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## **Statistical Data for Free-floating Car Sharing versus Public Transport**

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### **Summary**

Free-floating car sharing is a form of car rental used by people for short periods of time where the cars can be picked up and returned anywhere within a given area. In this paper, we have collected free-floating car sharing data, for electric as well as fossil fueled cars, and data for alternative trips using cycling, walking and public transport for the cities of Amsterdam, Berlin, Denver, Madrid, San Diego and Seattle. From this data, free-floating car sharing seems to be a compliment to other type of transports, including public transports, bicycling and walking, and not a competitor.

*Keywords: Car-sharing, EV (electric vehicle), public transport, data acquisition, city traffic*

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### **1 Introduction**

Many cars in cities in general imply congestions and much land use in the form of parking lots, which usually stands in contrast to achieving pleasant cities. Furthermore, many cars also imply much local emissions from e.g. fossil fuelled vehicles leading to unpleasant and unhealthy smog which more or less daily is reported in media for certain cities. Adding the carbon dioxide emissions affecting the climate means that changes in the transport sector are needed.

Many cities which try to solve the urban construction and transportation challenges usually end up in strategies to reduce the number of vehicle and instead provide solutions with mass-transportation, e.g. by public transport like busses, trams and metro, in combination with promoting bicycling by building bike lanes and walking which are prioritized in front of motorized vehicles. The reason is that many persons can be efficiently transported in this way resulting in low emissions per passenger, which can be even further reduced by public transportation run on renewable energy.

However, from an individual's perspective, mass-transit transportation usually does not fulfil all transportation needs implying that cars are still needed in certain situations, e.g. public transportation may not operate during night or is sparser during non-peak hours or in suburban areas. Other reasons might be that persons sometimes need to bring bulky or heavy luggage or have some kind of disability. People could use taxis or rent a car for these occasions, but if they occur frequently, people usually buy a car.

Car sharing is a form of car rental used by people for short periods of time, and the cars in traditional services are picked up and returned at specific stations or places. Free-floating car sharing (FFCS) is a more flexible option since the cars can be picked up and returned anywhere within a given area. Hence, the user convenience increases in the form of access and availability and consequently the utilization rate becomes higher which makes it easier for the operators to have a profitable business.

The research on FFCS is in an early stage. Many aspects of these services and their effects on society are not known with certainty. Most of the research is based on surveys or simulation [1], [2], [3], [4], [5] and [6]. Different electrification-scenarios are incorporated into an online survey of car2go-users in [7]. The results indicate that having driven an electric car2go increased the respondent's willingness to decline a private car purchase.

There are few studies that use revealed data on FFCS. Spatial characteristics of cities with car sharing, both traditional and free-floating, is analyzed in [8]. They find that high population, small household size, high transit use, and high levels of government employment are the characteristics of a city with a high potential for car sharing. They also predict membership and the market share of these services. The differences in spatial characteristics of where FFCS and non-car-sharing (NCS) users reside is compared in [6]. FFCS users live in denser areas with a better local supply of facilities. Despite better accessibility to public transport, FFCS users use it to the same extent as NCS users do. The usage of FFCS is investigated in Berlin in [9]. The results show that the demand is mostly concentrated on a few temporal peaks and spatial Hot Spots.

The positive effects of car sharing are not per se given but depend on a lot of factors. If people own cars and now and then use car-sharing vehicles, the number of vehicles increases requiring even more parking space. However, if there are sufficiently good transportation alternatives compared to owning a car, including public transport, taxis, car-sharing etc., there is a potential to decrease the number of cars. From this perspective, car-sharing might be one of the pieces to get people to get rid of their cars, or never buy a new one. From an environmental perspective, shared cars have a faster turnover which potentially reduces barriers buying low-emission vehicles like electric ones.

Due to lacking knowledge, some cities are sceptical to supporting free-floating car sharing operations. For this reason, it is important to try to understand what type of trips FFCS replace and compare it with reasonable public transportation solutions, in order to increase the knowledge and give a solid ground on which decisions can be made.

In this paper, we study the actual usage of FFCS by analyzing a data set with 27 million trips and compare it with collected public transportation data, which, to our knowledge, never has been done before. The FFCS data set has so far given rise to two publications [10] and [11]. The study in [10] is similar to [9] but uses different methods and a data set of 22 cities which made it possible to compare the usage pattern in different cities and examine whether or not there is a similar trend. In [11], the difference in usage of EVs and fossil driven vehicles and it was concluded that there is no statistical difference in how electric vehicles (EVs) and fossil driven FFCS vehicles are used. Despite this, we separate the data set into data for (EVs) and fossil driven vehicles, to make a clear distinction of the vehicle types, in case of both type of vehicles in a city. Common for this paper and [10] and [11] is that we use an explorative approach to try to understand how FFCS services are used in different cities, and in this paper compare it to alternative travelling possibilities.

It should be noted that this study is descriptive. We do not aim to answer the question of why the usage patterns are different in various cities but rather the question of how these patterns differ, and to compare it with aggregated alternative travelling possibilities. Therefore, we do not compare the underlying factors that may lead to different usage patterns in the cities such as population density, public transport performance or car ownership. The primary purpose of this studies is to identify similarities and differences of usage patterns. While not conclusive, these results can be valuable input for future studies to identify which cities might be of interest for further investigation, to simulation studies and to policy makers that wish to understand how the service function in their city compared to others.

## 2 Data

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 and non-booked, provided by the vehicle to the operator made publicly available through web-pages and/or smart phone applications to enable the user to find and book available vehicles, see Figure 1.

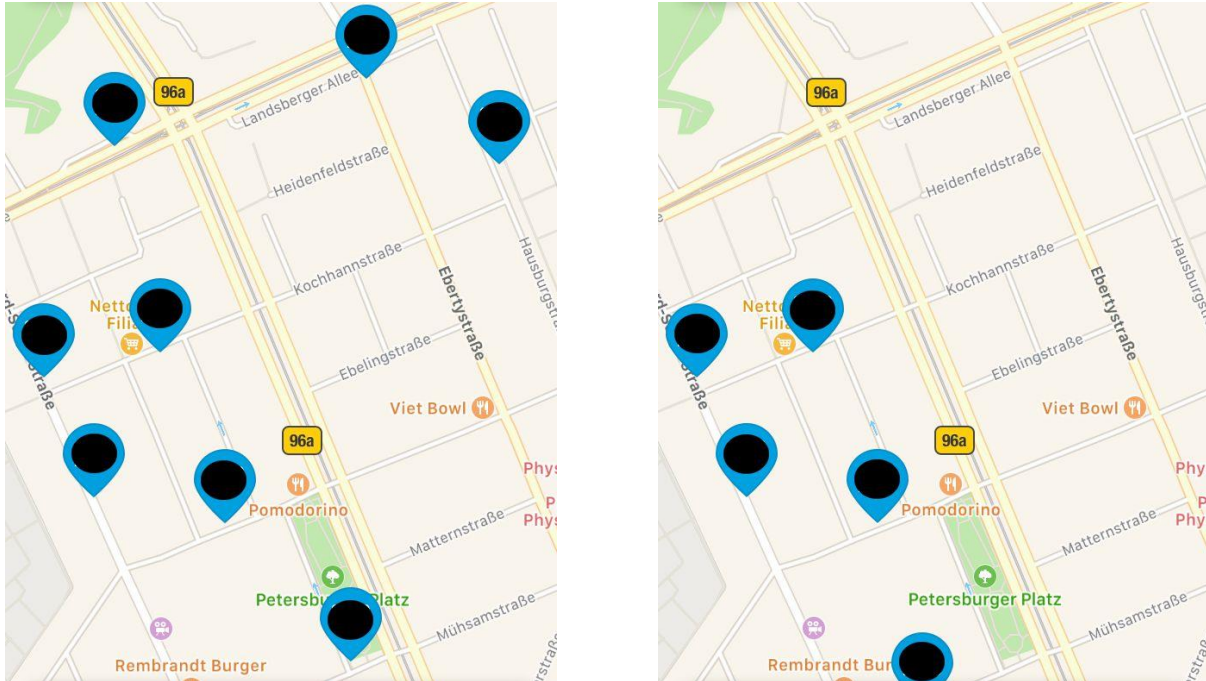


Figure 1: Screenshot examples of a free-floating car sharing smart device application, showing the location of cars in a map in a part of a city (Berlin). To the left there are eight bookable cars and to the right, taken seven minutes later, there are five bookable cars. The three upper cars in the left picture and the lower one has disappeared from the screen, indicating that they have been booked and potentially driven away. To the right, one further car in the lower part of the picture have shown up and is available for booking again, together with the other visible bookable cars in the picture.

Reservation of a car requires that the user application is aware of the car identity, which makes it possible to identify movements of individual cars. When a car is booked, it is no longer available for further bookings, until it is checked out again. It should be noted that it cannot be made any conclusions about which way a car has been driving between two points. The car disappears from the map when reserved, and cannot be seen again until it is checked out. Figure 2 gives a clear illustration what happens before, during, and after booking a car.

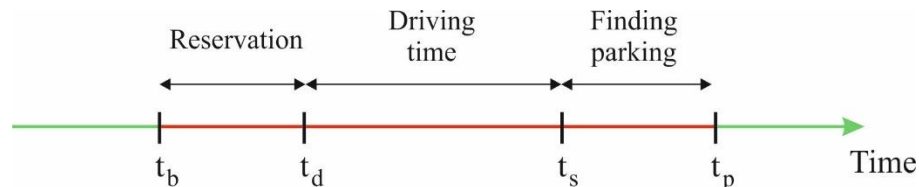


Figure 2: The green part, before time  $t_b$  and after time  $t_p$ , indicate times when a specific car is available for booking and the red part in between indicates when it is invisible on the map and non-bookable for others. At time  $t_b$ , a user books the car and then has a certain time to reach the car, typically 15 minutes. This is referred to as the *Reservation* time slot in the figure. When the car is reached it is unlocked and checked out, which is at time  $t_d$  in the figure, and is referred to as the *Driving time* in the figure. If the car is not checked out within time, the car becomes visible and available for others to book. Between time  $t_d$  and  $t_s$ , the driver drives away to the desired destination. In this vicinity, the driver starts to search for a free parking lot, referred to as the *Finding parking* time slot in the figure which is reached at time  $t_p$ , where the car is parked, locked and checked out.

Start location for each car movement corresponds to the sample before the vehicle is no longer indicated as available to other users ( $t_b$  in Figure 2) and end location corresponds to the first sample where it once again can be booked by others ( $t_p$  in Figure 2). To enrich the user experience further, information on vehicle type, powertrain, and fuel level is often provided by the operator via their websites and mobile applications.

The base dataset consists of vehicle availability data sampled between 2014 and 2016 from 3 different operators in over 30 different cities located in Europe and North America with sampling time of 1 minute. In total, approximately 27 million vehicle movements have so far been identified for electric as well as fossil fuelled cars.

In this paper, we focus on the cities of Amsterdam, Berlin, Denver, Madrid, San Diego and Seattle. The reasons for this choice is that Amsterdam, Berlin and Madrid are three cities in Europe and Denver, San Diego and Seattle are three cities in US. Furthermore, Berlin has both fossil fuelled vehicles (where we in this paper choose to study the fossil fuelled vehicles), while Amsterdam and Madrid only have EVs. In US, we have chosen to study Denver and Seattle having fossil fuelled vehicles and San Diego having EVs. Berlin and Madrid have been visited to better understand the FFCS services in these cities.

For the selected cities, we have also collected data for alternative modes of transport. For each collected FFCS trip, a query has been sent to Google Maps for how long time the same trip, from start to end locations, would take by public transport, bicycling, walking and by car. Since you only can put a query to Google Maps in advance, the query has been set for a trip to start exactly one week after the actual FFCS trip occurred, assuming that congestion and other conditions are about the same. There is a limited number of queries that can be sent to Google Maps for free, limiting the number of alternative trips to fewer than the 27 million vehicle movements that have been collected.

The expected time to go by car returned from Google Maps is compared with the actual FFCS time in order to a) get indications if the user has made some intermediate stop on the way (so called trip-chaining), and b) estimate average “non-driving time”, i.e. the time it takes for the user from booking to access the car (*Reservation* time in Figure 2) plus the time to find a parking and check-out the car (*Finding parking* time in Figure 2).

### 3 Results

To understand the following figures with plotted values, some explanations are needed. First, every (sub)picture contains 16 plots in 4 rows. The first row compares FFCS with cycling, the second row with walking, the third row compares FFCS with available public transport (like busses, metro, trams etc.) and the fourth row with car driving motivated by the last paragraph in the previous section.

For each row, there are four subplots representing different time intervals: the first for early *morning* (5-6 am), the second for *day* (1-2 pm), the third for *evening* (9-10 pm), and the fourth show aggregated data for the entire day and night, referred to as *all day*. The reason for showing different time intervals is to see if there are any differences various times.

The x-axis in all subplots indicates time differences in minutes and positive values in the plots means that the FFCS is slower than the compared alternative and negative values means that the FFCS is faster than the compared alternative. Beware that when we in a comparison say “slower” and “faster”, we mean that in statistical meaning, i.e. the mean value of the plots (distributions) are “slower” and “faster”. Individual trips may differ and the distribution gives an indication of the spreading.

The y-axis is the number of counted trips. Since the utilization of the FFCS differs during various times during the day, the counted trips also differ. Therefore, be aware of the scale of the y-axis.

### 3.1 Free-floating car sharing in Berlin using fossil fuelled vehicles

Let us start by studying FFCS in Berlin using fossil fuelled vehicles, see Figure 3. We begin by comparing FFCS with driving. It can be seen in the last row of the subpictures that FFCS is almost always slower than the car trips that Google Maps estimate. The peak values appear at approximately 5 minutes, which gives an indication of the “non-driving time” (reservation time + parking time in Figure 2). As mentioned earlier, Google Maps does not take this into account since it only estimates the driving time between two points. Furthermore, it can be seen from the same row that even if we neglect the non-driving time”, most FFCS trips take longer time than is estimated by Google Maps. This indicates that people do not drive the fastest or straightest way between two points on the map. Most likely, the FFCS is used for errands also between the origin and the destination. The number of trips during the morning hour is lesser than the two other times.

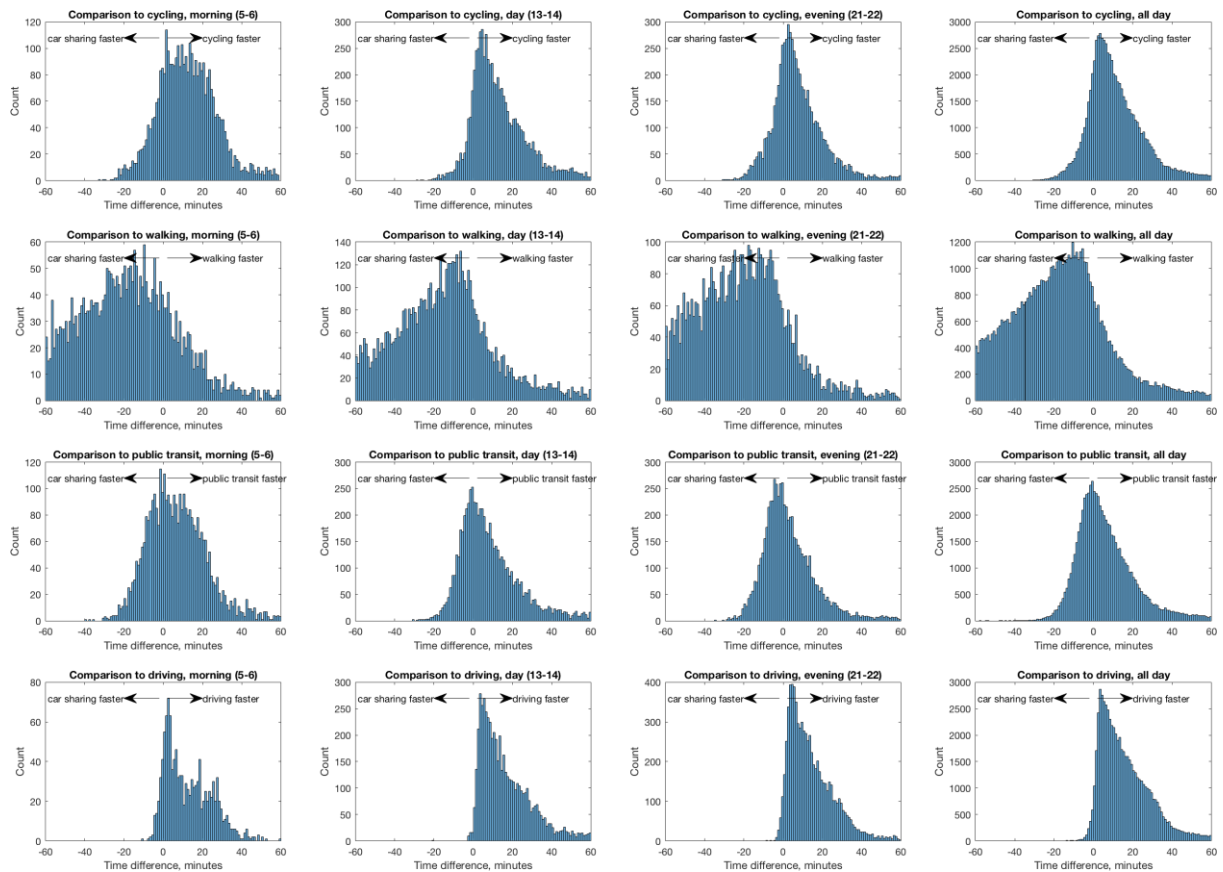


Figure 3: Comparison of fossil fuelled FFCS trips in **Berlin** with alternative transportations. First column, time between 5-6 am; Second column, time between 1-2 pm; Third column, time between 9-10 pm; Fourth column, average during day and night.

Comparing FFCS with public transport, it can be seen from the subplots (third row from top) that FFCS is slower during morning and lunch but comparable during evening. Overall over the day (fourth column) it seems to be roughly the same (zero mean minute value) even if the spread is large. This is most likely due to quick public transport in the early morning due to less people movements and an increasing traffic during the day that decreases during the evening.

Comparing the FFCS with walking, it can be seen from the subplots in the first row that FFCS is faster, regardless of the time interval of the day or during the day.

Finally, comparing the FFCS with cycling, it can be seen from the subplots that FFCS is slower, regardless of the time interval of the day or during the day. During evening, it is almost as fast as using FFCS, since the vehicle traffic is low and the cars can drive faster.

### 3.2 Free-floating car sharing in Amsterdam using electric vehicles

In Figure 4, the corresponding plots for Amsterdam are shown, this time for FFCS data of EVs.

As can be seen from the plots, the data from the city of Amsterdam is very similar to Berlin, even though the number of observed trips is fewer in Amsterdam compared to Berlin, and the vehicle type is electric vehicles instead of fossil fuelled cars.

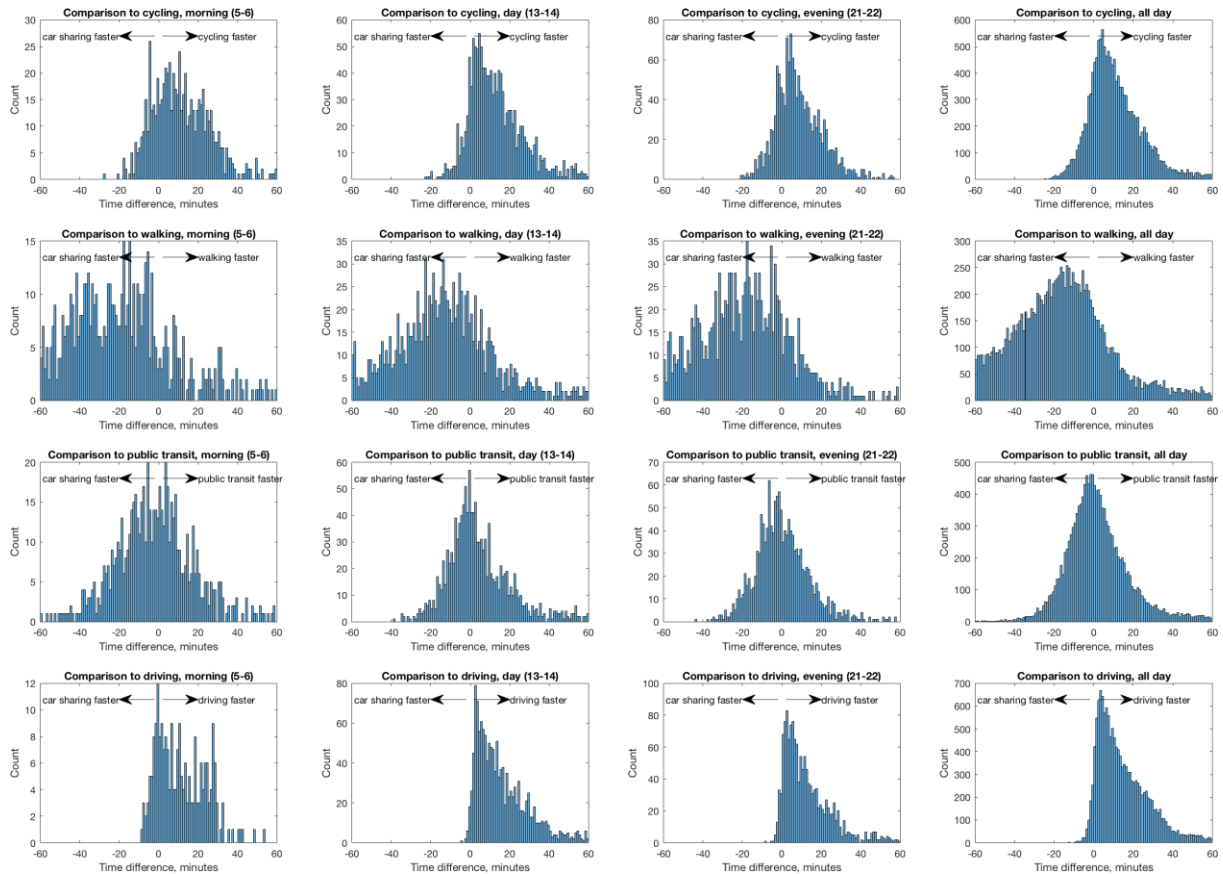


Figure 4: Comparison of fossil fuelled FFCS trips in **Amsterdam** with alternative transportations. First column, time between 5-6 am; Second column, time between 1-2 pm; Third column, time between 9-10 pm; Fourth column, average during day and night.

Also in Amsterdam, the FFCS is always slower than the car trips estimated by Google Maps, and the “non-driving time” is approximately 5 minutes also for Amsterdam. It can be seen from the same plots, as in Berlin, that even if we neglect the non-driving time”, most FFCS trips take longer time than is estimated by Google Maps for the same reasons as in Berlin.

Comparing the FFCS with public transport, it can be seen from the subplots that FFCS is comparable at all times but with a higher spread during morning.

Comparing the FFCS with walking, it can be seen from the subplots that FFCS is faster, regardless of the time interval of the day or during the day.

Finally, comparing the FFCS with cycling, it can be seen from the subplots that FFCS is slower, regardless of the time interval of the day or during the day. During evening, there is a slight tendency that it is almost as fast as using FFCS, since the vehicle traffic is low and the cars can drive faster, as in Berlin.

### 3.3 Free-floating car sharing in Denver using fossil fuelled vehicles

In Figure 5, the corresponding plots for Denver is given, for FFCS data of fossil fuelled cars. The number of observed trips for Denver is much lower than for Berlin and is roughly the same as in Amsterdam, as can be seen in the plots. During morning, only a few cars are booked, as can be seen in the upper left subpicture. Also in Denver, it can be concluded that FFCS is always slower than the car trips that Google Maps estimate, and the “non-driving time” is approximately 5 minutes also for Denver.

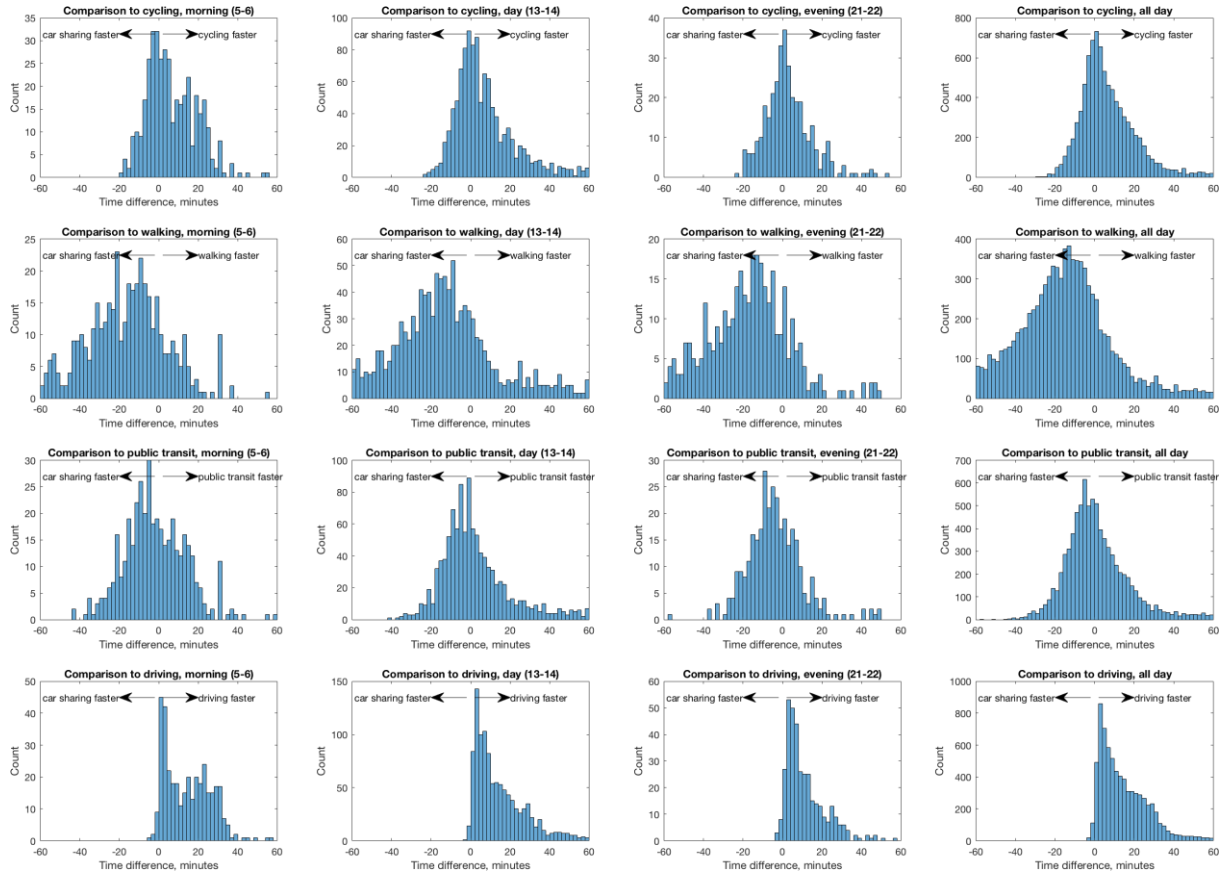


Figure 5: Comparison of fossil fuelled FFCS trips in **Denver** with alternative transportations. First column, time between 5-6 am; Second column, time between 1-2 pm; Third column, time between 9-10 pm; Fourth column, average during day and night.

Comparing the FFCS with public transport, it can be seen from the subplots that FFCS is faster, regardless of the time interval of the day or during the day, in contrast to Berlin and Amsterdam. FFCS is faster than walking and slightly faster than cycling, excepted possibly during morning. Hence, FFCS is more or less faster than all other modes of transportation in Denver.

### 3.4 Free-floating car sharing in Madrid using electric vehicles

In Figure 6, the corresponding plots for Madrid is shown, for FFCS data of EVs. The data set for Madrid is quite large, due to the many FFCS EVs in Madrid. Comparing FFCS with car trips, Madrid follows Berlin, Amsterdam and Denver and it can be concluded that FFCS is always slower than the car trips that Google Maps estimate, but the “non-driving time” in Madrid is approximately 10 minutes.

Comparing the FFCS with public transport, it can be seen from the subplots that FFCS is slightly faster, regardless of the time interval of the day or during the day. In the morning, it is much faster. Like Berlin, Amsterdam and Denver, FFCS is faster than walking. However, FFCS is slower than cycling, regardless of the time interval of the day or during the day, as in Berlin and Amsterdam but in contrast to Denver.

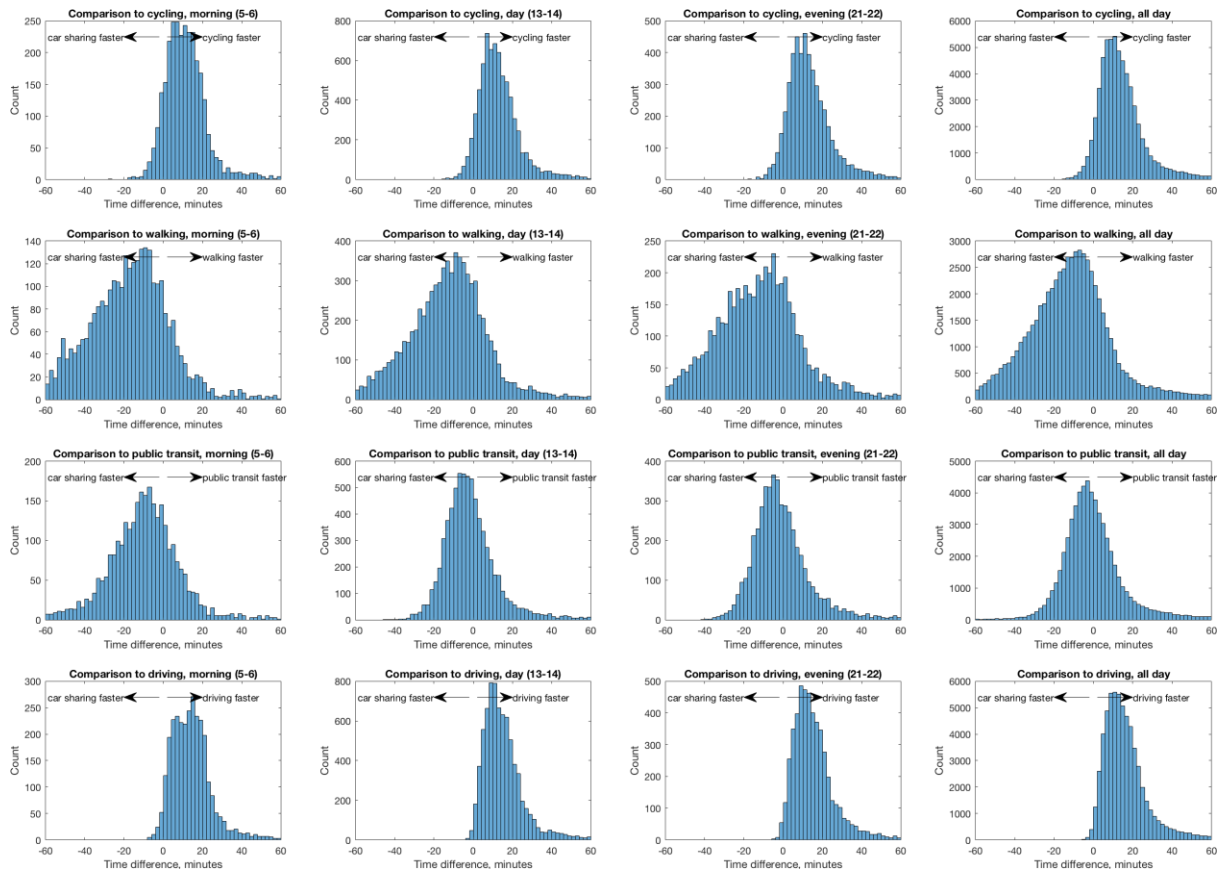


Figure 6: Comparison of fossil fuelled FFCS trips in **Madrid** with alternative transportations. First column, time between 5-6 am; Second column, time between 1-2 pm; Third column, time between 9-10 pm; Fourth column, average during day and night.

### 3.5 Free-floating car sharing in San Diego using electric vehicles

In Figure 7, the corresponding plots for San Diego is shown, for FFCS data of EVs. San Diego is similar to Denver. Comparing the FFCS with public transport, it can be seen from the subplots that FFCS is faster, regardless of the time interval of the day or during the day. FFCS is faster than walking and slightly faster than cycling, excepted possibly during morning and also evening. Hence, FFCS is more or less faster than all other modes of transportation in San Diego.

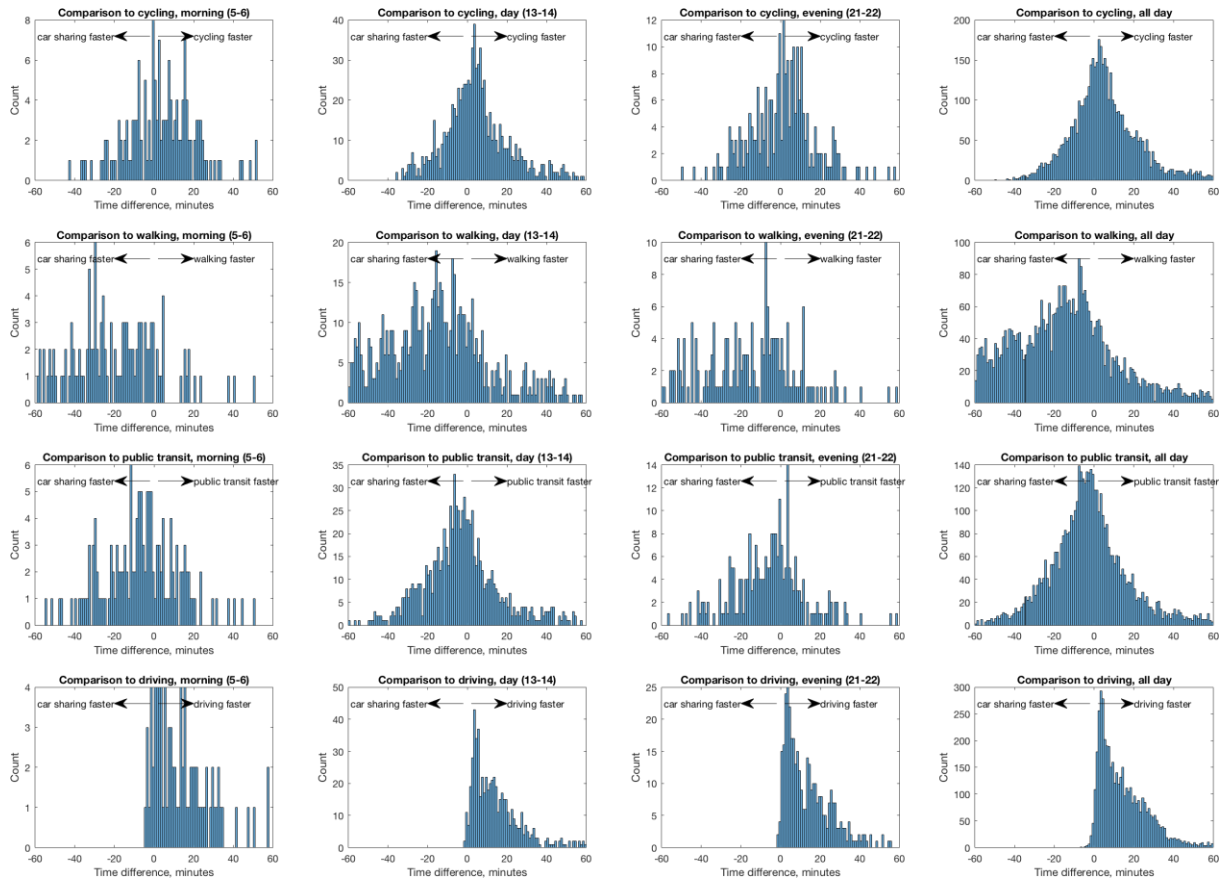


Figure 7: Comparison of fossil fuelled FFCS trips in **San Diego** with alternative transportations. First column, time between 5-6 am; Second column, time between 1-2 pm; Third column, time between 9-10 pm; Fourth column, average during day and night.

### 3.6 Free-floating car sharing in Seattle using fossil fuelled vehicles

In Figure 8, the corresponding plots for Seattle is shown, for FFCS data of fossil fuelled vehicles. Seattle does not differ significantly from the two other US cities Denver and San Diego.

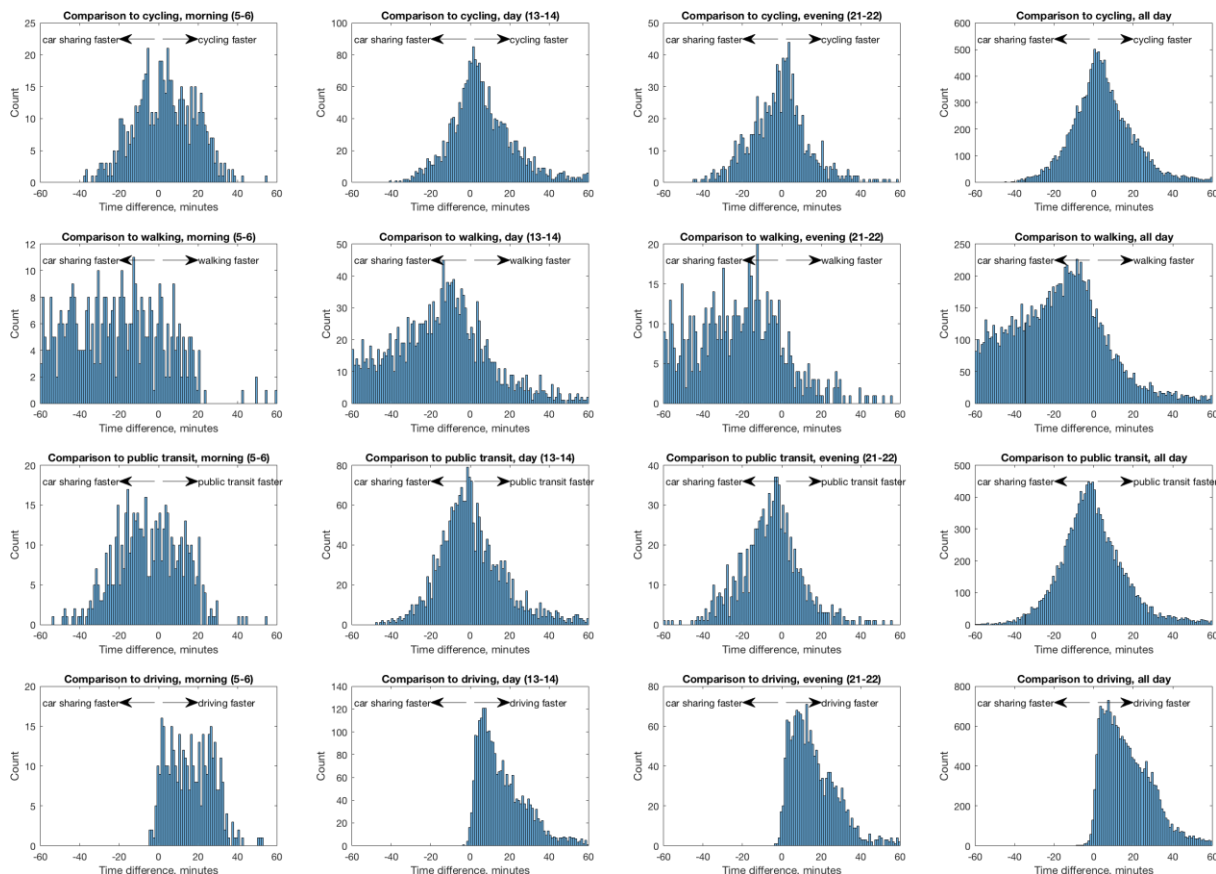


Figure 8: Comparison of fossil fuelled FFCS trips in **Seattle** with alternative transportations. First column, time between 5-6 am; Second column, time between 1-2 pm; Third column, time between 9-10 pm; Fourth column, average during day and night.

## 4 Conclusions

To sum up, comparing car-sharing with cycling (top row in the figures), FFCS is in general slower than cycling in the European cities (Berlin, Amsterdam, Madrid) but not in US cities (Denver, San Diego, Seattle).

Comparing FFCS with walking (second row in the figures), it is in general faster than walking in all cities.

Comparing FFCS with public transport (third row in the figures), FFCS is similar or faster in US cities but may be slower or faster in European cities. The reason is that the public transportation system is better expanded in European cities while many cities in US has been built around personal transport by car, which we can see in our data.

Comparing FFCS with driving (lowest row in the figures), FFCS is for all trips slower than the car trips estimated by Google Maps. Finding a free parking lot in Berlin takes time, we have experienced that ourselves. In Madrid, it also takes time but our feeling is that it is quicker than in Berlin based on own experience. In Amsterdam, it also from the plots seems to be a little quicker to find a free parking lot.

There are many trips where car-sharing is faster than public transport. The reason might be that the walk to the nearest public transport station is far away or that many interchanges are necessary. There are also trips where car-sharing is slower than public transport. Reasons might be that the car has been somewhere else

before reaching the final destination, or that the car drives in congested traffic during rush hours, which e.g. the metro is not exposed for; which of these reasons that is dominant is not possible to conclude from the collected data but need more detailed user studies.

It is interesting to ask why people use FFCS in cities where the public transport is faster (and cheaper). From our data (lowest row in the figures), we can see that there are many trips which take up to 60 minutes longer time than expected. The answer is most likely that FFCS not only is used to save time, but that there are other advantages taking these trips, like multiple destinations, bringing children or goods, etc. FFCS seems to be a complement to other type of mass-transport solutions, and should therefore be seen as a complement and not competitor. FFCS might be the solution for some people to manage without having a own car. However, more research is needed to verify this, in form of a more detailed analysis and interviews. Questions concerning the actual usage situation and the route and possible stops taken during rental time should be added to future surveys of FFCS users.

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## References

- [1] Ciari, Francesco, Bock, Benno, and Balmer, Michael (2014). Modeling Station-Based and Free-Floating Carsharing Demand: Test Case Study for Berlin. *Transportation Research Record: Journal of the Transportation Research Board*, (2416), 37-47.
- [2] Firmkorn, Jörg (2012), Triangulation of two methods measuring the impacts of a free-floating carsharing system in Germany. *Transportation Research Part A: Policy and Practice*. 46 (10), 1654-72.
- [3] Firmkorn, Jörg and Müller, Martin (2011), What will be the environmental effects of new free-floating car-sharing systems? The case of car2go in Ulm. *Ecological Economics*. 70 (8), 1519-28.
- [4] Firmkorn, J. (2012). *Triangulation of two methods measuring the impacts of a free-floating carsharing system in Germany*. *Transportation Research Part A: Policy and Practice*, 46(10), 1654-1672.
- [5] Kopp, J., Gerike, R., & Axhausen, K. W. (2013). *Status quo and perspectives for car-sharing systems: the example of DriveNow. Strategies for Sustainable Mobilities: Opportunities and Challenges*. Ashgate, 207-226.
- [6] Kopp, Johanna, Gerike, Regine, and Axhausen, Kay W. (2015). Do sharing people behave differently? An empirical evaluation of the distinctive mobility patterns of free-floating car-sharing members. *Transportation*, 42 (3), 449-69.
- [7] Firmkorn, J., & Müller, M. (2015). *Free-floating electric car sharing-fleets in smart cities: The dawning of a post-private car era in urban environments?* *Environmental Science & Policy*, 45, 30-40.
- [8] Kortum, Katherine and Machemehl, Randy B (2012). *Free-floating Carsharing Systems: Innovations in Membership Prediction, Mode Share, and Vehicle Allocation Optimization Methodologies*. Technical report SWUTC/12/476660-00079-1 2. Center for Transportation Research University of Texas at Austin, USA.
- [9] Schmöller, Stefan, et al. (2015), *Empirical analysis of free-floating carsharing usage: The Munich and Berlin case*. *Transportation Research Part C: Emerging Technologies*, 56, 34-51.
- [10] [Habibi, Shiva, et al. \(2017\) Comparison of free-floating car sharing services in cities. European Council for an Energy Efficient Economy \(ECEEE\) 2017 summer study Study on energy efficiency: Consumption, efficiency and limits](#). ISSN: 2001-7960 (online)/1653-7025 (print); ISBN: 978-91-983878-1-0 (online)/978-91-983878-0-3 (print).
- [11] Sprei, Frances, et al. (2017) *Comparing electric vehicles and fossil driven vehicles in free-floating car sharing services*. [European Battery, Hybrid & Fuel Cell Electric Vehicle Congress \(EEVC\), Geneva 14-16 March 2017](#).

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