Comparing electric vehicles and fossil driven vehicles in free-floating car sharing services

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Short abstract

In recent years, free-floating car sharing (FFCS) services have been offered as a more flexible option compared to traditional car sharing. FFCS allows users to pick up and return cars anywhere within a specified area of a city. These can be either electric or fossil driven vehicles. We analyze the difference in usage of these two types of vehicles. The analysis is based on a dataset consisting of vehicle availability data sampled between 2014 and 2016 for 9 cities with EVs in the FFCS fleet. We find that there is no statistical difference in how EVs and fossil driven FFCS vehicles are used. When it comes to charging of EVs two main strategies are identified: widespread "slow charging" versus tailored fast-charging.

Introduction

Mobility services such as car sharing and ride sharing are seen as part of a transition to a more sustainable transportation system. Still, despite the increased attention they have not yet achieved a major breakthrough. One of the reasons is that they cannot fully compete with the privately owned vehicle in terms of flexibility (Sprei and Ginnebaugh, 2015). In recent years, free-floating car sharing (FFCS) services have been offered by many organizations as a more flexible option compared to traditional car sharing. FFCS allows users to pick up and return cars anywhere within a specified area of a city. FFCS can provide a high degree of utilization of vehicles and less usage of infrastructure in the form of parking lots and roads and thus has the potential to increase the efficiency of the transport sector. FFCS offers both fossil driven and electric vehicles (EVs) in their services depending on the city. In Madrid and Amsterdam only electric vehicles are offered, whilst in other cities such as Berlin, Stockholm, Vienna and Munich there is a mix of vehicles. Offering electric vehicles instead of fossil driven vehicles in FFCS will increase their environmental benefit in terms of lower emissions. They may also help to showcase electromobility in the cities and allow more people to actually try and get acquainted with EVs. The city of Amsterdam highlights this as a motivator to support EV FFCS[1]. While EVs may be better from a sustainability point of view can they offer the same service as the fossil vehicles? As a first step in trying to answer the question in this paper, we study how EVs in FFCS are being used compared to conventional vehicles through data on the vehicles usage patterns; e.g. are they used less often since they need recharging, or for shorter distances? We also take a closer look at Madrid and Amsterdam, the two cities with exclusively EVs in their fleets. Since charging is a major issue related to EVs, especially if you want a high utilization rate of the FFCS, we look more closely at the charging strategies in these two cities.

The research on FFCS is in its early stages. Many aspects of these services and their effects to society are not known with certainty. A few studies report some statistics on the efficiency and sustainability of these services and are

[1] Interview with city representative for Amsterdam

mainly based on surveys (see e.g. Firnkorn, 2012; Kopp et al., 2013; Ciari et al., 2014; Kopp et al., 2015). Some of the operators introduce EVs in their fleet which can achieve additional environmental benefits in terms of reduced emissions and reduced noise. However, there are even fewer studies on including EVs into the fleets of these services. Firnkorn & Müller (2015) incorporate different electrification-scenarios into an online survey of Car2go-users. The results indicate that having driven an electric Car2go increased the respondent's willingness to decline a private car purchase. To the best of our knowledge, this is the first study that compares the usage of electric vehicles to that of conventional ones based on actual usage data.

DATA AND METHODS

Free-floating car sharing services are inherently reliant on information services to inform their users about the present position of available cars. Information about present position is, at least when parked, provided by the vehicle to the operators which is made publically available through web-pages and/or smart phone applications to enable the user to find and book available vehicles. To enrich the user experience further, information on vehicle type, powertrain, cleanliness and fuel level is often provided by the operator. This information was extracted for each movement for usage in further analysis.

Reservation of a vehicle requires that the user application is aware of the vehicle identity, which makes it possible to identify movements of individual vehicles. Start location for each movement corresponds to the sample before the vehicle is no longer indicated as available to the user and end location to the first sample where it once again can be booked.

The base dataset consists of vehicle availability data sampled between 2014 and 2016 from 3 different operators in over 20 different cities located in Europe and North America with sampling time of 60 seconds. In total, approximately 27 million vehicle movements have so far been identified. In this paper we focus on 9 European cities with EVs.

From the data we perform statistical analysis, such as computation of averages, standard deviation and t-tests, on measurements such as distance per trip and number of trips per day to analyze the differences in usage between fossil and electric driven vehicles. The distance of the trip is not the actual distance travel but rather the straight-line distance between the pick-up of the vehicle and the drop-off. The utilization rate is calculated by the total time (minutes) all cars are used each day divided by how many minutes they can be potentially driven per day.

RESULTS

Comparing all the fossil driven vehicles and all the EVs when it comes to usage parameters such as average distance, average duration and average number of trips, no statistically significant difference can be found. In the next step we look at differences within cities that have both EVs and fossil driven vehicles. These cities are: Stockholm, Berlin, Munich, Hamburg, Vienna, Düsseldorf and Cologne. Table 1 shows the total number of FFCS vehicles in the city and the number of EVs.

TABLE 1: TOTAL NUMBER OF FFCS VEHICLES IN THE STUDIED CITIES AND THE NUMBER OF EVs.

City	FFCS vehicles	EV
Amsterdam	350	350
Berlin	2595	139
Cologne	703	44
Düsseldorf	685	42
Hamburg	1472	69
Madrid	500	500

München	1527	86
Stockholm	545	29
Wien	446	20

Averages with standard deviations for trip distance, number of trips per day and trip duration can be found in Figure 1.

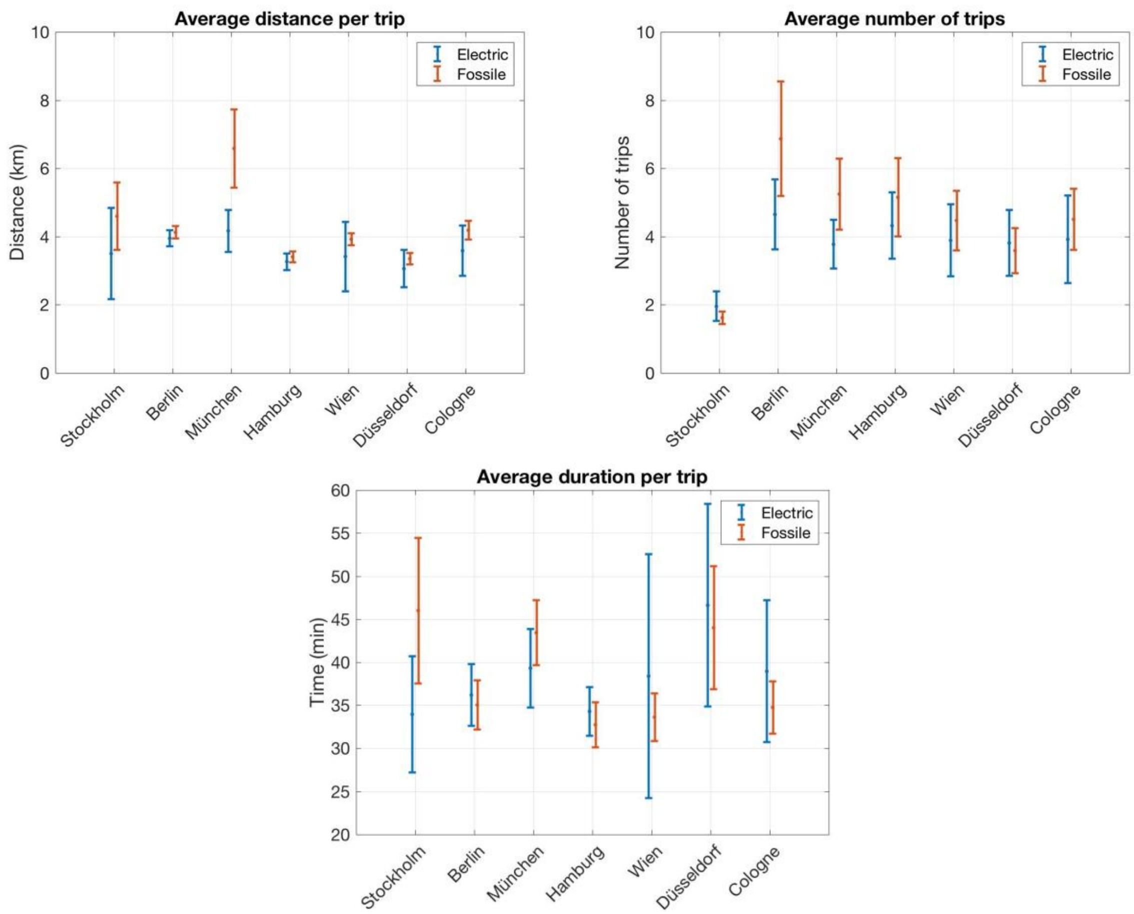

Figure 1: Average distance per trip (top left); average number of trips per day per vehicle (top right), and average duration per trip (bottom), all with standard deviations for 7 cities.

The only city where there is a statistical difference in the average distance per trip is Munich. In all the others, even if the average trip distance is longer for fossil vehicles, the spread of usage, especially for EVs, is so large that it can't be said that there is a significant difference. The average number of trips per vehicle and day is slightly higher for fossil vehicles, indicating that they might be used more frequently. Still, even in this case the spread indicates that this difference is not statistically significant. In Berlin and Munich the difference between the averages is the largest, still the standard deviations overlap. The same conclusion, i.e., that there is no statistically different usage pattern holds also for the average duration of the trip. The spread for EVs is in most cities larger than for fossil vehicles, e.g., in Wien the spread for EVs ranges from 25 minutes to almost 55 minutes. The largest difference in average can be found in Stockholm, where in average a trip with a fossil vehicle is of 47 minutes while the EV is 34 minutes. It should be noted that the number of EVs is lower than the number of fossil driven vehicles (see Table 1) which might explain the larger standard deviation for these vehicles.

Looking at the two cities with only EVs the numbers are similar to the other cities. In Amsterdam the average distance per trip is 3.3 km with a standard deviation of 0.16 km. In Madrid the average distance per trip is slightly lower, 2.8 km with a standard deviation of 0.14 km. The average number of trips on the other hand is higher for Madrid with an average of 9 trips per day (standard deviation 3.2 trips per day). However, about one third of these trips are expected to be charging trips. In Amsterdam the average number of trips per day is 4.5 (standard deviation 1.9 trips per day), which is similar to the values of the other cities observed. Trip duration in these two cities does not differ from other cities and lies around 30 minutes (35 minutes with a standard deviation of about 6 minutes for Amsterdam and 32 minutes, 3 minutes standard deviation for Madrid).

Looking at charging strategies we find that they differ markedly between Madrid and Amsterdam. In Madrid the vehicles are charged by the FFCS company at designated fast charging stations[2]. In our data, charging trips are identified by trips where the state of charge (SOC) of the battery is higher after the trip than before. We then find that about one third of the trips are charging trips and that the apparent 34% utilization rate of the vehicles rather is 22%, see the left of Figure 2. In Amsterdam the average utilization rate is 11% instead, see the right of Figure 2. Utilization rates in the different cities with FFCS vary from 4% to about 12 %. Madrid thus stands out as having one of the highest utilization rates and Amsterdam is also in the higher span. This is an indication that having a fleet of only EVs does not lower the usability of the service and can cater a high utilization rate.

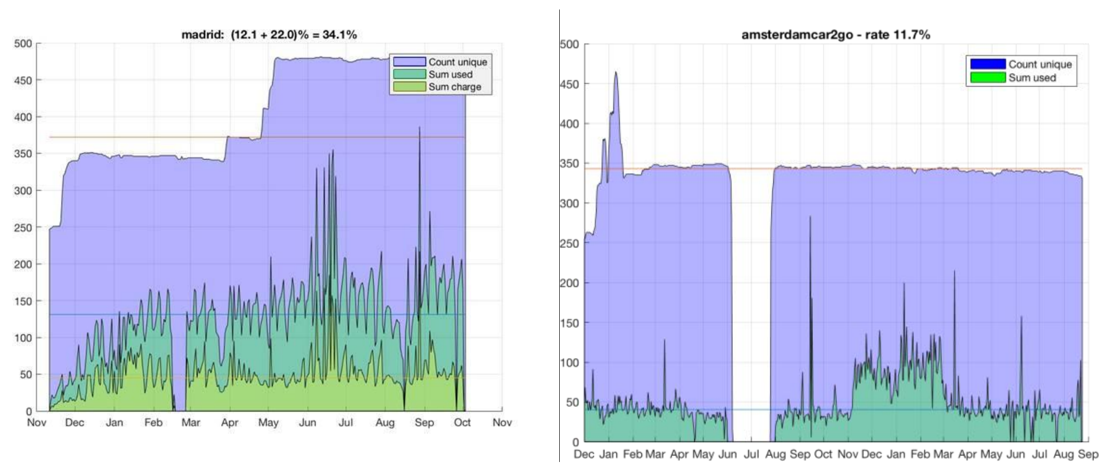

Figure 2 Utilization rate of FFCS vehicles in Madrid (left) and Amsterdam (right). The blue part is the total number of vehicles available while the green is the vehicles being used and the lighter green are vehicles that are being charged, identified by trips where the SOC of the battery is higher after the trip than before. The red line is the average number of vehicles available and the blue line is the average number of vehicles that are used.

In Amsterdam the charging is solved by a wide spread network of “slow” charging stations provided by the city of Amsterdam. These charging stations are available for any EV and in case of increased demand for charging the municipality will provide with new charging points[3]. Thus, the investment costs are covered by the city but the FFCS providers have to pay for the charging as any user would. This charging strategy implies that the vehicles are charged when parked and there are no so called charging trips as in the Madrid case.

[2] Interview with FFCS provider

[3] Interview with city representative for Amsterdam

Conclusions

There is no statistical difference on how EVs are used in FFCS compared to the fossil driven vehicles. When looking specifically at Amsterdam and Madrid, two cities with only EVs we find that, at least for Madrid, the distances seem to be shorter, but on the other hand the number of trips per day is relatively high, and the total utilization rate is the highest of the studied cities. We thus have indications that EVs in FFCS can provide similar services to fossil driven vehicles.

One issue that has to be dealt with for EVs in FFCS is charging the vehicles. Amsterdam and Madrid provide two different solutions: widespread "slow charging" versus tailored fast-charging. Further studies are needed to understand better which solution is preferable in the long run and for which city.

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