ENVIRONMENTAL SCIENCE & POLICY 45 (2015) 30–40

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Free-floating electric carsharing-fleets in smart cities: The dawning of a post-private car era in urban environments?

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ARTICLE INFO

Article history:
Available online 6 November 2014

Keywords:
Carsharing
Electric car
Randomised controlled trial
Private car reduction
car2go
Policy implication

ABSTRACT

Free-floating carsharing-systems allowing users to start and end vehicle-rentals at any point in cities (e.g. using smartphones to locate available cars) are expanding internationally. This article reports on the private car reduction potential of *car2go*, the first free-floating carsharing-system, which was launched in Germany in 2009. A randomised controlled trial of different electrification-scenarios was incorporated into an online survey of *car2go*-users. The results indicated that the shown electrification-scenario (e.g. regional vs. green electricity) influenced the respondents' car reduction willingness. An additional split-sample comparison of users having previously driven electric vs. gasoline *car2go*-cars showed that having driven an electric-*car2go* increased the willingness to forgo a private car purchase. Policymakers and carsharing-providers could use the findings to increase the environmental gains achieved by carsharing-systems.

1. Introduction

The automobile has changed the earth's natural and built environment more than any other invention. This was not obvious in its first days, given that the scientific community initially contrasted automobiles with horses regarding hygienic aspects (The Lancet, 1896a), safety (The Lancet, 1896b), and maintenance (Automobilist, 1899). Some early proponents speculated that "[p]robably the horse will never be banished, but (...) [s]ome day, perhaps, motor-cars will have tracks of their own" (The Lancet, 1901, p. 1429). However, neither scientists nor policymakers anticipated the automobile's unparalleled environmental impacts which have unfolded over the last century.

As of 2014, there are 1 billion passenger cars worldwide, with projections of up to 2.8 billion by 2050 (Meyer et al., 2012). For the *natural environment*, this global diffusion of cars means climate change, waste, and pollution (Aamaas et al., 2013; Chae, 2010; Tolón-Becerra et al., 2012), and these problems get worse: "Amongst the industries, transport is the sector with the fastest growth of greenhouse gases emissions, both in developed and in developing countries" (Berrittella et al., 2008, p. 307). For the *built environment*, cars brought a redefinition of urban life from the way people commute to work (García-Palomares, 2010) to where they go shopping (Reimers, 2013) – and ultimately cars are the decisive technology causing urban sprawl. The resulting problems in car-centric cities worldwide are well known, including congestion, noise, energy use, and parking shortage

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http://dx.doi.org/10.1016/j.envsci.2014.09.005
1462-9011/

(Loukopoulos et al., 2005). However, policymakers struggle to find solutions as even experts disagree on complex transportation policies (Berrittella et al., 2008), and as policies assumed to reduce car use often turn out (empirically) to be ineffective (Graham-Rowe et al., 2011).

Free-floating electric carsharing-fleets could simultaneously solve several problems resulting from the traditional use of private automobiles. ''Shared'' cars driven alternately by different users save resources compared to private cars – which are normally driven less than 1 hour per day (Firnkorn and Müller, 2012). ''Electric'' vehicles can reduce carbon dioxide (CO_2) emissions relative to cars powered by gasoline, depending on the mode of electricity generation (Oxley et al., 2012; Mao et al., 2012). ''Free-floating'' fleets enable location-independent car usage based on the global positioning system (GPS)-localisation of the cars (e.g. by smartphone apps), which offers a degree of flexibility similar to private cars: ''[A] free-floating set-up allows users to start and end a vehicle hire at any point within a specified area, which therefore enables discretionary one-way usage'' (Firnkorn and Müller, 2011, p. 1519). In summary, free-floating electric carsharing-fleets could combine all the above-indicated advantages regarding ownership (shared), power-train (electric), and system functionality (free-floating).

But the effects of free-floating electric carsharing-fleets are still unknown. Will such systems reduce private car ownership in cities? Should policymakers support such systems? As of March 2014, few studies on free-floating carsharing-systems exist – which is likely to be a temporary state given that the technology is new but spreading rapidly. The first free-floating carsharing-system was ''*car2go*'', launched by the automaker *Daimler* in 2009 in the city of Ulm, Germany. At present, *car2go*-fleets of 250–1200 vehicles are offered in 26 European and North American cities (www.car2go.com). Although other companies have started to offer similar free-floating systems (e.g. *BMW* in 2011, *CITROËN* in 2012), this article focuses on *car2go* in Ulm for two methodological reasons. First, Ulm has globally the longest operating free-floating carsharing-system. Second, *car2go* in Ulm offers a mixed fleet of electric and gasoline vehicles – an experimental advantage allowing a split-sample comparison of the associated user-behaviour (all other parameters being equal).

This article reports on *car2go*'s potential to reduce private car ownership in urban environments given the ongoing electrification of the system. The methodology consisted of a randomised controlled trial testing the *car2go*-users' willingness to reduce private car ownership depending on different electrification-scenarios. In addition, the answer patterns of the respondents who had already driven electric-*car2go* or only gasoline-*car2go* were compared. The results could support policymakers developing transportation policies for new free-floating electric carsharing-systems for which (as of March 2014) few empirical analyses exist and for which the science-policy discourse (Wesselink et al., 2013) has just begun. Schwedes et al. indicated that ''[i]t is still far from clear whether e-cars could be part of a sustainable transport strategy'' (Schwedes et al., 2013, p. 79). The present article contributes to a better understanding of electric cars in the context of free-floating carsharing-systems combining electric mobility with further technologies (e.g. real-time connectivity, instant and shared access, GPS-localisation) associated with future smart cities. While a standard definition of ''smart city'' does not exist (Hollands, 2008; Neirotti et al., 2014), ''a common recognition [is] that electric vehicles (EVs) form one of the most important elements of the FSC [future smart city]'' (Yamagata and Seya, 2013, p. 1467).

2. Method

The methodological core of this article is a randomised controlled trial of four *different* scenarios (stimuli) given to carsharing-user as the basis for consecutive *identical* questions about their mobility behaviour. This study was implemented in an online survey answered by *car2go*-users registered with *car2go* in the city of Ulm, Germany. The survey participants saw only one of the four scenarios displayed in Fig. 1.

As shown in Fig. 1, the survey participants were randomly asked to imagine one of the future scenarios ''Base'' (no electric cars mentioned), ''E-*car2go*'' (fully electric fleet), ''E-*car2go* & green'', or ''E-*car2go* & regional'' (the latter two scenarios differed by additional stimuli regarding the electricity generation). The scenario-randomisation (Fig. 1) was applied to avoid a selection bias (Caplow et al., 2011) and served to understand the impacts resulting from different electrification-variants.

The specific point in time of the measurement of the survey was chosen with the aim of approximately 50% of the *car2go*-users having driven either an electric-*car2go* or only a gasoline-*car2go* (an electric/gasoline mixed fleet is offered in Ulm). In the cleaned dataset used in this article ($N = 743$), 49.3% of the respondents had driven an electric-*car2go* at the time of the survey (Section 3.2.2), which allowed an additional split-sample comparison of the results via the dichotomous variable ''electric-*car2go* driving experience''.

3. Results

3.1. *Generated sample of carsharing-users*

The dataset of the present article was generated using an online survey of *car2go*-users. The authors programmed and pretested the survey, and *car2go* sent out the survey invitations via a group-mail software on 9 February 2013. Of the 17,000 *car2go*-members in Ulm in possession of a second-generation *car2go*-RFID-chip (required to access *car2go*-vehicles since March 2011), the survey was sent to all 4,577 *car2go*-newsletter subscribers (due to data protection laws). The invitation links were unique through URL-variables to exclude biases from multiple participations, yet no individual user-data was matched via the links (due to data protection laws). The survey worked independently of JavaScript (to ensure its functionality independent of browser settings and on mobile devices), the emails were sent non-HTML formatted (to avoid biases from filters), and the group-mailing was sent in batches (to avoid biases from firewalls). Of all completed cases, 93.4% were collected within the first week after the invitation emails were sent.

The raw dataset was verified regarding technical aspects and content. The *technical data verification* included checks for