of a carsharing program in the San Francisco Bay area (RP and SP model). In particular, changes in car ownership, mode choice and daily vehicle miles travelled were modelled through a Multinomial Logit Model. Morency et al. (2009) developed a dynamic econometric model to jointly predict the probability of being an active member and the frequency of usage per month. Furthermore, they developed an ordered probability model with Hidden Markov Chain in order to capture users’ behavioural dynamics. Habib et al. (2012), jointly modelled activity persistence (monthly frequency of usage) and membership duration. Costain et al. (2012) examined the administrative datasets of a carsharing service in Toronto proposing an econometric approach to model membership duration, frequency of use, vehicle type and total vehicle kilometres travelled. Morency et al. (2012) developed a probabilistic model of being active (using the system) and the monthly frequency of use (over the years); they used a dynamic ordered Probit model. Stillwater et al. (2009) focussed on the relationship between built environment and carsharing user activity using a GIS-based multivariate regression analysis. Ciari (2013) introduced a new methodology to estimate travel demand for carsharing based on activity-based micro-simulation. Shaefers (2013) explores carsharing usage motives through a hierarchical means-end approach.

Contributions based on SP data mainly propose descriptive analyses and, in some cases, introduce a modelling approach. Abraham (2000) discusses a SP survey on hypothetical carsharing contexts and estimates a Multinomial Logit model. Shaheen and Wright (2001) presented the findings of a pilot study on a commuter-based carsharing program. They found that carsharing can be a viable complementary mode to transit and feeder shuttles.

Huwer (2004) investigates mobility behaviour and the customer satisfaction of a combined service carsharing-transit whereby users have access to the flexibility offered by the car, they do not need to buy a car and are more receptive to public transport. Fukuda et al. (2005) investigates the potential of carsharing as an alternative mode based on a stated preference survey conducted in Bangkok. Nobis (2006) explores different logistic regression models to investigate the awareness of carsharing, the acceptance of sharing the vehicle with others indicates that user attitudes and behavioural aspects are the most important factors ensuring the success of any carsharing program. Zheng et al. (2009) analyse the potential market demand for carsharing within the University of Wisconsin. They develop probabilistic models that take into account socio-economic information, travel preferences, attitudes and knowledge about the concept of carsharing. Firnkorn and Muller (2011) discuss the environmental effects of a free-floating carsharing system starting from an SP survey. The focus is on the total number of car impacts but no modelling approach is proposed. Recently, Cascetta et al. (2014) specified and calibrated a consumers' choice model able to interpret and to model the potential demand for an urban car sharing service in which conventional and EVs are supplied. A Binomial Logit model was specified and the "pure preference" in using electric vehicles over traditional ones was quantified.

In conclusion, the following general considerations may be drawn:

a) An effective carsharing program can increase transit modal share, reduce drive-alone modal share, reduce car ownership, and reduce total vehicle-mile travel in suburban areas and traffic-related emissions in urban regions.
b) Carsharing serves as a complementary mode to transit and feeder shuttles.
c) The duration of membership as well as the presence of a carsharing service network in one's neighbourhood of residence has a profound impact on user activity persistency.
d) Carsharing users are more concerned with personal utility than social or environmental benefit, and are motivated more by convenience and less by affordability. In most studies the majority of carsharing users are transit users,
e) Finally, 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 important influential factors are: levels of household ownership, household income, education and professional condition (more likely to join carsharing programs), neighbourhood (walkability) 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 program cost.

f) Several studies have highlighted (Muheim, 1998; Krietmeyer, 1997) that carsharing users focus their mobility habits on public transport. Thus, attractive public transport is very important and could be combined with carsharing services.
g) Sometimes users are attracted to carsharing because of its good environmental image, and such image may be further improved by adopting electric vehicles.

3 Methodological framework

Based on the previous considerations, the aim of the paper was to understand if an inter-urban carsharing program would have been perceived and chosen, the secondary aim was to establish which modelling approach was the most effective and finally, identify the main determinants of the phenomenon. In particular, carsharing was viewed as an alternative transport mode that may be used to substitute the usually chosen transport mode. The proposed service was one-way, thus users would pay what they will use, and incentives were contemplated (more details in section 4).

The problem was investigated through the specification, calibration and validation of different modelling solutions founded on the behavioural paradigm of the utility theory. In particular, the following modelling solutions were tested:

a) Switching models conditional on the transport mode which is usually chosen (homoscedastic and heteroscedastic).

   Conditional switching models are expected to be the most effective, but in order to be applied they require the preliminary estimation of the consolidated transport modes' market share.

b) Unconditional switching models (homoscedastic and heteroscedastic).

   Unconditional switching models require the preliminary estimation of the market share, but their calibration might require a smaller number of observations. It was mainly investigated in order to verify if differences existed with regard to the conditional models in terms of attributes, of relative magnitudes and of sensitivity.

c) Holding models (homoscedastic, cross-correlated homoscedastic and heteroscedastic).

   It is assumed that carsharing is a "transport mode" which is always available, and it can be assumed that users systematically include carsharing in their own choice-set. Holding models overcome the limitations of switching models, but might pay for the limitations in a choice context with consolidated transport modes and a completely new alternative. Moreover, the holding approach makes it possible to explicitly simulate the competitiveness of the available transport modes. Anyhow, holding models were calibrated in order to compare their goodness-of-fit and their generalisation capability compared to switching solutions.

If the holding approach within the random utility paradigm is the most used in transportation mode choice issues (Domencich and McFadden, 1975; Ben-Akiva and Lerman, 1985; Cascetta, 2009, Ortuzar and Willumsem, 2011), transportation behavioural modifications can count on a smaller number of contributions (Ben-Akiva and Morikawa, 1990; Cairns et al., 2008; Fujii and Taniguchi, 2006; Garling and Fujii, 2009; Kearney and De Young, 1996) and have been mainly focussed on transport mode choice, on route choice or on departure time choice.

Switching behaviour may happen in a static context or in a dynamic one. In the former, modelling switching behaviour requires panel data (revealed or stated), in the latter cross-sectional revealed and/or stated intention. Switching behaviour has been mainly investigated through the random utility, stationary or dynamic theories. In the latter, it is of interest in conjunction with significant transportation system changes (e.g. a new transport mode), in this case, it is also of interest if the dynamic evolution is of interest and/or if an information system exists. In this paper we considered a stationary choice modelling framework.

Random utility theory is based on the hypothesis that every individual is a *rational decision-maker*, maximizing utility relative to his/her choices. The probability of selecting alternative j conditional on his/her choice set I, as the probability that the perceived utility of alternative j is greater than that of all the other available alternatives: The perceived utility U_j can be expressed by the sum of the *systematic utility* V_j and a *random residual* representing the (unknown) deviation of the utility perceived by the user from the systematic utility. Systematic utility represents the mean or the expected value of the utilities perceived by the decision-maker. It is supposed to be estimated by the analyst, and is usually expressed as a function of attributes relative to the alternatives and the decision-maker. The function may be of any type, but for analytical and statistical convenience, it is usually assumed that the systematic utility is a linear function in the parameters of the attributes X_{kj} or of their functional transformations: $\mathrm{V_j} = \Sigma_{\mathrm{k}} \beta_k X_{kj} + \Sigma_{\mathrm{q}} \beta_{\mathrm{q}} f(X_{qj})$

Various specifications of random utility models can be derived from the general hypotheses by assuming different joint probability distribution functions for the random residual.

In this paper Multinomial Logit (MNL), Hierarchical Logit (HL), Cross-Nested Logit (CNL) and Mixed Multinomial Logit (MMNL) models were investigated, but only MNL and MMNL resulted as statistically significant.

The Multinomial Logit (MNL) model is the simplest random utility model. It is based on the assumption that the random residuals are independently and identically distributed (iid) according to a Gumbel random variable of zero mean and parameter θ. The independence of the random residuals implies that the covariance between any pair of residuals is null. Under the assumptions made, the probability of choosing alternative j among those available and belonging to choice set I can be expressed in closed form as:

$$p[j] = \frac{exp(V_j / \theta)}{\sum_{m \in I} exp(V_m / \theta)}$$

The Mixed Multinomial Logit model (MMNL) is a highly flexible model that can approximate any random utility model (McFadden and Train, 2000). The most straightforward formulation is based on random parameters, where the utility of each decision-maker is specified as

$$U_j = \sum_k \beta_k X_{kj} + \sum_h \gamma_h X_{hj} + \varepsilon_j \quad \forall j \in I$$

where X_{kj} are the explanatory attributes that relate to the alternative and decision-maker introduced before, β_k is the generic parameter of attribute k, γ_h is the generic parameter of attribute h representing the decision-maker's taste that is supposed to be distributed randomly with density $f(\gamma_h)$, ε_j is the random term that is an iid Gumbel random variable of zero mean and parameter θ. Assuming that $\tilde{\gamma}$ and $\tilde{\beta}$ are the vectors of parameters, Mixed Logit probabilities are the integrals of standard Logit probabilities over a density of parameters.

$$p[j] = \int \frac{\exp\left[V_j(\tilde{\beta}/\theta, \tilde{\gamma}/\theta)\right]}{\sum_{m \in M} \exp\left[V_m(\tilde{\beta}/\theta, \tilde{\gamma}/\theta)\right]} \cdot f(\tilde{\gamma}/\theta) \cdot d(\tilde{\gamma}/\theta)$$

There are two sets of parameters in a Mixed Logit model: the parameters β_k, and the parameters that describe densities of parameters γ_h. Mixed Logit does not exhibit independence of irrelevant alternatives, it allows for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time.

Systematic utility functions were linear in the attributes, but non-linear transformations were tested for continuous attributes.

4 Case study, survey and descriptive results

As previously discussed, the investigated case study consisted in a carsharing program supplied among different municipalities belonging to the metropolitan area of Salerno.

The proposed program was a one-way service, with dedicated parking slots in several attractive locations of each municipality, and free parking and free access to the existent restricted traffic areas were guaranteed.

The geographical context taken into account was made up of one main municipality (Salerno - Campania Region, Southern Italy) and of three smaller municipalities that significantly interact with Salerno and partially interact each other (see figure 1 and table 1). Salerno is the capital city of the Salerno Province, it is located 55 km from Naples, it has about 140,000 residents, and it is characterised by 10,000 daily commuters. The three considered municipalities belonging to the metropolitan area of Salerno are: (1) Pontecagnano (25,000 inhabitants and 15 km from Salerno), (2) Baronissi (20,000 inhabitants and 10 km from Salerno), (3) Cava dè Tirreni (53,000 inhabitants and 12 km from Salerno). All of them are served by a transit system, are connected by highways, and commuting flows among each origin-destination pair mainly travel by car, carpool or bus/train. Users travel on average 30 km a day, and the inter-urban travel demand between the municipalities is not negligible and spreads over time periods longer than the peak hours and distributed over the whole day. Furthermore, the car ownership rate is much higher than those municipalities in which the travel demand ends within the municipality itself.

FIGURE 1 near here

TABLE 1 near here

With regard to this type of context, the potentiality of a carsharing system was investigated through a stated preferences survey.

The survey data were collected from a sample of 500 individuals aged 18 and over. Respondents were randomly selected residents from the above mentioned municipalities. In particular, an intercept survey was conducted at the main sites of each municipality (e.g. stations, squares and offices) and was carried out by students recruited (and trained) within a research project financed by the University of Salerno. The survey was carried out in the spring of 2012, only residents travelling for work between Salerno and the three municipalities (and vice versa) were considered. Respondents were randomly selected to match census data (ISTAT 2011) proportions by gender (male, female), age (18-30; 31-60; >60 years old) and type of occupation (employed, unemployed).

Although no incentive was proposed, the response rate was greater than 87%, thus, the non-response phenomenon was not a critical issue in the survey which was carried out.

Several precautionary strategies were taken into account during the interviewing process: respondents carried out the exact same survey; they were briefed about the decision context and were also introduced to the options' features and to the possible benefits (with pictorial presentations). The whole interview lasted approximately 15 minutes.

Each respondent was presented with the same questionnaire, which consisted into two parts.

The first part aimed to gather information on users' usual travel behaviour, on users' geographical and socio-economic characteristics; to investigate the general propensity to adhere to a carsharing program and to investigate the preferred features of the service. Respondents were asked to describe their usual travel habits (transport, travel cost, travel time, trip frequency, etc...); then he/she was introduced to the service and to the main qualitative characteristics (one way, distance-based fees, dedicated parking slots). Users' socio-economic characteristics were then collected, as well as users' trip characteristics (mode, activity duration, trip frequency, etc.), their interest in opting for the service (as it is, without knowing the fees, the type of car or the parking location) and their main motivations.

The second part of the questionnaire aimed to investigate users' switching behaviour through a specific stated preferences (SP) survey. Depending on the transport mode used to reach the usual destination, respondents were introduced to the main characteristics of the carsharing program and to possible/realistic scenarios (3 or 4 scenario per user).

The proposed carsharing program was familiar to all the respondents, it was described in terms of the main features (one-way service, dedicated parking slots, free parking, free access to restricted traffic areas). No details on the parking locations and/or the type of fare (distance-based or time-based) were introduced to the respondents. These characteristics were introduced in the SP scenarios as control variables. Indeed, the aim was to understand and to model users' behaviour in terms of the general level of service attributes, leaving the choice of parking location and fares to the decision maker who, starting from observed/estimated behaviour, may design the most effective and efficient service.

As a matter of fact, the control variables were: the access time to parking sites, the travel time to the destination, the service fare.

Once the control variables and the composition of the choice contexts to be proposed to the decision maker were identified, the decision makers were presented with different *choice contexts*.

Each scenario was defined by a set of *alternative options*; each option was accompanied by some *attributes* defining its characteristics. In the proposed choice contexts, the attributes vary between a prefixed numbers of values, or *levels* (see Table 2). These levels were defined in absolute terms or proposed as percentage variations compared to the values of the attributes for a real context previously experienced or known to the decision maker. The SP experiment was conducted through a *selection* of all of the possible scenarios starting from the *Full Factorial Design scenario* and then a subset of scenarios was generated introducing the partialisation techniques of the experiment known as *Fractional Factorial Design* (Cascetta, 2009). This eliminates completely some scenarios while retaining orthogonal comparisons which allow for the estimation of the main effects. If the resulting number of scenarios is still too high to be presented to a single decision-maker, they can be further broken down into blocks by using the method described previously. Each of the 500 surveyed users responded to 6 SP scenarios, thus 3000 observed behaviours were obtained.

TABLE 2 NEAR HERE

Descriptive results indicated 73% of the intercepted users would be interested in the proposed carsharing program. Interested users are mainly influenced by the inefficiencies of the public transport system (40%) and by the non-availability of the car transport mode (25%). It is interesting to note the financial gain which is obtainable by adhering to the carsharing program is not the main determinant in the decision process. Non-interested users are satisfied with the usual transport mode (53%). The remaining aliquot does not like to travel with other people, does not want to book the service in advance and does not want to subscribe to the service in advance.

Among the interested users, 68% make use of public transport, 23% travel by car and only 9% take part in carpooling. Non-interested users are mainly carpooling users (20%) and car users (44%). Gender and weekly trip frequency do not play a significant role in the decision of being interested or not.

In analysing the preferred way to take part in the carsharing program, it is interesting to note that only 1% would prefer to drive alone, 39% would be indifferent to people sharing the same car and 55% prefer to travel with known users. In particular, female users prefer to travel with known people (66%), male users are more flexible. Among the 99% of users that would prefer to travel with other people, more than 50% of the respondents stated that they were indifferent as regards being drivers or simply passengers. Such a result is interesting, since carsharing plays a different role from that played in urban contexts, it is not only a more flexible transport solution but, also, a realistic alternative that may compensate for public transport inefficiencies. This percentage decreases for female respondents (48% indifferent) whereas it increases for male respondents (55% indifferent). Moreover, non-indifferent users' preferences change according to the gender: female users prefer to be passengers (27%), male users prefer to be drivers (24%). The ratio between the number of cars and the number of households is not a negligible determinant. In fact, respondents with a ratio less than 0.75 show a percentage of interest greater than 70%; for ratios between 0.75 and 1.00 the percentage decreases to 58%; for ratios greater than 1, the percentage is less than 50% (48%). In investigating the percentage of interest compared to the usually chosen transport mode, it is noteworthy to indicate that public transport users are the easiest to influence with a percentage of interest equal to 86%; car and carpool users follow with a percentage equal to 70%.

Finally, users were asked to respond on the preferred service features. With respect to the booking technology, 73% responded internet, 13% by SMS and only the 14% declared to prefer a call center. As regards how long before book, 38% accept to book one hour before, the 30% wish to book at least six hours before, whereas the 32% wish to book the day before. Finally, about the 60% prefers automatic smartcard vehicle access (compared to human-based... and the 74% prefers distance-based fees, instead of time-based fees.

In conclusion, users seem to be interested in a carsharing program. They are not especially interested in a private share of the car and, moreover, carsharing may attract users from all of the transport modes currently offered, but public transport users seem to be more sensitive to the new transport alternative. Descriptive results confirm the potentiality of carsharing as an alternative both to public transport and to the car transport mode.

5 Estimation results

In this section estimation results are showed for three different modelling approaches:

i) switching model conditional on the usually chosen transport mode to reach the final destination;

ii) unconditional switching model;

iii) holding model, assuming that the choice set includes carsharing.

The aim was threefold: (i) compare different approaches (switching vs. holding; conditional vs. unconditional); (ii) investigate the main determinant of the choice process; (iii) investigate different modelling solutions within the random utility framework.

All the tested attributes and those which are statistically significant are resumed in Table 3.

TABLE 3 NEAR HERE

5.1 Conditional switching models

5.1.1 Car users

As introduced in section 3, random utility switching models were specified and estimated (see Table 4). Both the homoscedastic Logit binomial model and the heteroscedastic random parameter binomial model resulted in statistically significant findings. The systematic utility functions (proposed below) consisted in five attributes: access Time to Carsharing Parking (ATTcsp); Car Travel cost (CTC); Gender (Gen); the Car Frequency (FreqC).

Although travel time and several different socio-economic and activity based attributes were tested (age, income, trip-chaining), only gender resulted in statistically significant findings. Travel time difference between the two transport modes is too similar to be significant in users' perception; socio-economic and activity based attributes have the same impact for both transport modes, thus did not affect any change of behaviours.

In particular, the non-significance of users' age counteracts the literature which has shown that specific ages segments (usually referred to 25 year and 45 year old users) are more attracted by carsharing,. Notwithstanding, it has to be highlighted that the intercepted users are predominantly commuters which systematically use the car (or carpool). In this case, the inertia towards the carsharing service, usually age dependent, plays a minor role. As a matter of fact, the systematic user is more affected by the benefits than by the mistrust toward an innovative service and/or toward the need for driving a different car.

Estimation results show the high significance of Access Time and Monetary Cost. In particular, the value of time - VOT - (presumably walking time) is equal to 0.2 euros per minute (6 euros/hour). The estimated magnitude, aside from being similar to those estimated in different Italian case studies (Cantarella and de Luca, 2005), indicates the extreme importance of parking location. Assuming that the average one-way travel monetary cost is equal to 3€, 10 minutes walking time (about 700 meters at 4 km/h) is more than half of the whole travel monetary cost.

Gender, equal to 1 if male, represents a disutility in the switching option and shows a certain attraction of male users toward non-switching behaviour. This result has a socio-cultural interpretation in which male users usually own the car that they drive, whereas females usually share the family car. Such a result may be extended to those geographical contexts where the male is usually the owner and the prevalent user of the household's car.

Car trip weekly frequency shows a positive sign in the "NoSwitching" systematic utility, meaning that systematic car users have systematic car availability, thus they do not perceive any benefit in using a carsharing service. Finally, it should be noted that the alternative specific constant plays a significant role in switching propensity. The interpretation is twofold: (i) its value measures the immeasurable users' choice determinants; (ii) it represents the propensity to change the usual choice when a new alternative is proposed in a stated preference context.

Finally, CarAv shows a positive sign in the "NoSwitching" alternative. This attribute may be interpreted as a proxy of income and/or as a measure of the user's car availability. In both interpretations, it can be easily concluded that the probability of switching decreases as the easiness of using the household's car and/or as the household's income increase. However, it should be noted that CarAv plays a marginal role. Indeed, its monetary equivalent value is slightly greater than 0.5€ with a CarAV value equal to one.

Heteroscedasticity was investigated through both the random parameter and error components formulations. The former resulted in statistically significant findings and led to slightly better goodness-of-fit. The only distributed parameter was the monetary travel cost, with a not negligible standard deviation. This result makes it possible to conclude that heterogeneity among users mainly depends on the perception of travel costs, whereas access time seems to be more clearly perceived and/or not significantly distributed among users.

5.1.2 Carpool users

Systematic utility functions are reported below (see Table 4). Attributes which were statistically significant were the same as car users, except for car trip frequency. The results are coherent with the expectations and give robustness to both models. The simplicity of systematic utility functions is comprehensible since carpooling users already adhere to a sort of self-organized carsharing, thus their switching propensity mainly depends on the level of service attributes (access time and travel cost).

First of all, it is interesting to note that the ratios between access time, alternative specific constant and travel cost parameters are the same as those estimated for car users. The result confirms, as expected, that car and carpool users have similar behaviour.

As for car users, CarAv shows a positive sign in the "NoSwitching" alternative. The monetary equivalent value continues to be smaller than 1 € with CarAV value equal to one. In this case, if carpool users had a car available, they would not to switch to carsharing, but to the car or would continue carpooling.

The only remarkable difference is for gender parameter which increases its role. In fact female carpool users seem more attracted by a potential carsharing service. As introduced for car-users, female travellers usually show a smaller car ownership rate (or access to the household's car), thus they usually are passenger in a carpool. In this case, carsharing allows the access to a sort of private use of the car.

Unlike the car users' model, car trip frequency is not significant. This result is coherent with the interpretation that carpool users normally have a trip frequency greater than other users and similar among them.

5.1.3 Bus users

Unlike previous models, the bus users switching model shows different systematic utility specifications (see Table 4). In particular, the number of socio-economic and activity-related attributes increases (age, gender, going straight back home) as well as the travel related level of service attributes (access time to parking, access time to bus stop, on-board travel time, travel monetary cost).

In terms of socio-economic attributes, female and older users show a higher switching propensity. Home-based trips increase the systematic utility of non-switching behaviours.

Female are usually attracted by transit alternatives for socio-cultural reasons (low car ownership rates, low availability of the family's car), but in the presence of an available car-based system they would change. However, the estimated parameter has an absolute value 10 times smaller than 1 equivalent euro.

Differently from car and carpool users, users' age plays a role not negligible. Utility of switching increases with age, and it increases up to 1.5 equivalent euros for an age interval greater than 40 years old. If on the one hand this result may appear in contrast with existing evidences, on the other hand it should be reminded that model refers to bus users only, to systematic users and to an inter-urban context. In this case, it is reasonable that older commuting users, due to their greater experience and the fact that they are more disillusioned with the transit system, would be more inclined to switch.

Users travelling home after work are less interested in switching to a more flexible transport mode. The attribute's role is meaningful, its parameter's value is equal to 0.5 equivalent euros, confirming that carsharing may effectively support after work activities. In fact, users taking part in a trip chain after work prefer to adhere to the carsharing service since they may count on the same flexibility granted by a car, and they can do different or more complex trip chains.

With regards to the level of service attributes, it is noteworthy how access time to parking and access time to the bus stop are perceived and weighted differently. The corresponding value of time are sensibly different, 0.23 euros/minute (2.3 per 10 minutes) for the access time to parking and 0.07 €/minute (0.7 € per 10 minutes) for the access time to bus stop. Such a result indicates that the two attributes should be considered separately and that parking location is a crucial design issue.

Surprisingly, travel time has a small value and its corresponding value of time (0.85 €/hour) is quite small compared to values existing in mode choice case studies. Overall, the result highlights the need for a service different from that supplied by the transit system. The interpretation may be twofold: (i) travellers that have to choose between bus and carsharing may be not much interested in a gain in terms of a travel time saving, but in having an alternative to the bus. In other words users desire reliability and efficiency, not solely shorter travel times. (ii) A limited willingness to pay due to the socio-economic background of the investigated users (see also the aggregate economic indicators in table 1).

As for the previous models, CarAv continues to show a positive sign in the "NoSwitching" alternative. The monetary equivalent value compared to car and carpool users models increases up 1.2€. It continues to play a minor role, but it is interesting to conclude that if bus users had a car available, they would not to switch to carsharing, but they would switch to the car.

As for the previous models, heteroscedasticity was modelled by a mixed binomial Logit model and only the random parameter turned out to be statistically significant. Among the level of service attributes, only travel monetary cost resulted as normally distributed, though with a small standard deviation. The result is coherent and gives further robustness to the behavioural interpretation drawn for car users' model.

TABLE 4 NEAR HERE

5.2 Unconditional switching models

In this section estimation results for the unconditional model are proposed (see Table 5).

As shown in table 5, systematic utility functions are much more complex in the attributes since they have to model/interpret behaviour of travellers using different transport modes. In terms of the unconditional models, socio-economic, travel-related and level of service attributes were used. Homoscedastic and heteroscedastic modelling solutions were tested and non-linear transformations were investigated for the level of service attributes.

Overall, the specification of a unique switching model for all the users required a segmentation of travellers with respect to the type of trip origin (city area) and to the number of car per household.

Estimation results confirm most of the comments proposed in the previous sections: being female increases the probability of switching (+0.32 €eq), home-based trips increase the probability of not-switching (0.43 €eq). Access time to parking and to bus stops should be estimated separately; in fact access time to bus stops shows a VOT equal to 0.1 €/min (5.4 €/h), whereas the VOT of access time to carsharing parking is slightly less than 0.3 €/min (17 €/h). Travel time, though statistically significant, shows a VOT of 2.9 (€/h) coherently with conditional models estimation results and coherently with estimation carried out on previous RP surveys.

TABLE 5 NEAR HERE

It is worthwhile noting the role of the alternative specific constant with a positive value in switching behaviour utility. This highlights how travellers are attracted by new alternatives.

Furthermore, the ratio between the number of vehicles per household increases the utility of not switching. The same comments made for the conditional models hold.

Finally, it is interesting to note that the geographical attribute *city area* increases the switching probability, meaning that users living in the outskirts are more motivated to take part in carsharing. As a matter of fact, they usually have to deal with poor (not frequent or not existing) transit services; therefore, on the one hand they will be surely more car dependent, but on the other hand they be more inclined to switch to a carsharing service. In this case, carsharing will allow reducing the car-ownership rate.

As shown in Table 5, Box-Cox transformation of travel cost resulted in statistically significant findings and allowed for a slight increase of the model's goodness-of-fit. The Box-Cox parameter is smaller than one, meaning that marginal travel cost disutility decreases as travel cost increases. Unlike conditional models, Heteroscedastic formulation was successfully calibrated. Such a result is comprehensible since a same model was calibrated independently from the transport mode. In particular, the Mixed-Logit random parameter model was estimated assuming travel time and travel cost was distributed normally. The model's goodness-of-fit did not noticeably increase, but standard deviation values were not negligible, other than allowing a further interpretative hint. The result regarding the travel cost confirm what it has already been observed for the conditional models; as concerns the travel time, the result is reasonable since the unconditional choice model was calibrated on users travelling by different transport modes and, presumably, characterized by much different travel time perceptions.

5.3 Holding models

The holding model explicitly simulates the choice among the possible transport modes. If on the one hand the conditional switching approach requires the preliminary estimation of the current transport market shares, on the other hand, the holding approach overcomes such a limit by directly estimating the market shares for all the transport modes. Moreover, the holding approach may allow to explicitly simulate the competitiveness between the available transport modes, thus it will allow the simulation of planning scenarios.in which the carsharing alternative is a stable alternative, and/or in which the level of service of the other transport modes might change.

To this aim, the choice model was calibrated using the combined results of Stated Preferences (SP) and Revealed Preferences (RP) surveys. In fact, SP surveys should be considered as complementary to traditional RP surveys and the combined use of the two can balance reciprocal merits and shortcomings. Experimental evidence indicates that the combined use of RP and SP data for estimating the parameters usually results in an improvement in statistical precision and in more reasonable parameter values.

From an operational point of view, specific models were individually calibrated for actual mode choice behaviour (choice set I_{RP}: car, bus, carpool) and stated choice behaviour (choice set I_{SP}: car, bus, carpool, carsharing), then combined by calibrating the scale parameters (Ben-Akiva and Morikawa, 1990; Cascetta, 2009; Ortúzar and Willumsen, 2011). Along with the attributes used in the switching models (see table 3), the inertia attribute was introduced to represent the conditioning of the generic SP decision-maker with respect to the alternative actually chosen (RP). Inertia was modelled as a dummy variable equal to one if the generic user chose an alternative present in the RP context, zero otherwise.

Assuming the random residuals for RP and SP models ($\boldsymbol{\varepsilon}^{RP}$ and $\boldsymbol{\varepsilon}^{SP}$) as i.i.d. Gumbel variables of parameters θ_{SP} and θ_{RP} respectively, the probability of choosing the generic alternative assumes the form of a Multinomial Logit model for both the RP and the SP models. Furthermore, as usual, to take into account the possible difference of the variances of the residuals $\boldsymbol{\varepsilon}^{RP}$ and $\boldsymbol{\varepsilon}^{SP}$, a scale factor μ, equal to the ratio between the parameters, θ_{SP} and θ_{RP}, of the two random vectors, was introduced and calibrated.

In particular, the systematic utility functions are shown in table 6.

Table 6 – NEAR HERE

Estimation results (see table 7) indicated that the typical level of service attributes were statistically significant. In particular the corresponding VOTs were 10€/h for travel time and

0.30€/min (18€/h) for the access time to bus stop or to parking locations. In this case was not possible to distinguish the access time to bus stop or to parking locations, however results show, once more, how access time is a crucial design parameter both for carsharing and transit systems.

Weekly travel frequency (Freq) took a positive value in the systematic utilities of current transport modes. In particular, Freq's equivalent monetary value is equal to about 2€ equivalent, meaning that as weekly travel frequency increases, the disutility of choosing carsharing may increase up to 8-10€ equivalent. This result allows several interpretations: (i) although the trip purpose is home-to-work, the trip frequency varies among users; (ii) the attribute is a sort of measure of the inertia (the more weekly trips, the more inertia to change the consolidated transport modes); (iii) carsharing may be a potentially solution for systematic users, but users with smaller trip frequency are more inclined to change the current transport mode.

To confirm the previous interpretation, the inertia attribute turned out highly correlated with the Freq attribute, and was statistically significant at a level smaller than 75%. If on the one hand, such a result indicates that the inertia phenomenon exists and cannot be neglected, on the other hand the inertia may be better interpreted in the light of the trip frequency.

In terms of socio-economic attributes, the only statistically significant was age. In fact, Carsharing systematic utility increases, on average, as age increases. Different age segments were tested and those proposed in table 7 are the most significant ones. As also noted for the switching models, users with more travel experience are more inclined and/or motivated to choose carsharing.

Finally, the role of the alternative specific constants should be noted. They are statistically significant for carsharing and carpool alternatives. Both take values not negligible: positive and equal to 22 equivalent € for carsharing; negative and equal to 25 equivalent € for the carpool alternative. These results leads to two main conclusions: first, the holding approach, compared to the switching approach, needs to be supported by alternative specific constants, indeed the holding approach is not able to reproduce users' choice through observable and/or measurable attributes; secondly, the choice probabilities will be more rigid with regard to the level of service attributes. In conclusion, the holding approach should be better adopted in ex-post analyses, where users are aware of the real choice-set, and the competitiveness among transport modes can be more easily observed and modelled in terms of the level of service features of each mode.

TABLE 7 NEAR HERE

6 Cross comparison between modelling solutions

In this section the different approaches and the different modelling solutions within the single approach are compared. In particular, the models' goodness-of-fit were validated through consolidated statistic tests and through specific indicators. Along with the Percent-Right indicators, a models comparison was carried out through the validation protocol proposed by de Luca and Cantarella (2009). The protocol, developed to compare discrete choice models based on different theoretical paradigms, introduces several indicators able to highlight the models' effectiveness and goodness-of-fit:

- $\text{MSE} = \sum_i \sum_k \left(p^{sim}{}_{k,i} - p^{obs}{}_{k,i} \right)^2 / N_{users} \geq 0$ mean square error between the user observed choice fractions and the simulated ones, over the number of users in the sample, N_{users}. (SD is the corresponding standard deviation, which represents how the predictions are dispersed if compared with the choices observed.); If different models have similar MSE errors, the one with the smallest SD is preferable
- $\text{MAE} = \sum_i \sum_k \left| p^{sim}{}_{k,i} - p^{obs}{}_{k,i} \right| / N_{users} \geq 0$ mean absolute error;
- $\text{FF} = \sum_i p^{sim}{}_i / N_{users} \in [0,1]$, with FF = 1, *Fitting Factor* (FF). This is the ratio between the sum over the users in the sample of the simulated choice probability for the mode actually chosen, $p^{sim}_{user} \in [0,1]$, and the number of users in the sample, N_{users}. FF = 1 means that the model perfectly simulates the choice actually made by each user ($p^{sim}_{user} = 1$);
- *%right:* It is common practice to compare different models through the *%right* indicator, that is the percentage of users in the calibration sample whose observed choices are given the maximum probability (whatever the value) by the model;
- $\%_{clearly\ right}$(t) percentage of users in the sample whose observed choices are given a probability greater than threshold t by the model;
- $\%_{clearly\ wrong}$(t) percentage of users in the sample for whom the model gives a probability greater than threshold t to a choice alternative different to the observed one.

All the indicators were computed on the calibration data set and, in order to compare the conditional switching probabilities with the unconditional ones, resulting switching probabilities were estimated from the conditional switching probabilities estimated for each transport mode.

Moreover, direct elasticities were computed by introducing the variation of the attributes equal to 20% of the initial value.

Comparison results for the switching models are proposed in Table 8.

Regarding conditional switching homoscedastic models, the bus users switching model shows goodness-of-fit which is better than car and carpool users; Simulating Heteroscedasticity slightly improves goodness-of-fit of all models. Differences among the models decrease. The unconditional model, compared with the resulting switching probabilities, shows all of the indicators values dominated. In particular, the Fitting Factor, the MSE and its standard deviation are significantly different and %clearlyright and %clearlywrong state that the conditional modelling approach is advisable.

TABLE 8 NEAR HERE

Comparing elasticity (table 9 and 10), it can be noted that elasticity values (for shared attributes) are quite different for the three conditional switching models. In particular,

- The main effects of the attributes variation can be seen in Car users switching models with regard to the cost attributes and to the carsharing parking access time (see table 9).
- In the case of carpool switching models, all attributes variations have a significant effect on the choice probability (see table 9).
- In the case of Bus switching models the variations of carsharing Parking access time, the carsharing travel costs and the Bus travel costs have a significant effect on alternative choices (see table 9).

Bus users' switching models, as expected, are much more affected by access travel time to parking. Elasticity with regard to carsharing travel costs (TCcarsharing) is similar for car and bus users' switching models, and sensitivity increases for carpool users. Moreover, elasticities with regard to the travel costs of used transport modes (car, carpool and bus travel costs) are different and confirm the need for conditional models. Heteroscedastic models lead to slightly greater elasticity values.

TABLE 9 NEAR HERE

With regard to unconditional switching models, the variation of travel costs and travel time has a significant effect on the probability of the switching choice (table 9). However, elasticity values, except for travel time, are about ten times smaller than the conditional switching models. This result, together with the validation indicators, makes it possible to conclude that the unconditional switching model cannot be an effective modelling solution.

TABLE 10 NEAR HERE

With respect to the holding model, it is meaningless to compare the indicators from the validation protocol (their values are shown in table 11), whereas it is interesting to compare the direct elasticities.

As for the switching models, direct elasticities were computed by introducing the variation of the attributes equal to 20% of the initial value (see Table 11). The more significant variations of attributes are in bold. Except for a few attributes, elasticity values show values much smaller than those estimated for switching models. It should be said that the holding model might show smaller elasticity due to the jointly calibration of RP and SP data, anyhow the elasticity values are significantly different and significantly smaller the switching models.

As introduced in the previous section, the holding approach leads to rather rigid choice probabilities, thus it leads to low generalisation capabilities. As for the validation indicators, the switching approach can be confirmed as being the most effective and advisable.

TABLE 11 NEAR HERE

7 Conclusions

Although carsharing has become a consolidated transport alternative in many urban contexts, carsharing behaviours have been mainly analysed through ex-post analysis and in terms of vehicle usage and/or ownership rate. In this paper carsharing behaviour was investigated with regard to an inter-urban context and through an ex-ante approach based on a stated preferences survey, and in terms of mode choice phenomenon within the random utility paradigm.

The aim was fourfold: (i) to analyse the feasibility of a inter-urban carsharing program; (ii) to investigate the main determinants of the choice behaviour; (iii) to compare different approaches (switching vs. holding; conditional vs. unconditional); (iv) to investigate different modelling solutions within the random utility framework (homoscedastic, heteroscedastic and cross-correlated closed-form solutions).

Overall, results highlighted that the inter-urban carsharing service may be a substitute of the car transport mode, but also a complementary alternative to the transit system.

The proposed models and the achieved insights indicate potential market segments and a way to model potential user’s behaviour. The obtained results should be interpreted as a step towards understanding the “potential use of the service”, could be transferred to other similar case studies and may support viability/feasibility analyses (technical, economic and environmental). However, they do not ensure the viability/feasibility of the investigated carsharing service, especially with regard to the operator point of view, but it was out of the scope of this research.

Concerning the modelling approaches, all led to statistically significant results.

In the conditional switching approach, different systematic utility functions resulted in statistically significant findings. Car and carpool users were characterised by systematic utility functions which were simpler than those of bus users, these included different types of attributes: age, trip type (round trip vs. trip chain) and access time to buses. This result indicates that if the usually chosen transport mode is similar to the carsharing alternative, the level of service attributes are the main determinants of the choice process. On the other hand, bus users' switching behaviour is more affected by the user's specific characteristics.

In the unconditional switching approach, geographical (location of trip origin) and economic (number of cars per household) segmentations have to be introduced to gain a statistically significant model. This result is coherent with expectations, since a single choice model had to interpret different users' choice processes. Nevertheless, though the goodness-of-fit was comparable to the conditional models, the unconditional model showed worse generalisation capabilities. Indeed, the sensitivity to the level of service attributes was much less than the conditional switching models. Therefore, it is possible to conclude that the conditional switching approach is the approach to be pursued.

In the holding approach, the mix of RP and SP lead to the best validation indicators. Compared to the switching models, age and trip frequency can be confirmed as being statistically significant, but the role of dummy or constant attributes increased (alternative specific constants and inertia attribute) and, above all, validation indicators showed worse goodness-of-fit and smaller sensitivity to the level of service attributes. Thus, it is possible to conclude that the holding approach, though statistically significant, is not the most effective solution for modelling carsharing choice behaviour in ex-ante scenarios. It should be better pursued in ex-post scenarios, where carsharing is already a perceived and known transport alternative.

Among the investigated modelling solutions within the random utility theory and within each of the proposed approaches, random parameter Mixed Multinomial Logit formulation was statistically significant. Depending on the specific approach, only a two attributes, such as travel cost or access time to parking, turned out to be randomly distributed. However, explicit simulation of taste variation among users, where significant, did not lead to significant gain in the models' goodness-of-fit, except for the holding models.

With regard to the attributes' relevance, although in altering the modelling solution, the systematic utility functions changed, estimation results highlighted the great importance of travel monetary cost and access time to carsharing parking slots. Gender, age, trip frequency, car availability and the type of trip (home-based) influenced the probability of choosing carsharing or not. Elasticity results for the conditional switching models showed that access time to the parking slots predominantly influences choice probability for bus and carpool users; change in carsharing travel costs mainly affects carpool users; change in travel costs of the usually chosen transport mode mainly affects car and carpool users. In conclusions, (i) access time to parking slots is the most important design attribute; (ii) the carsharing service's characteristics should be specifically designed in order to deal with specific target groups (e.g. car users vs. bus users); (iii) socio-economic and activity based attributes play a significant role compared to level of service attributes.

Finally, although the case study refers to a specific geographical context, the obtained results allow drawing some operational conclusions.

- First of all, it exists a market segment made by inter-urban commuters, usually not considered in carsharing market analyses, that perceives and would choose carsharing as an alternative to the existing transport modes.
- A carsharing service may give the proper flexibility to those demand flows not served by the transit service (not frequent and continuous), thus it could be a complementary alternative to the transit system in those time periods in which the service is not guaranteed or efficient.
- The proposed methodological insights may be transferred to those contexts in which a carsharing service should be beforehand designed.
- Furthermore, the determinants of the choice process, if on the one hand are case-specific in the estimated values, on the other hand do emerge a set of attributes which is slightly different from those acknowledged in urban contexts and which may be generalized to similar inter-urban contexts.

Some research perspectives seem worthy of interest: investigating choice determinants in the case of non-systematic use of carsharing, investigating the effect of the reliability of the service, investigating the effect of the non-availability of the service due to the overbooking phenomena and the possible effects of carsharing on mobility behaviours (trip frequency and trip-chaining). Finally, the implementation of different theoretical paradigms for modelling switching behaviours could be of interest.

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Table

Table 1 – case study: municipalities and demographic characteristics

Municipality	**inhabitants**	**Extension (kmq)**	**Density (inhab../kmq)**	**Income €/inhab.**	**#car/household**	**Systematic trips toward Salerno**	**Systematic trips from Salerno**
Salerno	132,000	60	2,237	12,700	1.50	-	-
Cava dè Tirreni	54,000	36	1,474	8,300	1.92	1,700	550
Pontecagnano	26,000	37	686	8,000	2.23	1,800	650
Baronissi	17,000	18	942	8,400	2.13	1,100	350

* from census data (ISTAT 2011)

Table 2 – control attributes and values

Attribute	**values**						
Access time to carsharing parking	5min	10min	15min	20min			
Travel time	equal to travel time by Car						
Travel cost wrt Bus (Δ)	+0€	+1€	+2€	+3€	+4€		
Travel cost wrt Car (Δ)	-30%	-20%	-10%	=	+10%	+20%	+30%

Table 3 – systematic utility attributes

Attribute		**Acronym**	**Unit**	**Min**	**Max**	**Mean**
Alternative specific constant		ASC	-	1	1	1
Travel time		TT	Minutes	13	43	28.5
Travel cost	car	TC	Euro	4	10	5.9
	carsharing			4	13	5.8
	Bus			3	8	2
Carsharing travel time		CSTT	minutes	13	43	28.5
Access time		ATT	minutes	5	20	9.5
Access time to carsharing Parking		ATTcsp	minutes	5	20	9.9
Access time to bus stop		ATTbs	minutes	5	15	8.7
Age_{x-y}		Age_{x-y}	equal to 1 for age within interval [x,y]	0	1	-
Gender		Gen	equal to 1 for male users	0	1	0.52
Car frequency		FreqC	number of weekly trips made by car	0	5	2.0
Frequency		Freq	number of weekly trips	2	5	4.3
Go straight back home		GSBack	equal to 1 for home-based trips	0	1	-
City $Area_x$		$CityArea_{1,\ 2\ or\ 3}$	equal to 1 for users belonging to trip origin type x	0	1	0.4
Car Availability		CarAV	n° of household vehicles / n° of household members	0	1.25	0.55

Table 4 – Estimation results for Conditional Switching models

	Car users				**Carpool users**		**Bus users**	
	Homoscedastic		*Heteroscedastic*		*Homoscedastic*		*Heteroscedastic*	
	$S_{witching}$	$NS_{witching}$	$S_{witching}$	$NS_{witching}$	$S_{witching}$	$NS_{witching}$	$S_{witching}$	$NS_{witching}$
ASC	+2.62 *(+3.17)*	-	+3.05 *(+3.25)*	-	+4.13 *(+3.44)*	-	-	-
ATTcsp	-0.180 *(-6.18)*	-	-0.199 *(-5.61)*	-	-0.349 *(-4.36)*	-	-0.325 *(-8.09)*	-
ATTcsp (s.d.)	-	-	-	-	-	-	-0.0606 *(-1.40)*	-
TC	-0.903 *(-6.29)*	-0.903 *(-6.29)*	-1.16 *(-4.39)*	-1.16 *(-4.39)*	-1.94 *(-4.27)*	-1.94 *(-4.27)*	-1.34 *(-9.27)*	-1.34 *(-9.27)*
TC (s.d.)	-	-	-0.838 *(-1.89)*	-0.838 *(-1.89)*	-	-	-	-
Gen	-0.716 *(-2.66)*	-	-0.893 *(-2.87)*	-	-2.51 *(-3.42)*	-	-0.179 *(-1.62)*	-
FreqC	-	+0.327 *(+2.22)*	-	+0.376 *(+2.30)*	-	-	-	-
CarAv	-	+0.596 *(+1.86)*		+0.602 *(+1.92)*	-	+1.83 *(+1.82)*	-	+1.64 *(+2.30)*
ATTbs	-	-	-	-	-	-	-0.101 *(-4.30)*	-
CSTT	-	-	-	-	-	-	-0.0196 *(-2.39)*	-0.0196 *(-2.39)*
Age_{18-26}	-	-	-	-	-	-	+0.311 *(+2.97)*	-
Age_{26-40}	-	-	-	-	-	-	+0.349 *(+5.15)*	-
$Age_{>40}$	-	-	-	-	-	-	+0.511 *(+3.05)*	-
GSBack	-	-	-	-	-	-	-	+0.737 *(+3.51)*
Init log-likelihood	-233		-233		-66.5		-718	
Final log-likelihood	-180.1		-179.0		-38.0		-475.8	
Rho-square	0.226		0.231		0.430		0.337	
Adjusted rho-square	0.205		0.205		0.370		0.325	

** in parenthesis the t-student test value*

Table 5 – Estimation results for Unconditional Switching models

	Homoscedastic				Heteroscedastic	
	Linear		*Non Linear*			
	$S_{witching}$	$NS_{witching}$	$S_{witching}$	$NS_{witching}$	$S_{witching}$	$NS_{witching}$
ASC	+2.96 *(+6.15)*	-	+2.95 *(+6.14)*	-	+3.36 *(+5.65)*	-
TT	-	-0.0453 *(-7.71)*	-	-0.0462 *(-7.76)*	-	-0.0611 *(-5.41)*
TT (s.d.)	-	-	-	-	-0.0276 *(-2.06)*	-0.0276 *(-2.06)*
ATTcsp	-0.280 *(-15.50)*	-	-0.280 *(-15.50)*	-	-0.320 *(-10.29)*	-
ATTbs	-	-0.0852 *(-4.99)*	-	-0.0842 *(-4.92)*	-	-0.0999 *(-4.66)*
TC	-0.946 *(-13.78)*	-0.946 *(-13.78)*	-0.534 *(-7.55)*	-0.534 *(-7.55)*	-1.16 *(-7.68)*	-1.16 *(-7.68)*
TC (s.d.)	-	-	-	-	+0.447 *(+2.38)*	+0.447 *(+2.38)*
TC (Box-Cox λ)	-	-	+0.829 *(+4.72)*	-	-	-
Gen	-0.299 *(-2.29)*	-	-0.288 *(-2.20)*	-	-0.373 (-2.40)	-
GSBack	-	+0.410 *(+2.52)*	-	+0.413 *(+2.54)*	-	+0.429 *(+2.27)*
CarAV	-	+0.672 *(+1.78)*	-	+0.689 *(+1.82)*	-	+0.731 *(+1.69)*
CityArea $_{city\text{-}centre}$	+0.090 *(+1.41)*	-	+0.098 *(+1.49)*	-	+0.08 *(+1.12)*	-
CityArea $_{suburbs}$	+0.110 *(+2.71)*	-	+0.124 *(+3.23)*	-	+0.100 *(+2.63)*	-
CityArea $_{outskirts}$	+0.142 *(+1.98)*	-	+0.150 *(+1.86)*	-	+0.130 *(+2.05)*	-
Init log-likelihood	-1017.5		-1017.5		-1017.5	
Final log-likelihood	-720.8		-720.2		-718.3	
Rho-square	0.292		0.292		0.294	
Adjusted rho-square	0.283		0.282		0.283	

** in parenthesis the t-student test value*

Table 6 – Systematic utility functions for RP and SP models

		RP model	SP model
V_{car}	=	$\beta_1 \cdot TT + \beta_2 \cdot TC + \beta_3 \cdot Freq$	$\beta_1 \cdot TT + \beta_2 \cdot TC + \beta_3 \cdot Freq + \beta_3 \cdot Inertia^*$
$V_{carpool}$	=	$\beta_1 \cdot TT + \beta_2 \cdot TC + \beta_3 \cdot Freq + \beta_9 \cdot ASC_{RP}$	$\beta_1 \cdot TT + \beta_2 \cdot TC + \beta_3 \cdot Freq + \beta_9 \cdot ASC_{SP} + \beta_3 \cdot Inertia^*$
V_{bus}	=	$\beta_1 \cdot TT + \beta_2 \cdot TC + \beta_3 \cdot Freq + \beta_4\ ATT$	$\beta_1 \cdot TT + \beta_2 \cdot TC + \beta_3 \cdot Freq + \beta_4 \cdot ATT + \beta_3 \cdot Inertia^*$
$V_{carsharing}$	=	-	$\beta_1 \cdot TT + \beta_2 \cdot TC + \beta_5 \cdot ATT + \beta_6 \cdot Age_{18\text{-}25} + \beta_7 \cdot Age_{26\text{-}40} + \beta_8 \cdot Age_{>40}$

Table 7 – Estimation results for the holding model

	Carsharing	Car	Carpool	Bus
ASC_{RP}	*1.87* *(+5.12)*	-	-	-
ASC_{SP}	-	-	*-1.72* *(+11.72)*	-
ATT	-0.0251 *(-4.32)*	-	-	-0.0251 *(-4.32)*
TT	-0.0139 (-2.76)	-0.0139 (-2.76)	-0.0139 (-2.76)	-0.0139 (-2.76)
TC	*-0.0833* *(-2.32)*	*-0.0833* *(-2.32)*	*-0.0833* *(-2.32)*	*-0.0833* *(-2.32)*
$Age_{18\text{-}25}$	*0.223* *(+1.98)*	-	-	-
$Age_{26\text{-}40}$	*0.367* *(+2.32)*	-	-	-
$Age_{>40}$	*0.777* *(+2.10)*	-	-	-
Freq	-	0.432 *(+17.87)*	0.432 *(+17.87)*	0.432 *(+17.87)*
Inertia*	-	0.0866 *(-0.63)*	0.0866 *(-0.63)*	0.0866 *(-0.63)*
Scale parameter μ	0.689 *(2.47)*			
Init log-likelihood	-3001			
Final log-likelihood	-1632			
Rho-square	0.456			
Adjusted rho-square	0.454			

** in parenthesis the t-student test value*

Table 8 – Validation protocol for conditional and unconditional switching models

	Models		**FF%**	**MSE**	**SD**	**MAE**	**%Right**	**%clearly**	
								right 0.9	**wrong 0.9**
Conditional $S_{witching}$	homo	Car users	64	0.350	0.157	0.711	76	12	2
		Carpool users	74	0.262	0.161	0.520	77	35	2
		Bus users	77	0.144	0.021	0.453	76	23	3
	hetero	Car users	66	0.346	0.190	0.676	76	17	3
		Carpool users	78	0.136	0.021	0.432	76	26	3
		Bus users	78	0.397	0.584	0.439	79	73	19
Resulting $S_{witching}$	homo		74	0.199	0.061	0.516	75	21	2
	hetero		76	0.201	0.096	0.489	76	39	6
Unconditional $S_{witching}$	homo linear		61	0.494	0.347	0.790	65	21	9
	homo non linear		54	0.663	0.481	0.925	55	21	16
	hetero		60	0.540	0.436	0.797	64	27	13

Table 9 – Direct elasticities: conditional switching models

		Car users			**Carpool users**			**Bus users**				
	attribute	ATTcsp	TCcarsharing	TCcar	ATTcsp	TCcarsharing	TCcarpool	ATTcsp	ATTbs	TCcarsharing	TCbus	TTbus
Homo	$S_{witching}$	-0.210	-0.565	-	-0.368	-0.833	-	-0.563	-	-0.587	-	-
	$NS_{witching}$	-	-	-0.452	-	-	-0.792	-	-0.069	-	-0.292	-0.063
Hetero	$S_{witching}$	-0.238	-0.678	-	-0.948	-0.999	-	-0.589	-	-0.600	-	-
	$NS_{witching}$	-	-	-0.548	-	-	-0.998	-	-0.073	-	-0.298	-0.065

Table 10 – Direct elasticities: unconditional switching models

attribute			**ATTcsp**	**ATTbs**	**TCcarsharing**	**TCothermodes**	**TT**
Homo	linear	$S_{witching}$	-0.0185		-0.0420	-	-
		$NS_{witching}$	-	-0.0785	-	-0.4937	-0.3193
	non linear	$S_{witching}$	-0.0250	-	-0.0562	-	-
		$NS_{witching}$	-	-0.0773		-0.4897	-0.3158
Hetero		$S_{witching}$	-0.0097		-0.0254	-	-
		$NS_{witching}$	-	-0.0935	-	-0.5726	-0.4112

Table 11 – Validation Protocol and direct elasticities for the holding model

Indicators	**FF%**	**MSE**	**SD**	**MAE**	**%Right**	**%clearly**	
						right 0.9	**wrong 0.9**
Holding	57	0.731	0.137	1.021	62	4	9

Attributes		**TCbus**	**TCcarpool**	**TCcar**	**TCcarsharing**	**ATTbs**	**ATTcsp**	**TTbus**	**TTcarpool**	**TTcar**	**TTcarsharing**
Alternatives	carsharing	-	-	-	-0.015	-	-0.071	-	-	-	**-0.208**
	car	-	-	-0.008	-	-	-	-	-	-0.020	-
	carpool	-	-0.011		-	-	-	-	-0.021	-	-
	bus	**-0.768**	-	-	-	**-0.197**	-	-0.032	-	-	

Figure

Figure 1 – Case study (MapData, 2013© Google)