AN INNOVATIVE CAR SHARING ELECTRIC VEHICLE SYSTEM: AN ITALIAN EXPERIENCE

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ABSTRACT

This paper focuses on the introduction of an innovative electric vehicle car sharing system in Rome. Specifically, the system is designed for a university community (Roma Tre University), thus it is reserved for students and employees. The fleet is composed by 30 electric vehicles and 56 recharging points have been installed in several departments of the University. The service is designed as a free floating system, allowing commuting and leisure trips. The trips are not spatially limited, but the rental has to be opened and closed within a delimited area in the city. This paper analyses the starting stage of the project. The results of a RP (Revealed Preferences) and SP (Stated Preferences) survey are discussed. The survey has been filled out by a sample of 950 potential users. Important indications have been obtained on the behavioural attributes that mostly affect the electric vehicle car sharing subscriptors and service utilization. Afterwards, specific behavioural models based on random utility theory have been proposed for predicting modal switch, considering the introduction of the new service. Attributes such as the "Green Attitude", the "Sharing Attitude" and the "Device attitude" have been analysed in terms of their impacts on the mode choice, underlining their weight and statistical significance compared to attributes as distances and travel times.

Keywords: EV car sharing, sharing mobility, user's behaviour, mode choice, transport policy.

1 INTRODUCTION

The urban mobility is central issue for the smart cities development. The European Commission in order to define a new paradigm of urban planning approved in 2013 a document containing the guidelines to empower current planning theories about the smart cities, see [1] for more details. The European official guidelines can be considered an attempt to find an equilibrium between sustainability and urban life quality [2].

Scientific literature agrees that the car use is one of the main determinants of air pollution and network congestion in urban area. From this perspective, sharing mobility is the greatest innovation of the last decades, and it is increasingly spreading among the users.

Among sharing mobility services, the Electric Vehicles Car Sharing represents the new frontier of sustainable urban mobility. The introduction of Electric Vehicle Car Sharing (EVCS) systems date back to 1990s. The first EVCS system, named LISELEC, was launched in France in the small town of Rochelle [3]. The service is still working under the name Yelómobile (https://www.yelomobile.fr/). In 1999, a EVCS system was developed in Inagi City, Japan [4]. Initially the project was free and had a positive feedback but as fees were implemented, the program closed in three year. Nissan carried out another relevant experience in 1997: the pilot project spread in many Japanese cities and it was called Intelligent Transportation System/Car sharing Electric Vehicle (ITS/EVCS). It later was known as Orix CarSharing (http://www.orix-carshare.com/), including about 400 vehicles. Orix CarSharing stopped using exclusively electric vehicles and now it uses hybrids and gasoline vehicles. Even in the US in 1999, a pilot EVCS test named UCR Intellishare was launched [5]. After 10 years, it ended in July 2010 due to logistic problems for the recharge of vehicles. Currently most important experiences of such systems are only a few: Car2Go

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electric Amsterdam; Ibilek car sharing service in Bilbao; Zipcar from San Francisco City Hall; DriveNow with BMW ActiveE electric cars in the San Francisco Bay Area. As investigated by [6], EVCS system growth had difficult time in the early 2000s. In general terms, in these pioneering experiences the most important discouraging factors are high operating costs, low reliability of vehicles due to the short life-time of the battery and lack of recharging stations. In general, problems could arise either if the system is designed as "free floating" or if the system is set to be "one way" . In the first case, users can drive wherever they need but they have to terminate the rental of the vehicle by returning it within a delimited area. In this case, the service can be financially sustainable only if a very high spatial coverage of recharge stations is guaranteed; otherwise, the costs of relocation and charging of vehicles strongly increase. Taking into account the battery recharge time, an EVCS system can be designed as a "one-way" (also called "point-to-point") system. It is built on a network of dedicated stations: the constraint is that the customer can take and return the vehicle in any of these dedicated stations. Thus, as the number of recharge stations increases, the "one-way" system can ideally tend to the "free floating" system, without the limits of the last one.

Simultaneously scientific literature and research is making a breakthrough to understand what motivates people to join Car Sharing (CS) services and to develop data collection strategies, method and models for CS systems. A wide review can be found in [7].

Focusing on household's habits, many studies have highlighted that the car sharing usage decreases as the income and car ownership increase [8]. Instead, high education and good professional status are factors that encourage CS utilization [9]. However, as mentioned by [8], the student status does not influence positively car sharing joining because of high per minute fee. Most authors agree with the fact that the CS rise is related to advertising activity [10]. User's behaviour and their personal attitudes are important factors that influence frequency of CS usage [11]. Green Attitude (GA), i.e. the user environmental concern, is a controversial matter in this sector. In fact, author in [10], underlines the positive influence of GA. Meanwhile, authors in [8], found that GA is not a key factor in determining people willingness to subscribe a car sharing service.

This study describes a project powered by Enel Energia S.p.A (the largest electricity company in Italy) and Roma Tre University, Rome, Italy. The goal of the project is the design and the realisation of a university-based EVCS system reserved for students and employees of Roma Tre University: the fleet is composed by 30 electric vehicles and 56 recharging points have been installed in several departments of the University for limiting the refloating cost. The service is designed as a free-floating system, allowing for commuting and leisure trips. The trips are not spatially limited, but the rental has to be opened and closed within a delimited area in the city.

In this paper, we investigate the initial phase of the project, focusing on the data collected before the beginning of the service and investigating the behavioural attributes that mostly affect the potential EVCS demand.

The paper is organized as follows. Firstly, the project involving Roma Tre University is presented. Then the data collection strategy, including the surveys design and dissemination, are presented: data collected from an ex-ante survey are analyzed and statistically proved in order to have an aggregate evaluation of the behavioural attributes, which may affect the EVCS subscription and utilization. Moreover, specific behavioural models based on random utility theory are calibrated and validated. Conclusions and further research on method and models for EVCS system follow in the last section.

2 E-GO CAR SHARING PROJECT

The *e–go car sharing Roma 3* project, developed in partnership between Roma Tre University, Rome, Italy and Enel Energia S.p.A, represents an innovation in term of sustainable transport solutions. This project is designed as "a third generation" Car Sharing [12]. The whole fleet has electric traction and the totality of users are students and employees of the University. These two aspects identify the innovative vocation of the project, both from the research and commercial point of view. From the infrastructural standpoint, 28 recharge stations were installed in four University departments (Engineering, Economics, Law and Literature). Each of these hubs has seven recharge stations. Outside the University, Enel Energia S.p.A has about 110 recharge stations spread in the city of Rome and fifteen of these are located both at the interchange nodes, such as metro and railway stations, and at special attraction points of the city. The fleet is composed by 20 Twizy, Neighbourhood Electric Vehicle, and 10 Zoe, a five doors electric car, both produced by Renault. The service has been designed as a "free floating" car sharing: users can start and finish the rent in any point of a selected area in the city using a dedicated IT platform. The user interface is a smartphone app free downloaded. To rent a car students and employees have to pay a really fair fee, 0.20 €/min for Twizy and 0.23 €/min for Zoe. Students who decide to end the rent in a recharging point inside the campus get five minutes bonus. The project has been divided into 3 main stages: (1) the first stage regards the service planning, its infrastructural implementation, financial feasibility and demand analysis. An ex-ante survey has been organized and conducted based on both a Revealed Preference (RP) and a Stated Preference (SP) survey, with the aim to identify the behavioural attributes that characterize the potential demand for the service; (2) the second, in which 100 students were allowed to use E-GO free of charge, regards the supervision of the starting phase of the project and the effective users response has been examined thorough frequent data report. (3) the third stage regards the opening of the service to the all University community, introducing fees; (4) in the fourth stage it is planned to make available the service in a wider area of Rome. This will be realized after the placement of new recharge stations in the city area. The first stage started with the sign of a framework agreement between Enel Energia S.p.A and Roma Tre in April 2016 and ended in September 2016, and the entire project will last five years: nine months for the first stage, two years for the third stage and the last two years for the fourth stage.

3 SURVEY RESULTS

This section analyses the data collected through the RP and SP surveys conducted in the first stage of the project. The online surveys were conducted emailing students and employees of University of Roma Tre. The final amount of completed and useful answers was 950. The study aimed to understand the potential demand of the service, focusing on the collection of socio-economics, attitudinal and transportation-linked attributes that most influence the potential subscription and user's mode choice.

The questionnaire was organized in 3 modules: (1) the first module focuses on users socio-economics data; (2) the second module focuses on general mobility characteristics; (3) the third module has been designed with the purpose of identifying users behavioural characteristics such as "Green attitude", "Sharing attitude" and "Car sharing device attitude". Interesting results have been obtained especially related to this specific "attitudes" of the potential users and in their influence for the subscription and utilization of the service. Specifically, the "Green Attitude" and the "Car sharing device attitude" results the most relevant attributes in the choice of the EV Car Sharing. The most relevant attributes and results of the surveys are described below:

Socio-economics characteristics: Students (82%) mainly characterize the sample; other positions held are employees (7%), professors (7%) and a mixture of PhD students and researchers, hereinafter called DAB, (4%). The sample is heterogeneous in terms of gender: male (51%) and female (49%). Moreover, the interviewees are distributed in the four Departments, where the recharge stations will be located, as follow: Engineering (27%), Literature (13%), Law (13%), Economics (8%); other interviews have been done at the administrative offices (3%) and in other departments (36%). As far as average family income is concerned, 59% of the sample declares to be below 2000 euro monthly, 28% in the range of 2000 to 4000 euro, the remaining 13% declare a monthly average family income over 4000 euros. Previous studies [13], have shown that the propensity to car sharing is high for low-medium income.

Mobility characteristics: Data show that 34% of the sample performs a short-distance trip from home to University (less or equal then 5 km); 28% a medium-distance trip (more than 5 km, but less or equal than 15 km); 16% a long-distance trip (more than 15 km but less or equal than 25 km). The remaining ones perform a trip longer than 25 km. 92% of respondents has a driving license. According to the Romans' habits, public transport subscription is not diffused [14]: considering that most of the respondents are students, about 52% declared to not have any kind of subscription;

Car sharing device attitude: it is fundamental to understand the propensity of the respondents to use technological features usually adopted for car sharing system. On that aspect, it is underlined that almost the whole sample (99%) has a smartphone. This is fundamental since the EVCS will be based on a mobile user interface. Moreover the 55% of the sample frequently adopts mobile applications (app) on their smartphone for mobility purposes;

Green Attitude (GA): To determine GA respondents have been asked to measure their environmental awareness through a Likert-type scale. This attribute explores users environmental consciousness and open mindedness about new sustainable transport modes. Data shows that GA is not linked to the user's economic conditions and to the level of education. GA does not depend on the gender but there is a sensible positive correlation with the age. In fact, about 70% of respondents over 45 years old declared to be aware of environment. This percentage drops to 55% for students (from 18 to 25 years old). GA value is strictly related to mobility habits. As the private vehicle choice increases, the GA decreases while public transport users show higher GA values: 73% of those who not drive a car for commuting trips show a high GA. This percentage drops to 60% for frequent car drivers; 73% of public transport frequent users declares to be highly environmentally conscious. This percentage declines to 23% for those who never ride public transport;

Sharing Attitude (SA): to determine SA, four questions have been proposed to the respondents, dealing with cohousing and other sharing experiences such as standard car sharing or carpooling. SA decreases with the increase of age and income. Students and DAB have higher SA then professors (respectively 15% and 8% full sharing attitude, i.e. the highest level of SA). About the gender, males are slightly more opened to share goods and services than females from our sample (respectively 60% full sharing attitude and 47% full sharing attitude). As expected, GA and SA are positively correlated. Respondents classified as inclined to share are more likely aware of environmental care.

4 BEHAVIOURAL MODELS FOR EV CAR SHARING

Starting from the results of the surveys, first experiments have been done in order to derive demand models able to describe the choice between existing mode choices and the new EVCS service. Specifically, we proposed Multinomial Logit (MNL) behavioural models

based on the random utility theory, where single user chooses the alternative that maximizes his/her own utility. For more detail see [15]. The structure of the models calibrated and validated in order to describe the transport mode choice of the decision maker *i* is depicted in Fig. 1: it consists in a multinomial logit model where the three alternatives are 1) car; 2) public transport; 3) EVCS. The utility functions can be derived from Table 3, where the attribute ASCj is referred to the specific coefficient of the choice *j*. Attributes such as "GA" or "SA", that are attributes related to the single decision maker, are reported in only one of the utility functions (Table 2). It is possible to observe that the number of attributes adopted in the models are lower than the number of attributes collected during the surveys: this happens because only the models and thus the attributes statistically significant are here reported. As reported in Table 1, five values of GA have been defined ranging from very low to very high. About the SA, 5 values have been defined based on the final score obtained on the questions in the survey related to the sharing attitude and the respective average value of the sample. About the car sharing device attitude (CS_DA), it is considered as a binary variable where the value 1 is assigned if the respondent adopts frequently a mobile app for mobility purpose. Travel times and distances are not declared attributes, but they are obtained indirectly by simulation, once known the home address and the final destination point at University. Thus, the models reported below refer to home-University trips and to the morning peak hour where most of the trips direct to University are concentrated.

Model coefficients and parameters have been estimated using a subset of the sample (about 700 interviews on 950 interviews). Estimation results are reported in Table 3. From the analysis of the t-student test values, the most statistically significant attributes can be derived:

- The Green Attitude (GA) is fundamental in all the models (t-test higher than |4.5|) and it acts as a disutility in the choice of the car, therefore, in favour of more sustainable transport modes as car sharing and public transport; this result confirms what derived from the analysis of the surveys, where the GA is not only correlated with a higher propensity in subscribing a car sharing service, but with the fact that the service proposed is in particular an electric, thus "green" service;
- The Sharing Attitude (SA) works instead as a utility in the choice of car sharing; however, its statistical significance is lower than GA and not stable according to the considered model. Only in MNL3, the respective t-student increases to 3.81, thus where it is associated with the CS_DA binary variable in the utility of EVCS;
- The CS_DA has a high statistical significance especially in MNL3, where it positively affects the car sharing choice with the higher t-test value resulted (10.93). It is interesting to note how much it can influence the mode choice toward the EVCS, respect to SA but especially respect to GA. Vice versa, the incidence of standard attributes as travel times and distance is quite low respect to CS_DA and GA.

Table 1: Attributes description.

Attribute	Unit	Description
GA	dummy	Likert scale from 1 (very low) to 5 (very high)
SA	dummy	Likert scale from 1 (very low) to 5 (very high)
CS_DA	binary	Car sharing device attitude: No (0); Yes (1)
T	min	Travel time Home-University in the morning peak hour
$D_{O/D}$	km	Distance from home to University

Table 2: Systematic utility functions.

	V_{CAR}			$V_{TRANSIT}$			V_{EVCS}		
Attributes	MNL1	MNL2	MNL3	MNL1	MNL2	MNL3	MNL1	MNL2	MNL3
ASC_{CAR}	√	√	√	-	-	-	-	-	-
$ASC_{TRANSIT}$	-	-	-	-	-	-	-	-	-
$ASEVCS_{CS}$	-	-	-	-	-	-	√	√	
GA	√	√	√	-	-	-	-	-	-
SA	-	-	-	-	-	-	√	√	√
CS_DA	-	-	-	-	√	-	-	-	√
T_{CAR}	√	√	√	-	-	-	-	-	-
$T_{TRANSIT}$	-	-	-	√	√	√	-	-	-
$D_{O/D}$	-	-	-	-	-	-	√	√	-

Table 3: Estimations results.

Estimated coefficients*	MNL 1	MNL 2	MNL 3
ASC_{CAR}	3.23 (7.68)	2.69 (6.29)	3.19 (7.53)
$ASC_{TRANSIT}$	-	-	-
$ASEVCS_{CS}$	1.16 (5.37)	0.565 (2.41)	-
GA	-0.420 (-4.57)	-0.424 (-4.60)	-0.448 (-4.71)
SA	0.291 (2.22)	0.311 (2.31)	0.430 (3.81)
CS_DA	-	-1.11 (-6.70)	1.55 (10.93)
T_{CAR}	-0.0236 (-4.01)	-0.0227 (-3.83)	-0.0182 (-3.45)
$T_{TRANSIT}$	0.00643 (2.07)	0.00693 (2.16)	0.00799 (4.10)
$D_{O/D}$	-0.0103 (-2.42)	-0.00885 (-2.05)	-
LogL(β)	-717.135	-693.940	-671.191
LogL(0)	-810.374	-810.374	-810.374
ρ^2	0.115	0.144	0.172
ρ^2 corrected	0.106	0.134	0.164
Sample reconstitution (calibration phase)	59.7%	62.3%	65.0%
Sample reconstitution (validation phase)	55.4%	60.0%	63.0%

*The T-test value in bracket.

The higher value of ρ^2 has been obtained with MNL3 (0.172) with a not trivial sample reconstitution (65%). All the models have been validated applying them to remaining subset of the sample (250 interviews) compared to the one adopted for the calibration, obtaining the sample reconstitution (validation phase) values reported in Table 3.

5 CONCLUSIONS AND FURTHER RESEARCH

This paper presents first results of the project involving Roma Tre University, Rome, Italy and Enel Energia S.p.A, the largest electricity company in Italy, in the development of a university-based EVCS system, named *e-go car sharing*. The project is currently only at its early stage, since the framework agreement between the two partners has been signed recently.

Here, in addition to report the main features of the proposed service, the results of an ex-ante survey campaign have been shown: interesting insights have been obtained especially related to specific "attitudes" of the potential users and in their influence for the subscription and utilization of the service. Specifically, the "Green Attitude" and the "Car sharing device attitude" results the most relevant attributes in the choice of the EVCS. They represent respectively: 1) a measure of how much users are environmental conscious and open minded about new sustainable transport modes; 2) the propensity of the users to use technological features usually adopted for car sharing systems. These results have been confirmed also by calibrating appropriate behavioural demand models for the mode choice (including the EVCS mode) based on random utility theory and evaluating the statistical significance of the attributes.

The "Sharing Attitude", i.e. the propensity to share something, can also explain the choice of the EVCS, but its influence is lower respect to the "Green Attitude" and the "Car sharing device attitude".

The family income, which appeared to be relevant since it can reflect the purchasing power, especially for students, is not a statistical significant attribute for the EVCS choice. Standard attributes for the mode choice, as travel times and distances, exhibit an incidence comparable with the "Sharing Attitude".

Future developments of the study will follow the evolution of the project. Since May 2017, ego car sharing will be available for all the university community. For our further research interests, data will be collected about users' impression on the service and about their mobility behaviour as well as the frequency of using EVCS. Thus, the research will be oriented on several levels: the demand point of view, on travel demand modelling with an emphasis on activity-based demand modelling, the infrastructural aspect on the optimal location of recharge stations, as well as on other potential research topics as pricing and environmental evaluations [1].

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