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## User groups and usage patterns

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## Abstract

Free-floating car-sharing schemes operate without fixed car-sharing stations, ahead reservations or return-trip requirements. Providing fast and convenient motorization, they attract both public transportation users and (former) car-owners. However, given their highly flexible nature and different pricing structures, previous findings on user groups and environmental impact of station-based car-sharing may not be easily transferable. Therefore, this research uses survey data to directly compare user groups and usage patterns of a free-floating and station-based car-sharing service both operating in the city of Basel. The findings suggest, that the schemes indeed attract different user groups and are also used differently. Moreover, it is shown, that car-sharing membership is governed by other factors than car-sharing activity. Given the observed structural differences, the environmental impact of free-floating car-sharing is yet to be determined.

## Keywords

free-floating car-sharing, station-based round-trip car-sharing, GPS-tracking, prompted recall

# 1 Introduction

Since its first implementation in the late 1940s, car-sharing has for a very long time been a niche service unable to attract a substantial share of the urban population. This was due to both the inflexibility of the car-sharing schemes themselves and the social importance of car-ownership. In recent years, the game has changed: Modern information technology has allowed the schemes to become more user-friendly and a social trend promoting sharing over ownership supports their adoption.

The latest addition to the car-sharing market has been free-floating car-sharing. Instead of relying on designated car-sharing stations it allows customers to pick-up and drop-off the vehicle anywhere within a city-wide service area. By this, it removes the obstacles of station-based car-sharing such as the requirement of ahead reservations and the restriction to a set of pre-defined stations as trip origins and destinations.

Given these structural differences between the two service types, knowledge about user groups and environmental effects of station-based car-sharing may not be directly transferrable to free-floating car-sharing. However, only few empirical studies have explored the user groups and usage patterns of free-floating car-sharing (Kopp *et al.,* 2013*,* Schmöller *et al.,* 2014). Estimating the environmental effects of the new service has proven even more difficult. Offering a convenient and fast new form of urban mobility, free-floating car-sharing attracts both (former) car owners and transit users. Therefore, it is still unclear how its growing diffusion affects overall travel behavior (Seattle Department of Transportation*,* 2014).

The introduction of the novel free-floating car-sharing service in Basel for the first time allows an investigation of the usage and impacts of the different forms of car-sharing in the Swiss context. Using empirical data, this research allows to directly compate user groups and usage patterns of a station-based and free-floating car-sharing scheme operating in the same city. The results are a first step towards a better understanding the specific environmental impact of free-floating car-sharing.

The remainder of this paper is structured as follows: Section 2 provides a short overview of the relevant scientific literature, Section 3 describes the methodology of this study including details about the response behaviour. The results of this study are then presented in Section 5. Section 6 concludes with an outlook onto the next steps of this research.

# 2 Background

The roots of today's more and more successful car-sharing systems can be traced back to the late 1940s, when the first systems were conceived to share a useful, yet expensive asset - the car. As the first implementation of a car-sharing service, the Sefage program in Zurich was established in 1948 (Harms and Truffer, 1998). Systems in other European cities followed. However, in an era of fast and ever-cheaper private motorization beginning in the 1950s, car-sharing lacked attractiveness. Only in the early 1990s rising fuel prices and a congested road network built the path for a successful revival of the idea of car-sharing. Technology has been key to unlock this new potential by providing user-friendly systems and efficient allocation strategies and has even led to the development of new forms such as peer-to-peer car-sharing or free-floating car-sharing.

The scientific literature about car-sharing has grown in scope and size in recent years as has the diffusion of the service itself. There already exists a large corpus of literature that deals with many of its different aspects.

The overwhelming majority of the literature on car-sharing has been written in the last 20 years (Millard-Ball *et al.,* 2005) and mainly covered traditional station-based car-sharing services. The research has produced agreement on several issues: For station-based car-sharing, it is widely accepted that the most suitable markets are dense urban areas with a good public transport supply (Stillwater *et al.,* 2008, Grasset and Morency, 2010) and that the prototype user is relatively young, affluent and well educated. Regarding the impact of car-sharing on the transportation system, researchers were able to confirm several positive impacts like less vehicle travel and lower emissions (Martin and Shaheen, 2011b) as well as reducing the need for parking (Millard-Ball *et al.,* 2005, Shaheen *et al.,* 2010).

Predictions concerning car-sharing demand and diffusion levels, however, proved overly optimistic: For example an early study in Austria estimating a market potential of 9% (Steininger *et al.,* 1996) as well as a Swiss study predicting a potential of 600 000 customers for the service of Mobility Switzerland (Muheim and Reinhardt, 1999) were both off by more than a factor of five.

Only recently, research has extended its scope to the newest forms of car-sharing such as free-floating car-sharing and their environmental impact. Whilst early studies expected a significant reduction in car ownership and $CO_2$ emissions (Firnkorn and Müller, 2011) due to free-floating car-sharing, the actual impact seems to be more complex as non-car-owners reduce bike, walk and public transit trips, but start to use a (shared) car instead (Firnkorn, 2012). First reports from municipalities having introduced free-floating car-sharing are also ambivalent. For

example, a first study after one year of operation of *car2go*, a free-floating car-sharing service, in Seattle found the following inconclusive results: Whilst 39% of *car2go* members had at least considered giving up a car and a third of the members were traveling fewer miles with their private car, nearly half reported to ride transit less frequently and two thirds have not changed the amount vehicle miles travelled with their private car despite despite their (additional) *car2go* use (Seattle Department of Transportation, 2014).

A similar pattern has also been observed in the case of traditional car-sharing services, where slight increases of vehicle miles travelled (VMT) by the majority of customers were more than balanced by substantial decreases in VMT by the remainder of the customers (Martin and Shaheen, 2011a) resulting in a significantly positive overall impact.

But it is not clear, whether this also holds true for free-floating car-sharing. A recent British study directly comparing point-to-point car-sharing to round-trip car-sharing, confirmed, that the structural differences between the services imply different usage patterns. In particular, they found that round-trip car-sharing has a far more positive impact on the transport system as it is used to complement public transit, whereas point-to-point car-sharing is used in parallel to public transit and therefore has a questionable impact on the transportation system (Le Vine *et al.,* 2014b). Nonetheless, point-to-point car-sharing - due to its flexibility - was found to have a substantially higher market potential.

Given this higher market potential and the fact, that free-floating car-sharing services depend on local authorities to issue special parking permits, their environmental impact is of particular interest. However, it turned out, that the systems' impact on their members' travel behaviour is complex and not straighforward to determine. For example, point-to-point car-sharing lets non-car-owning members shop for groceries less frequently, visit fewer distinct food shops and spend less total time traveling for grocery shopping purposes (Le Vine *et al.,* 2014a). Moreover, the impact of free-floating car-sharing, is not stable, but highly dependent on weather conditions (Schmöller *et al.,* 2014) or pricing structures (Ciari *et al.,* 2014).

As a first step to better understand the particularities of free-floating car-sharing, this research uses empirical survey data to compare its user groups and usage patterns with station-based car-sharing.

## 2.1 Car-sharing schemes in Basel

The station-based car-sharing scheme currently operating in Switzerland dates back to 1987. It is probably the only scheme offering a seamless system serving the whole country with almost 3 000 vehicles of various types at 1 500 car-sharing stations. Members can either buy a share of the company or subscribe to the service for an annual fee of 200 to 300 CHF. The membership fee can be substantially reduced to CHF 25 for holders of a public transportation subscription in exchange for higher rental fees. Rentals are charged by both the hour and by distance travelled (3 to 4 CHF/h plus 0.50 to 1.00 CHF/km, depending on the vehicle type).

In August 2014, a free-floating car-sharing pilot program has been launched in Basel, Switzerland. 120 cars of the type VW Up have been distributed around the city. They can be located via a website or smartphone-app and reserved for up to 15 minutes. Customers have to pay a small registration fee upfront and then only pay on a per-use basis. The fare structure distinguishes between parking and driving time; customers are charged per minute (fares: 0.41 CHF/min driving and 0.24 CHF/min parking). At the end of the journey, the vehicle can be parked on any public parking bay within the service area. It will then become available for other members.

Although both the station-based round-trip car-sharing scheme and the free-floating car-sharing scheme are operated by the same company, they are treated entirely separately. As a consequence, customers wishing to use both schemes have to register for each scheme separately.

# 3 Methodology and Data

Since August 2014, there have been two different car-sharing services operating in Basel: a new free-floating car-sharing pilot has been added to the market, which has for decades been served by a round-trip and station-based scheme. Both services are offered by the same operator.

The results of this paper are based on a survey of three different participant groups surveyed around one year after the launch of the free-floating car-sharing scheme. The three groups considered for the survey are: members of the new free-floating car-sharing service, members of the conventional car-sharing service and driver license holders among a random sample of the local population. This way, the user groups of the free-floating car-sharing service can be compared to both a station-based car-sharing users as well as a representative control group of the local population.

For an ease of notation, the conventional station-based round-trip car-sharing scheme in Basel will from now on be referred to as station-based car-sharing. References to one-way station-based schemes will be marked explicitly.

## 3.1 Recruitment and data acquisition

In total, 1 104 free-floating members, 1 616 station-based members and 3 094 members of the random sample were invited to take part in the survey. Whilst address lists of car-sharing members were made available by the operator, surface-mail addresses for the random sample of the population were provided by the Cantonal Statistical Office of Basel-Stadt. The random sample was drawn from the local population above legal age.

Each of the three participant groups was provided with a dedicated questionnaire capturing their socio-demographic background as well as information on their general travel behaviour and their last car-sharing ride (where applicable). Whilst car-sharing members were recruited via e-mail and were able to access an online-survey using personalized links, members of the control group received the survey in pencil-and-paper-format via surface mail including a reply-paid envelope. No incentive was promised for returning a completed questionnaire. However, respondents could qualify for a CHF 15 car-sharing credit (car-sharing members) or CHF 20 in cash (control group) if they subsequently also completed weeklong travel diary, which is not part of this paper.

Respondents were invited to take part in the study in weekly waves in November 2015. Re-

Table 1: Response rates per participant groups

| | free-floating | station-based | control group |
|---|---|---|---|
| Invitations sent | 1 104 | 1 616 | 3 094 |
| Surveys completed | 412 | 515 | 553 |
| Respondents with drivers license | 412 | 515 | 432 |
| Response rate of the eligible | 37.3% | 31.9% | 13.8% |

minders were sent out to all those car-sharing members who had failed to answer the survey within two weeks. The response burdens of the questionaires were calculated as 178 points (free-floating members), 173 points (station-based members) and 135 (control group) (Axhausen *et al.,* 2015). The response rates for the questionnaires are well within the expected range. For the free-floating car-sharing members a slightly higher response rate could be observed indicating a high level of identification with the service. In contrast, the response rate for the control groups falls off. The difference may be explained by the fact, that both of the car-sharing groups were contacted on behalf of the service they were member of and can therefore be regarded as pre-recruited.

## 3.2 Data Preparation

Response bias was addressed using three measures: Firstly, only completed questionnaires were considered for the analysis. Secondly, responses from car-sharing members who completed the survey in less than seven minutes (a third of the average time) were excluded. Thirdly, unreasonable answers were identified on a per-question basis (e.g. year of birth before 1900).

In order to check for a selection bias, the response groups of the car-sharing members were compared to age and gender information available from the address lists finding a good match. To enhance the representativity of the results, sample weights by gender and age group (in five-year steps) were applied. Given the fact, that likelihood to participate in such a survey is a function of education (Armoogrum and Madre*,* 1996), responses from the control group were also weighted by level of education. Since no marginal distribution of education level was available for the population of neither car-sharing group, weighting according to this variable has not been possible. However, given the higher response rate among car-sharing members, sample bias is expected to be much weaker than for the control group. It is assumed, that no further attributes had an effect on survey participation, such that the weighted samples can be

regarded representative for their respective population.

The average response time for the online survey was slightly less than 15 minutes. Given the lower response burden of the paper-and-pencil questionnaire, an even lower response time can be assumed for the control group. Given this compact survey design, fatigue effects were not expected.

For the control group, only the subgroup of driver license owners is considered. Although this limits the comparability of car-sharing members with the general population, it reflects the fact, that only drivers-licence holders are potential car-sharing members.

# 4 Survey Results

In this section, the most important results of the survey are summarized. All three survey groups are treated separately, such that the properties of the free-floating car-sharing service can be compared to both the station-based car-sharing service and the control group. Moreover, a group of double-users (members of both the free-floating and the station-based car-sharing scheme) have been identified allowing for additional analyses. Although further information supporting the hypotheses of this paper was available, some of it had to be withheld in order to protect the operator's commercial interests.

## 4.1 Member Profiles

### 4.1.1 Socio-Demographics

70% of the free-floating car-sharing members in Basel are male compared to 60% for the station-based car-sharing service. Hence, men are substantially overrepresented among car-sharing members compared to their share of 55% among the control group of driver license holders. This effect is strongest for free-floating car-sharing.

Moreover it is well-known from the literature, that station-based car-sharing attracts customers who are several years younger than the average of the adult population (Millard-Ball *et al.,* 2005). Similar to the gender distribution described above, the average age of free-floating car-sharing members was found to be even lower than the one of the station-based car-sharing service. In fact, half of the members of the free-floating car-sharing scheme were less than 36 years old.

Differences in the highest educational degree are also apparent. 70% of the members of the free-floating car-sharing scheme and even 75% of the station-based members hold a university degree (or equivalent) compared to 37% of the control group.

The age differences are also reflected in the employment status: 80% of the members of both car-sharing schemes are in the working population compared with 70% of the control group members ($N_{\text{ff}} = 412$, $N_{\text{sb}} = 512$, $N_{\text{control}} = 432$). Especially self-employed workers and students are over-represented among station-based car-sharing members. Only 3% of the car-sharing members are retirees.

Regarding their household size and income, free-floating car-sharing members' average is

slightly above the control group and members of the station-based car-sharing slightly below. Yet, these differences do not appear to be significant.

### 4.1.2 Attitudes

In order to explore the role of attitudes for car-sharing membership, respondents were presented different statements as in (Millard-Ball *et al.,* 2005). They were asked to state their agreement on a Likert Scale. Whilst there were no substantial differences in attitudes towards environmental issues and social responsibility, differences were observable in three other dimensions: 13% of free-floating car-sharing members agree, that a private car still serves as status symbol. Thus consent is higher than among the station-based car-sharing group (6%) as well as among the control group (12%; $N_{\text{ff}} = 408$, $N_{\text{sb}} = 508$, $N_{\text{control}} = 425$). Moreover, 64% of the free-floating car-sharing members consider it important to save money, whereas agreement among station-based members (60%) and control group members (57%) was slightly lower ($N_{\text{ff}} = 410$, $N_{\text{sb}} = 511$, $N_{\text{control}} = 420$). Larger differences occurred in consent with the statement "I like to try new things", to which 95% of free-floating car-sharers and 85% of station-based car-sharers agree, compared to 76% consent among the control group ($N_{\text{ff}} = 409$, $N_{\text{sb}} = 513$, $N_{\text{control}} = 420$).

### 4.1.3 Travel Behaviour

Car-sharing member households also appear to be much less car-oriented compared to households from the control group. In particular, more than 90% of the members of the station-based car-sharing service live in car-free households. Instead, they are well-equipped with bicycles. Car-ownership is much more prevalent in free-floating members' and control group households (c.f. Table 2), where floating members lie between station-based members and the control group.

A reverse situation was observed in season ticket holdership. In particular the share of GA travelcard holders (allowing for year-long free public transport use across Switzerland) is almost twice as high among free-floating (26%) and station-based (28%) car-sharing members as in the control group (14%). Local season tickets are equally distributed among car-sharing members and the control group.

The differences in mobility tool ownership are also reflected in the respondents' mode use. Whilst 50% of the members of the control group drive an own car at least once a week, this only holds for 14% of the free-floating members and 4% of the station-based members ($N_{\text{ff}} = 256$,

Table 2: Vehicle Ownership

| | 0 | 1 | 2 | 3+ |
|---|---|---|---|---|
| **Cars** | | | | |
| free-floating | 73.2% | 22.4% | 3.2% | 1.3% |
| station-based | 91.1% | 8.0% | 0.7% | 0.1% |
| control group | 38.5% | 51.1% | 9.6% | 0.9% |
| **Motorbikes** | | | | |
| free-floating | 84.0% | 14.4% | 1.0% | 0.6% |
| station-based | 91.4% | 8.0% | 0.5% | 0.1% |
| control group | 80.7% | 13.7% | 4.6% | 1.0% |
| **Bikes** | | | | |
| free-floating | 7.6% | 22.9% | 29.6% | 39.9% |
| station-based | 5.3% | 22.4% | 28.8% | 43.5% |
| control group | 14.7% | 23.0% | 26.8% | 35.4% |

$N_{sb} = 314$, $N_{control} = 224$). In turn, car-sharers use their bike and public transportation (particularly trains) more often than the control group.

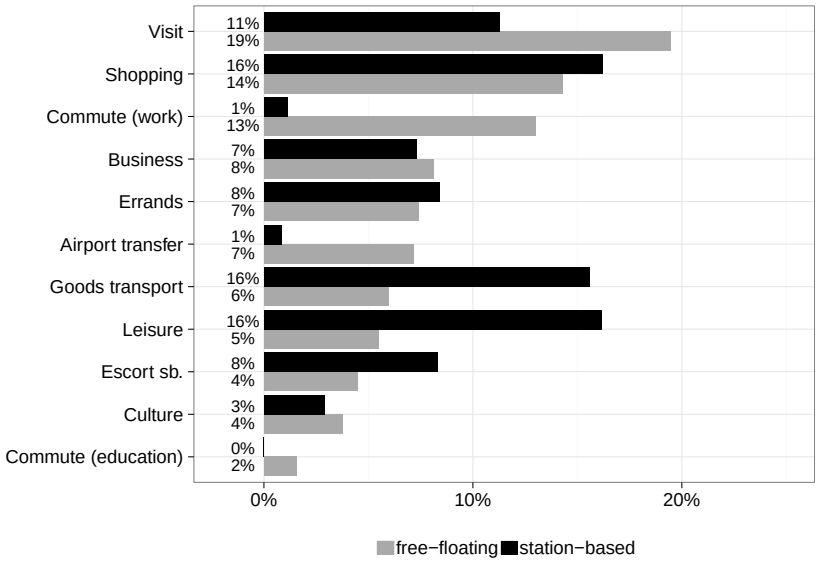
## 4.2 Usage Patterns

Due to their distinct design, free-floating and station-based car-sharing can be anticipated to serve different markets. In order to address this issue, car-sharing members were asked to provide details about their most recent car-sharing ride. To allow conclusions for the whole system, the responses were additionally weighted by frequency of car-sharing use.

As illustrated in Figure 1, most of the trips undertaken with a station-based car-sharing vehicle are shopping or leisure trips or trips, for which the customer had large items to carry. In contrast, the free-floating car-sharing service is employed for a larger variety of purposes. In particular, there is also substantial usage for commute trips and airport transfers.

Asked, why they had used car-sharing for their last car-sharing ride, 76% of the free-floating members stated, that car-sharing was the fastest option. Members of the station-based service, however, also cited goods to carry as a main reason to use car-sharing (40%). In fact, 50% of the station-based members carried large items on their last car-sharing ride, compared to 23% of

Figure 1: Main purpose of the last car-sharing ride ($N_{free\text{-}floating}$ = 412, $N_{station\text{-}based}$ = 515). Rest to 100% is "other".




the free-floating members.

Not only are station-based car-sharing vehicles more likely to be loaded with goods, they also have more passengers on board. Whereas 64% of the free-floating trips ($N$ = 148) were conducted by a single driver, 58% of the station-based cars ($N$ = 195) had at two or more people on board. Consequently, the average occupancy is higher for station-based car-sharing (1.8) than for the the free-floating service (1.4).

Moreover, the different nature of the car-sharing services is reflected in the members' planning horizon. Whereas 62% of the station-based car-sharing members planned their last car-sharing ride at least one day ahead, 72% of free-floating members planned their car-sharing trip less than one hour in advance.

In order to better understand, how the different kinds of car-sharing are used, respondents were asked, whether they have already experienced unavailability of the car-sharing service (i.e. they wanted to use car-sharing, but no vehicle was available within an acceptable distance). Figure 2 shows, how the respondents reacted to this situation. Whilst 56% of the station-based trips had been postponed or even cancelled, 53% of the free-floating car-sharing trips were replaced by public transportation.

Figure 2: Reason for using car-sharing for the last car-sharing ride ($N_{free\text{-}floating}$ = 384, $N_{station\text{-}based}$ = 472). Multiple responses permitted.

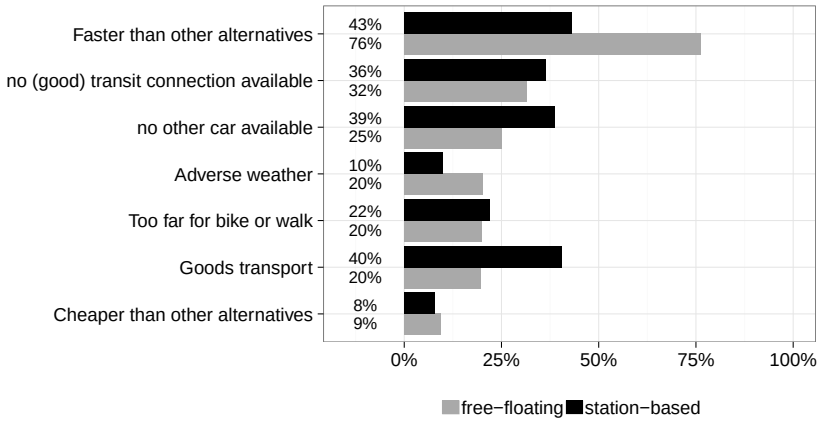
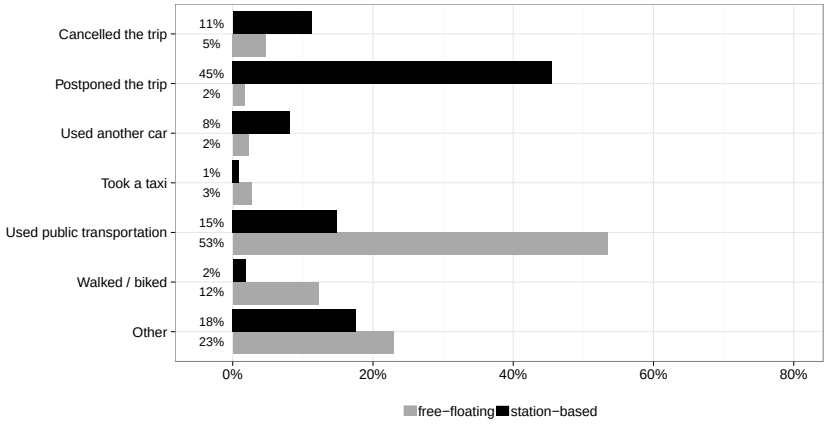



Figure 3: Reaction when no car-sharing vehicle was available ($N_{free\text{-}floating}$ = 329, $N_{station\text{-}based}$ = 420).




## 4.3 Travel Behaviour Impact

By providing a flexible alternative to a private vehicle, car-sharing has a direct impact on its members' travel behaviour (Cervero *et al.,* 2007). The survey data allows a first insight into the different effects of the car-sharing schemes.

### 4.3.1 Car Ownership

The most important impact of car-sharing is, that it helps households to reduce their private vehicle holdings and turn towards a transit-oriented lifestyle. In the survey, 8% of the free-

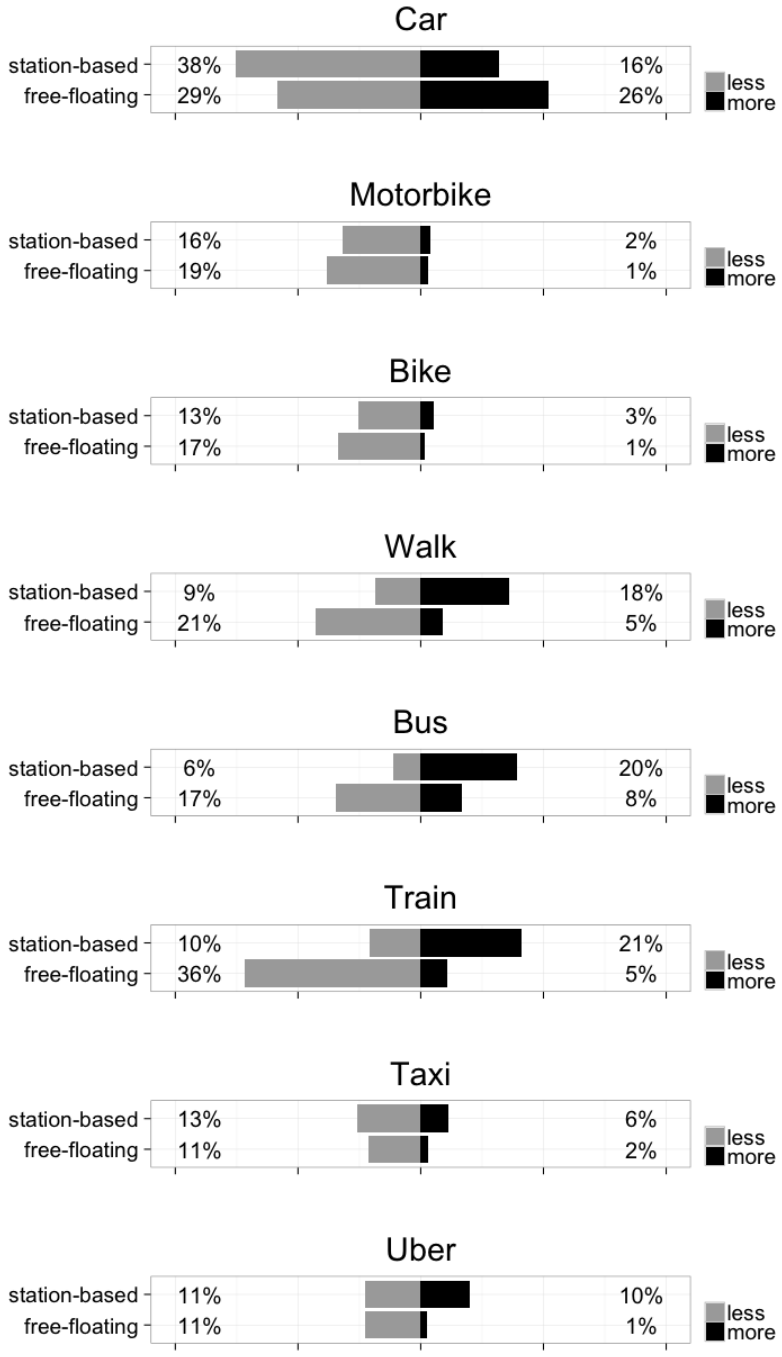
floating car-sharing members and even 18% of the station-based car-sharing members stated, that they would buy a car, if the respective car-sharing scheme would not exist. Although such hypothetical scenarios (as well as retrospective questions) do not allow a valid quantification of the impact of such systems, it is safe to assume, that both kinds of car-sharing contribute to lower private vehicle holdings. Moreover, the impact of station-based car-sharing appears to be stronger than the impact of free-floating car-sharing.

### 4.3.2 Mode Choice

Figure 4 shows, which transport modes the respondents use more or less often due to their car-sharing membership. The figure reveals a substantial difference in the schemes' impact on travel behaviour. Whilst station-based car-sharing encourages the use of public and non-motorized transportation among most of its members, more free-floating car-sharing members have reduced their use of those modes. Moreover, a similar number of free-floating car-sharing members have increased and decreased their car use, whereas the trend is more clear towards a reduction in car use among station-based car-sharers.

It is important to note, that those qualitative changes in mode use alone do not permit any conclusions on the environmental impact of the single car-sharing schemes. Only quantitative data on the actual changes in individual mode use would allow to estimate a net effect on mode use.

Figure 4: Perceived change in mode use through the car-sharing membership ($N_{\text{free-floating}} = 337$, $N_{\text{station-based}} = 380$). Rest to 100%: "no change"



# 5 Modelling Adoption

Car-sharing adoption can be described in two variables: membership and frequency of use. Since the latter can only be observed for actual car-sharing members, the model needs to account for censored observations. Therefore, a Heckman sample selection model has been used to describe both membership and use in an unbiased way (Heckman, 1979). The data was obtained from the completed questionnaires and weighted according to age, gender (all groups) and education (control group only). For each model, the responses from the control group and the respective member group were used.

In the selection stage, the effect of various socio-demographic factors on active car-sharing membership is modeled using a binomial probit model. An active member is a member with at least one rental within the last 12 months. In the main regression, frequency of use was modeled in an ordinal probit approach according to the responses from the questionnaires. Since there were almost no observations of free-floating car-sharing users without a recent ride, only three levels of use are modeled for free-floating car-sharing compared to four levels for station-based car-sharing (compare Table 4).

The highly significant Wald test indicates a good model fit for both models, but surprisingly, the insignificant $\rho$ indicates, that the null-hypothesis, that the errors of the selection and the outcome equation are uncorrelated, cannot be rejected. This means, that for both free-floating and station-based car-sharing, activity is governed by different factors as membership.

In addition, the models reveal similarities and differences in the customer base of the two schemes. Whilst both schemes predominantly attract university alumni living in car-free households as members, household size, income and a GA travelcard are also a significant positive predictors for free-floating car-sharing membership, but not for station-based car-sharing membership. Moreover, membership in the station-based scheme seems to depend more on the life-cycle stage, whereas free-floating car-sharing is most appealing to young males. An excellent level of public transportation service at the home location reduces the odds of becoming a free-floating car-sharing member, but has no significant effect on station-based membership. In turn, station-based car-sharing is especially attractive to self-employed workers. In addition, membership in the station-based car-sharing service has a significant and substantial positive effect on membership in the free-floating car-sharing service, which can at least partly be explained by the fact, that members of the station-based car-sharing scheme were subject to special advertisement through newsletters and were offered a reduced (or waived) registration fee for signup.

Table 3: Ordered Probit Model with Sample Selection and Weighted Observations to Describe Car-Sharing Adoption. Refer to Table 4 for a description of the variables.

| | **free-floating** | | **station-based** | |
|---|---|---|---|---|
| | Coef. | s.e. | Coef. | s.e. |
| **Frequency of use** | | | | |
| Age | -0.013** | (0.006) | -0.005 | (0.005) |
| Male | 0.408** | (0.166) | 0.167 | (0.131) |
| # adults in household | 0.189* | (0.100) | | |
| Normalized income [kCHF] | 0.095** | (0.038) | | |
| Employment level [%] | | | 0.004*** | (0.001) |
| Occupation type: self-employed | | | 0.446** | (0.186) |
| Suburban home | 0.289* | (0.153) | | |
| GA travelcard | -0.374** | (0.150) | -0.248* | (0.133) |
| Car-free household | 0.557*** | (0.193) | 0.845*** | (0.276) |
| Station-based member | -0.358** | (0.167) | | |
| **Active Membership** | | | | |
| Age | -0.024*** | (0.004) | | |
| Male | 0.445*** | (0.116) | | |
| # adults in household | 0.300*** | (0.110) | | |
| University degree | 0.594*** | (0.117) | 0.856*** | (0.116) |
| log household income [kCHF] | | | 0.070 | (0.089) |
| log normalized income [kCHF] | 0.315*** | (0.107) | | |
| Employment level [%] | -0.005*** | (0.001) | -0.005*** | (0.001) |
| Occupation type: retiree | | | -0.709*** | (0.166) |
| Occupation type: self-employed | | | 0.448*** | (0.165) |
| Home in transit quality zone A | -0.513*** | (0.113) | | |
| GA travelcard | 0.272** | (0.131) | | |
| # cars in household | -0.502*** | (0.102) | -1.167*** | (0.207) |
| Station-based member | 0.638*** | (0.128) | | |
| Constant | 0.082 | (0.315) | 0.243* | (0.144) |
| cut1 | 0.383 | (0.541) | -2.479*** | (0.464) |
| cut2 | 2.943*** | (0.551) | 0.759* | (0.404) |
| cut3 | | | 3.573*** | (0.534) |
| athrho | 0.132 | (0.280) | 0.080 | (0.221) |
| $N$ | 769 | | 864 | |
| log pseudolikelihood | -664.56 | | -749.74 | |
| Wald $\chi^2$ | 32.77*** | | 27.56*** | |
| $\rho$ | 0.131 | (0.275) | 0.080 | (0.220) |

*Significance codes: 0.10 * 0.05 ** 0.01 ****

Table 4: List of Attributes

| Variable | Type | Description |
|---|---|---|
| Frequency of Use | factor | Stated frequency of use of the respective car-sharing service; levels are *(almost) never*, *rarely*, *regular (monthly or weekly)*, *(almost) daily* |
| Active Membership | factor | Member of the scheme and at least one rental within the last 12 months |
| Age | numeric | |
| Male | factor | |
| # adults in household | numeric | Number of adults in the respondent's household |
| University degree | factor | Respondent holds a degree from a university or university of applied sciences |
| Household income [kCHF] | numeric | Gross household income |
| Normalized income [kCHF] | numeric | Household income divided by adult household members |
| Employment level [%] | numeric | Workload, 100% corresponds to 42 h/week |
| Occupation type | factor | includes three levels: *retiree*, *self-employed* and *other* (reference) |
| Transit quality zone A | factor | home location in transit service quality zone A as defined in the Swiss standard SN 640 290; requires a maximum departure interval of <5 min per main load direction at rail stops in a 500 m perimeter |
| Suburban home | factor | home location outside of city center and not in transit quality zone A |
| GA travelcard | factor | Public transportation subscription allowing for the free use of public transportation throughout Switzerland for one year |
| Car-free household | factor | Respondent's household does not own a private car |
| Station-based member | factor | Respondent stated to also be member of the station-based car-sharing service |

The frequency of use of the two services is more difficult to predict than membership. As expected, members from car-free households are substantially more active car-sharers. Moreover, a GA travelcard has a weakly significant negative effect on the outcome. In addition, frequency of use of station-based car-sharing is governed by its members' employment status, whereas free-floating car-sharing is used most by young males with a higher income. Surprisingly, a university degree - a significant and substantial predictor for membership - was not found to have any significant effect on the frequency of use. In addition, station-based car-sharing membership has a negative effect on free-floating car-sharing use.

For the use of station-based car-sharing, the distance to the closest car-sharing station was not significant in any model, which is not astonishing given that car-sharing stations are available

throughout the country with an average distance of 300m to the household locations of the study participants.

For both services, the cut between regular users is much more significant, than between rare and regular users. In the model for station-based car-sharing the cut between non-users and rare users are also significant, indicating, that there are three clusters of car-sharing users: non-users, occasional users and daily users.

# 6 Discussion

Due to their different nature, station-based car-sharing and free-floating car-sharing appear to address different markets. Whilst station-based car-sharing is mostly used in situations, which actually require a car (c.f. Figure 3), free-floating car-sharing is used, when it helps to save time with respect to other alternatives (c.f. Figure 2). This notion is supported by the observation, that free-floating car-sharing serves a much broader variety of trips than station-based car-sharing. In particular, it opens up car-sharing for one-way trips such as airport or commute trips (c.f. Figure 1).

Figure 4 furthermore shows the different impact on their members' overall mode choice behaviour. Whilst station-based car-sharing seems to trigger a net shift away from the private vehicle and towards public transportation or active modes, the impact of free-floating car-sharing is less clear. In most cases, it reduces use of public transportation or active modes in the favor of car trips, but it does not necessarily produce more car trips. A possible interpretation is, that it helps to make the whole transportation system more efficient, although quantitative data on the individual travel behaviour impact is requred to draw sound conclusions.

Not only are the schemes used in different ways, they are also used by different people. Although they both mainly attract highly educated peers living in households with only few private cars, differences are apparent: Whilst station-based car-sharing seems to be mostly adopted by self-employed workers appreciating the flexibility to use a car when needed, free-floating car-sharing thrives best among young males with higher incomes whose home location is not optimally served by public transportation (c.f. Table 3). Especially the latter indicates, that the scheme fills a service gap left by public transportation.

Already from the questionnaires, it has become clear, that neither of the two car-sharing groups stands out by particularly environmentally friendly attitudes. Instead, openness to new services and developments seems to correlate with car-sharing membership. However, this observation does not exclude a positive environmental impact of the two services given that a significant share of members of both schemes report a reduction in their private vehicle ownership.

The sample selection model (Table 3) furthermore revealed, that car-sharing membership is governed by different factors than its use. In particular, university alumni are substantially more likely to become car-sharing members, but do not stand out by a higher degree of use. For holders of the GA travelcard or station-based members (in the case of free-floating car-sharing), the contrast is even stronger - whilst they are much more likely to become members of the respective service, they are less likely to actually use it. This may be a valuable insight to better

design future advertisement campaigns.

# 7 Conclusion

To the authors' best knowledge, this is the first attempt to jointly study a free-floating car-sharing and station-based scheme operating in the same city. While confirming several aspects already well-known from the literature on station-based car-sharing, this research was able to reveal, that due to their different nature, the two schemes address different markets. Moreover, it has become clear, that membership and active use of a car-sharing service have to be treated separately from each other.

Confirming the anticipation, that the two car-sharing schemes work completely different from each other, the question of the environmental impact of free-floating car-sharing becomes even more pressing. Given the fact, that it requires not only selected dedicated parking spots, but parking permissions for the public space, knowledge about its overall impact will bes key to justify governmental support.

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