Evaluating the effects of variable user demand on a round-trip, one-way, and free-floating car sharing fleet in the city of Zurich, Switzerland

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Extended Abstract

1. Introduction

Car sharing is an alternative to conventional private car ownership that allows members of a specific program to use a fleet of cars collectively. These cars are paid for, generally, on an hourly basis or number of kilometers driven or both. This kind of service has become increasingly popular in the last decade, experiencing a worldwide member growth of 260% between 2006 and 2010 [1]. While its origin dates back to the Selbsfahrergemeinschaft (Sefage) in Zurich in 1948 [2], it wasn't until the late 1980's that carsharing found a stable market, mainly in Europe. Recently, car sharing has widened its market in North America, Asia and Australia, achieving over a million members and over 30,000 cars worldwide [1].

Along with the growth of worldwide car sharing, the number of competing actors in the market is also on the rise. As a consequence, optimization of car sharing operations has acquired an increasing role for service providers. In this context, simulations can have an important role as tools to study and predict possible market developments and to formulate strategies to tackle these new challenges.

The main purpose of this study is to get an insight on the relationship between the fleet size and that of the pool of users. Is it possible to find an optimal ratio between them? To answer this question, an agent-based simulation software which can predict the demand for carsharing in a given region is used. The test case is the greater Zurich region, and this has two main reasons. On one hand, Switzerland has a very well established service of round-trip carsharing by a company called Mobility, with over 2,500 cars in 1,350 stations [3], which through its subsidiary "Catch a Car", has also started a 2 year pilot phase of a free-floating carsharing service in Basel [4]. Therefore, Zurich is a city where this kind of questions might be particularly relevant, given the affinity to carsharing and the fact that free-floating might be soon introduced. On the other hand, this allows to build up on previous work where some of the necessary modeling capabilities have been developed and tested. For instance, Ciari et al. [5] and Balac et al. [6] have recently researched market dynamics not only for the standard round-trip carsharing model, but also for the more flexible one-way station based and free-floating services in Zurich using the multi agent transport simulation software MATSim [7].

2. Methodology

The reason people travel is to perform daily activities, whether work, education, leisure or shopping. MATSim is a tool which simulates this process, with an agent-based simulation approach, in which the activity chains of a synthetic population of agents are executed in a physical model of transport. The attributes of the agents comprising the socio-demographic attributes, their activity diaries and their available transport modes are based on census data; the spatial model is composed of the roads where agents travel from one activity to the next and facilities in which the activities take place. Simulating one day in the lives of the agents, MATSim runs the activity sets (plans) of the agents iteratively, whose goal is to maximize their individual utility by using a co-evolutionary algorithm for the selection and improvement of the plans. This approach presents an advantage compared to other trip generation and traffic assignment models (such as the four-step model), in that spatial and temporal dynamics of the agents' travel can be captured and studied.

The modeled region, slightly larger than the Canton Zurich, contains a population of approximately 1.6 Million. The agents' mode choices include private cars, shared cars, public transport, bicycle, and walking. The number of shared cars corresponds to the amount of mobility shared cars present in the modelled area in the year 2012: 911.

Three carsharing services were simulated individually. In the conventional round-trip based and in the one-way car sharing services, cars are parked in predefined stations and the agents can only pick up or drop the shared cars in them, whereas in the free-floating service, the cars are respectively initialized in these stations, and during the simulation they are shifted according to the agents' itineraries within the simulation perimeter. The study is carried out with five scenarios for each carsharing option, with a total of 15 simulation runs. These five scenarios include a base scenario where the actual number of car sharing members (x = 34'822 members) is simulated, along with four other scenarios with reduced and increased number of members (0.5x, 1.5x, 2.0x, 2.5x).

To be able to better compare the results from the various levels, the membership assignment process was carried out in a way that each increasing membership level includes the members of the previous level. The membership assignment model as estimated by Ciari and Weis [8] was used for this purpose.

3. Results

Figure 1 depicts the number of active car sharing users and the amount of rentals for every membership level (market penetration) in the system. In the case of the round-trip scheme it is clear that a gain in the number of users is very small. This might be due to the competition between the agents and a disinterest to use round-trip carsharing outside of densely populated zones, coupled with the fact that car ownership outside of the city is bigger, which makes car sharing less attractive in these areas. However, with one-way and free-floating services, the number of users roughly tripled, indicating that the system can accommodate a significantly larger amount of users for these services, in comparison to the existing round-trip system. The flexibility that the one-way and the free-floating services offer to better integrate them in the agents' activity chains come to light in this respect.

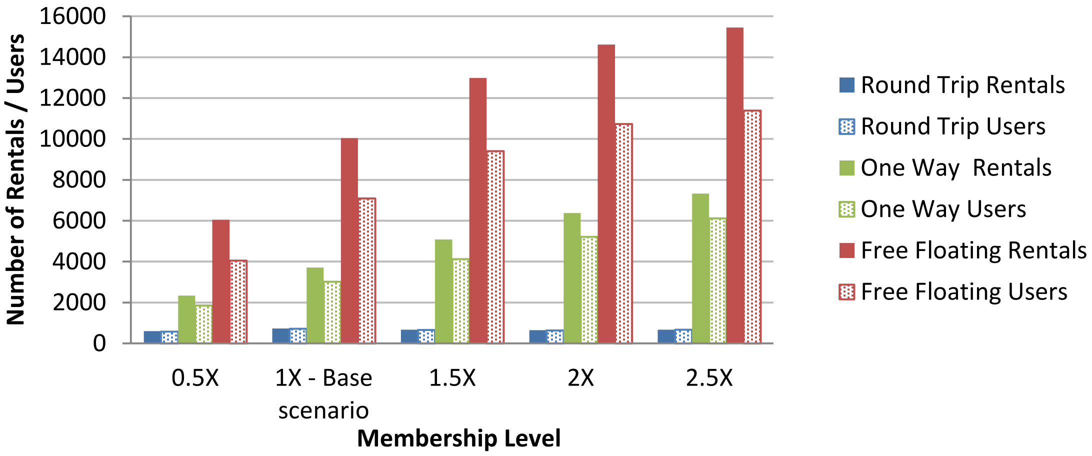

Figure 1: Amount of car sharing unique users and rentals for all membership levels

Table 1 contains an overview of the most relevant numbers for all the simulations. The trips and users per car statistics offer an interesting comparison between the services. With the same amount of members, the one-way service reaches a two to five times higher average of rentals per car compared to the round-trip service, whereas the free-floating service reaches five to ten times higher average rentals per car. In this regard, the free-floating and one-way car sharing services allow for a better utilization of the fleet. It is also relevant that in the free-floating scenario roughly 95% to 100% of the cars are used at least once during the day, whereas in the one-way service this number ranges between 84% and 97%, and for round-trip between 44% and 49%. The shorter average rental times for the one-way and free-floating schemes help understand the much larger car usage for these services, and why competition between the users might play a bigger role in the conventional round-trip service, since having the cars reserved for longer periods means that other users do not have access to them during a bigger portion of the day.

Scenario	Round Trip					One Way					Free Floating				
	0.5X	1X	1.5X	2X	2.5X	0.5X	1X	1.5X	2X	2.5X	0.5X	1X	1.5X	2X	2.5X
Members	17'409	34'822	52'071	69'445	86'714	17'409	34'822	52'071	69'445	86'714	17'409	34'822	52'071	69'445	86'714
Users	573	713	659	635	671	1'858	3'013	4'117	5'215	6'114	4'056	7'088	9'407	10'726	11'387
Rentals	601	726	676	647	673	2'341	3'708	5'084	6'372	7'323	6'046	10'042	12'984	14'612	15'446
Trips	1'726	2'154	2'153	2'045	2'076	2'341	3'707	5'084	6'372	7'323	6'046	10'042	12'894	14'611	15'445
Cars total	911	911	911	911	911	911	911	911	911	911	911	911	911	911	911
Cars used	399	446	432	427	442	767	816	848	863	886	852	878	881	890	907
Avg. users / car	1.4	1.6	1.5	1.5	1.5	2.4	3.7	4.9	6.0	6.9	4.8	8.1	10.7	12.1	12.6
Avg. rentals / car	1.5	1.6	1.6	1.5	1.5	3.1	4.5	6.0	7.4	8.3	7.1	11.4	14.7	16.4	17.0
Avg trips/car	4.3	4.8	5.0	4.8	4.7	3.1	4.5	6.0	7.4	8.3	7.1	11.4	14.6	16.4	17.0
Avg. rental time [min]	262.3	289.1	361.0	367.6	365.7	7.2	6.9	7.0	6.9	6.7	6.1	6.1	6.2	6.2	6.1
Avg. Access time [min]	5.5	5.9	6.2	6.5	6.2	6.4	6.4	6.4	6.6	6.5	6.6	7.9	8.8	10.0	10.2
Turnover [CHF]	13'298	17'732	18'656	17'973	18'740	12'556	19'875	27'313	34'198	39'330	24'380	43'779	59'664	72'803	77'038

Table 1: Results overview

The turnover was estimated on the basis of the current car sharing rates used by mobility for their conventional round-trip service in Switzerland (2.8 CHF/h, 0.60 CHF/km) and their free-floating service in Basel (driving: 0.37CHF/min, parking: 0.27CHF/min). In the case of the one-way service, since there are no providers for this service in Switzerland, the price per hour was approximated from that of the Autolib' provider in Paris to 16 CHF/h, with a similar minimum rental time of 20 minutes. When comparing the three systems for the same amount of members, the expected turnover also shows advantages of the one-way and free-floating systems compared to the round-trip system. Especially the expected turnover for the free-floating service shows an important margin that could be improved for the current amount of members. This difference becomes even bigger with larger membership levels.

Figure 2 shows the share of trips made by active car sharing users (those who use car sharing at some point during the simulation) with the three different car sharing schemes. Because of the way round-trip carsharing works (cars have to be returned at the station they were picked up), users perform more trips with these shared cars, at least two. This is reflected in a larger mode share for round-trip carsharing. The other types of car sharing are more compatible with other modes and do not require agents to use the same mode for the outbound trips as for the inbound trips, yielding a smaller share. Although the mode shares for car sharing remain relatively constant, a slight decrease is evident as the member numbers grow. This is due to the fact that there are more agents competing for the use of the shared cars and a larger amount of agents has to use other modes of transport, as there is a limited amount of shared cars available.

Figure 2: Share of trips made by car sharing users with car sharing

The share for each activity for which trips are performed is shown in Figure 3 for all scenarios. A larger share of the trips for leisure activities are made with the round-trip service, which makes sense, since these activities often have a more flexible schedule. An increase in the use of one-way and free-floating carsharing driving to education activities can also be seen. Although the distributions show various similarities, it is also important to keep the absolute numbers in mind. For the one-way and free-floating scenarios, a much larger amount of agents was able to perform their scheduled activities using car sharing.

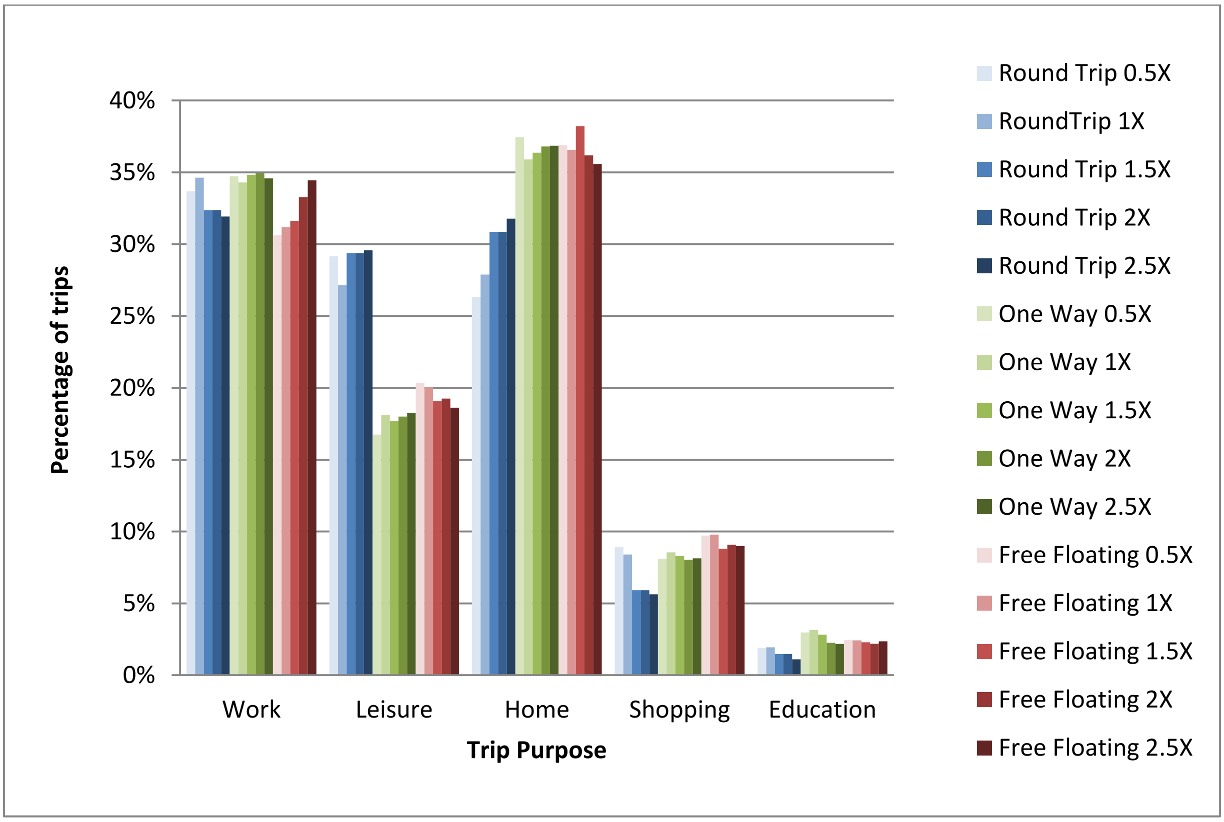

Figure 3: Activity shares for the trips made with car sharing

It is worth noting that the simulation presented here also has some limitations and could be improved in some aspects. On the one hand, the fact that agents can park the shared cars easily at the facilities where they perform their activities makes free-floating car sharing more attractive than it would be in reality in comparison to one-way car sharing. Taking into consideration Zurich's historic compromise to cap the number of parking spots to the 1990 level [8], parking immediately close to the desired facility could be difficult, increasing the generalized costs of the trips and thus having an effect in the attractiveness of round-trip carsharing. Although MATsim has a module which allows simulating parking search, its use together with carsharing is still being tested. This enhancement of the simulation will likely generate more reliable results. Another aspect is that the service area in the simulation is considerably larger than what one would probably have in reality. This also makes the system very susceptible to become unbalanced at the end of the day, needing more resources to relocate the cars in order for the system to keep functioning properly the next day. The free-floating service area in Basel is approximately 5 km radius, compared to the 30 km radius network in the present simulation. The effect on the results of reducing the radius to 5 km in the simulation is also unclear. Although the statistics per car might improve, it is difficult to foresee the exact effect on the absolute numbers. Addressing these issues was out of the scope of the current work, but these aspects should be considered in the further work.

The results presented above indicate a vast potential for free-floating and one-way car sharing services. If round-trip services are replaced with the other types of car sharing, the number of rentals increases by at least two times, as shown by the simulation results, with the consequence of vast turnover gains. For a given fleet of shared cars and a given number of members, the free-floating service seems to be the best option to get the most out of a car fleet. This knowledge is important for service operators as a possible tool to optimize the use of their fleet and increase their turnover. This is also relevant for policy makers, since all types of car sharing interact with the transport of a city, but especially in the case of free-floating car sharing, the success of the operation relies heavily on the availability of public parking spaces. In light of recent developments, such as car free housing cooperatives, the use of electric shared cars and an increasing environmental awareness, among other factors, free-floating and one-way car sharing could become important components of future urban mobility. This increased role will likely be reflected by the increased importance of tools able to provide useful insights into car sharing operations, as the one presented here.

4. References

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