Modelling Station-Based Carsharing in Switzerland

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Abstract

Worldwide carsharing use has grown considerably in recent years. The traditional station-based operation model - where a car needs to be picked-up and returned at the same station - is no longer the only one offered. One-way carsharing, after some unsuccessful experiments in the past, is being offered again and free-floating carsharing is gaining quickly more and more users. From a modelling standpoint, the main challenge is to develop suitable models for simulating different kinds of carsharing operations. The work presented in this paper makes use of the multi-agent simulation tool (MATSim) - which was used in the previous work on carsharing, to model round-based and one-way carsharing for the metropolitan area of the city of Zurich. Main findings show the big opportunity of expanding a carsharing service in Switzerland and a complementarity of these two carsharing alternatives. Moreover, an impact on the demand, of the relocation of existing carsharing stations in order to increase the number of members, is also presented. Finally, this work presents improvements over the previously developed model for traditional carsharing MATSim implementation.

Keywords

carsharing - round-based - one-way - demand modeling

1 Introduction

In recent years, the number of carsharing operators in the world has grown significantly (Shaheen and Cohen (2007)), especially in North America and Europe. This increase in supply is a response to the increasing demand for different transport options by the public and its growing awareness of shared mobility solutions as viable alternative to traditional modes. Next to traditional round-based carsharing, where the vehicle needs to be picked up and returned to the same station, some operators have started to offer one-way station based carsharing (Autolib (2014)), where the car can be returned to any available station and free-floating (Car2Go (2014a,b,c)), where vehicles are not linked to the stations and thus can be picked-up and returned anywhere within the service area.

Traditional carsharing users are generally charged based on the rental time and the distances travelled with the vehicle. One of the main limitations of this carsharing service form is the burden imposed on the users to return the vehicle to the starting station. It forces, therefore, the users to use the service mainly when performing short-term activities before returning the vehicle. Taking this burden away from the customers, should attract more members and increase the rental volume as suggested by (Le Vine (2012)).

Station-based one-way carsharing systems, however, face a different problem. Since, the members are allowed to leave vehicles at any station there is a risk that the system might become unbalanced and a periodic relocation of vehicles is necessary. This issue was addressed in a number of sources, for example (Kek et al. (2009); Barth et al. (2004); Weikl and Bogenberger (2013)). They all suggest that to be able to successfully tackle the problem, both spatial and temporal knowledge of the demand is highly important. One of the first attempts to introduce one-way carsharing on a large scale was probably the one in Singapore (Barth et al. (2006)), but vehicle relocation costs, forced the operator to revert to round-based carsharing. However, recent developments have brought one-way carsharing back as a viable option (Autolib (2014)).

Switzerland has a long carsharing tradition, and in Zurich was deployed the first carsharing initiative worldwide, dating 1948. Currently, Switzerland has only one carsharing operator - Mobility (Mobility (2014)), which provides only traditional carsharing service. In this work we try to estimate the demand of one-way carsharing in the Zurich region based on the already existing traditional service and pricing structures that are already in place. Both traditional and one-way carsharing services are implemented as modes into the agent-based transport simulation software, MATSim (Balmer et al. (2009)). This builds on a previous effort (Ciari et al. (2013)), where round-based carsharing was implemented, but the explicit modelling of stations capacities and of the reservation system were lacking. In the new model these feature have been introduced. Carsharing membership is assumed to give accessibility to both carsharing options. The previously developed model for estimating the round-based carsharing membership (Ciari and Weis (2013)) was used again in this work. Various scenarios are tested and the impacts of pricing structures, station locations and number of carsharing members are analysed. The remainder of the paper is organized in three sections. The next section provides a description of the methodology and the modelling framework. Section three explains the scenarios used and results obtained. The last section presents the conclusion and the plans for the future work.

2 Methodology

As mentioned previously, for this work the multi-agent simulation tool (MATSim) was used to model the demand for round-based and one-way carsharing and observe how different levels and combinations of them would work.

2.1 Simulation Model

In the case of round-based carsharing, individuals are allowed to use it as a mode on the subtour level, meaning that they pick-up a carsharing car after finishing an activity at a given location and they return it after coming back to the same location. The following steps are modelled and simulated:

1. Agent finishes his activity, finds the closest available car and reserves it (making it unavailable for other agents),
2. Agent walks to the station where he has reserved a vehicle,
3. Agent drives the car (interaction with other vehicles is modelled),
4. Park the car close to the next activity,
5. Take the car and drive to the next activity,..
6. Before reaching the last activity in the subtour, end the rental and leave the vehicle at the starting station making it available to other agents,
7. Walk to the activity,
8. Carry out the rest of the daily plan.

In the case of one-way carsharing, the steps are similar, but the list is shorter reflecting the more comfortable way to use it:

1. Agent finishes his activity, finds the closest available car and reserves it (making it unavailable for other agents),
2. Agent walks to the station where it has reserved the car,
3. Agent drives the car to the next activity,
4. Park the car at the station closest to the next activity and ends the rental,
5. Walk to the next activity
6. Carry out the rest of the daily plan.

This new model of round-based carsharing along with the newly introduced one-way carsharing model addresses previous limitations by introducing:

(a) station capacities,
(b) reservation system
(c) physical simulation of carsharing vehicles.

2.2 Behavioural Model

The behaviour of agents is evaluated based on the utility function that evaluates each component of the agents daily plan (Eq. (1)) generating a final score:

$$U_{\text{plan}} = \sum_{i=1}^{m} (U_{\text{act,i}} + U_{\text{travel,i}}) \tag{1}$$

In general, performing activities increases the score (positive utility), while traveling decreases it (negative utility). The specific components of carsharing (both round-based and one-way) travel are:

- Time cost of walking (access and egress)
- Carsharing constant
- Driving time
- Rental time fee
- Distance cost

The functions are used by the agents to determine, in the iterative process in the MATSim simulation, which mobility option suits them best. The formal description of the carsharing utility function can be found here (Ciari et al. (2013)).

3 Scenarios and Results

The simulation area used in this work was ”Zurich-Greater” area which is created by drawing a circle of 30km radius with the centre at Bellevue square in the Zurich city-centre. The area has the population of approx. 1.6 million. Number of agents actually simulated was 161,810 (10% of the population). The population is based on the 2000 census and 2005 travel diaries data. The road network was also scaled down based on the percentage of the population used. Different scenarios used to investigate carsharing alternatives are described below:

1. Scenario I: Only round-based carsharing is available, with the current Mobility stations (376 stations in the simulated area with 695 cars) and membership assigned to agents based on the current stations locations and the number of available vehicles at the stations - resulting in 2650 members.
2. Scenario II: In addition to round-based carsharing, one-way station based carsharing is made available to all the current members. For each round-based vehicle, a one-way vehicle is added to each station. A member of the round-based scheme from scenario I is now also allowed to use a one-way carsharing.
3. Scenario III: Station-relocation module, which was designed previously (Ciari and Weis, 2013) is used to find a better position of stations to increase the number of members. Then with these new locations and a set of agents having membership, scenario I is evaluated again.
4. Scenario IV: One-way carsharing alternative is added to the carsharing options and scenario III is evaluated again.

3.1 Results

To provide a better estimation of the carsharing demand, the number of vehicles at each station was also scaled down based on the percentage of the population simulated. To provide a picture of how the existing carsharing service looks, its supply and demand in the simulated area, we first analyse Scenario I as a base case. Then, for the scenarios II, III and IV, with the change of the carsharing supply, the results are analysed and compared.

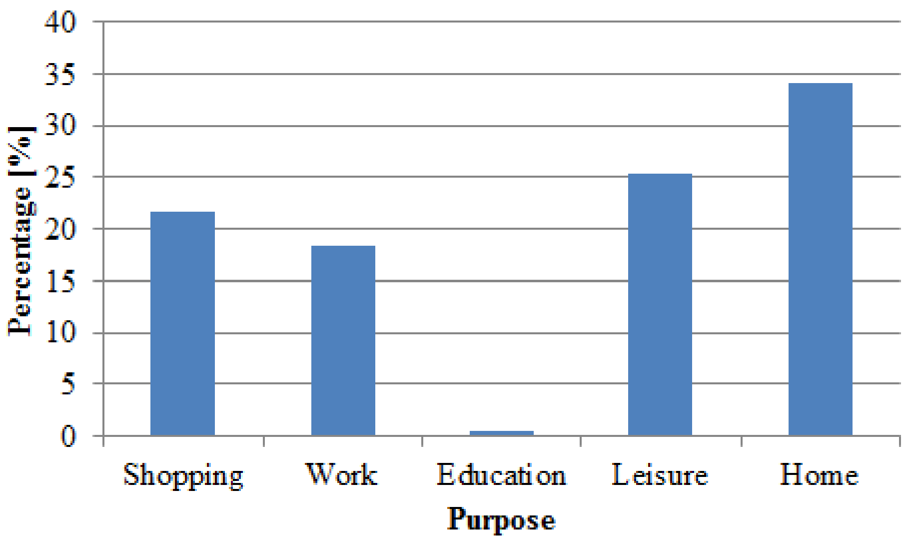
Scenario I: Prices for renting a round-based carsharing vehicle were taken to represent the current prices that Mobility charges their customers (2.8CHF per hour and 0.68CHF per km). In Table 1 some of the most important rental statistics for the base scenario are presented.

Table 1: Scenario I round-based carsharing rental results.

Scenario	# of Rentals	# of Trips	Avg. # Trips per Rental	# of Different Users
I:	153	414	2.7	146

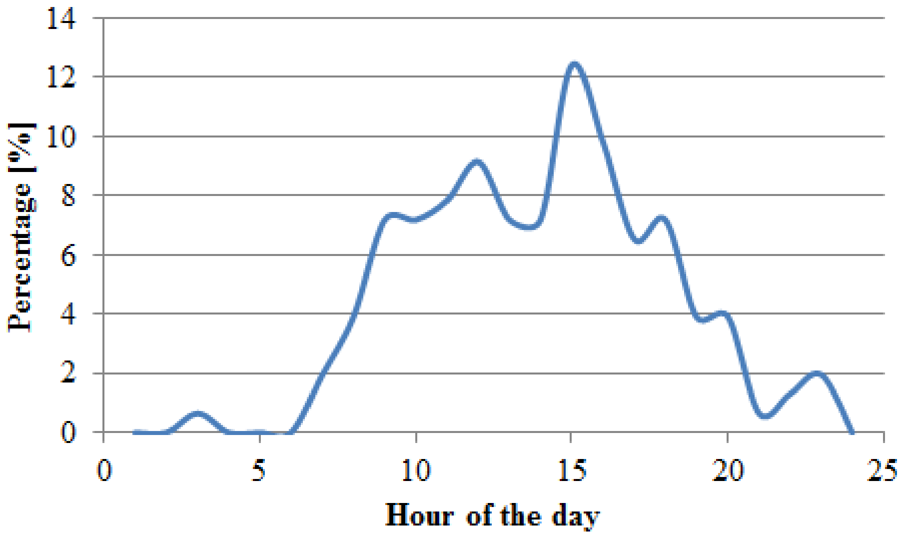
It can be seen that each rental generates around 2.7 trips per rental and that almost each rental is from a unique user. This suggests that carsharing vehicle is used to perform on average close to 1.5 activities before returning the vehicle and that the users tend to have one rental per day. In Figure 1 the distribution of trips by purpose made (for round-based carsharing vehicles) can be observed. It shows that users tend to use this kind of service mostly for shopping and leisure trips and a lot less for commuting, as was anticipated since working activities are longer than other out of home activities. Having a home activity at almost 35% is not surprising, since 76% of rentals are starting from a home location.

Figure 1: Percentage of trips performed by round-based carsharing service, by purpose.



Finally, in Figure 2 distribution of the rental starting times is presented. The largest number of rentals is around 15:00 with smaller peaks around 12:00 and 18:00.

Figure 2: Distribution of the rental start times for round-based carsharing in Scenario I.



Scenario II: In the second scenario, one-way carsharing service was introduced. Rental fee was based on the experience and the ratio between round-based and one-way fees from other operators, and it was assumed that the price in Switzerland would be 0.3CHF per minute.

Most important rental results for both carsharing options in the second scenario can be seen in Table 2.

Table 2: Round-based and one-way carsharing rental statistics for Scenario II.

CS Option	# of Rentals	# of Trips	Avg. # Trips per Rental	# of Different Users
Round-based:	139	367	2.64	134
One-way:	1388	1388	1.00	779

The results from Table 2 show that the one-way service is much more attractive for the public. It generates 3.8 times more trips than round-based and almost one third of the actual members are using this service on a daily bases. It is interesting to notice that with the introduction of one-way service, round-based service demand did not decline significantly. Since the activities performed, while renting a round-based vehicle, were to a large extent, short ones (up to 3 hours) and considering a convenience of having a vehicle ready for the return trip, this is not surprising. It is also significant to mention that there was only 1 user using both carsharing options in his daily plan.

Figure 3: Percentage of trips made with round-based and one-way options, by purpose, in Scenario II.

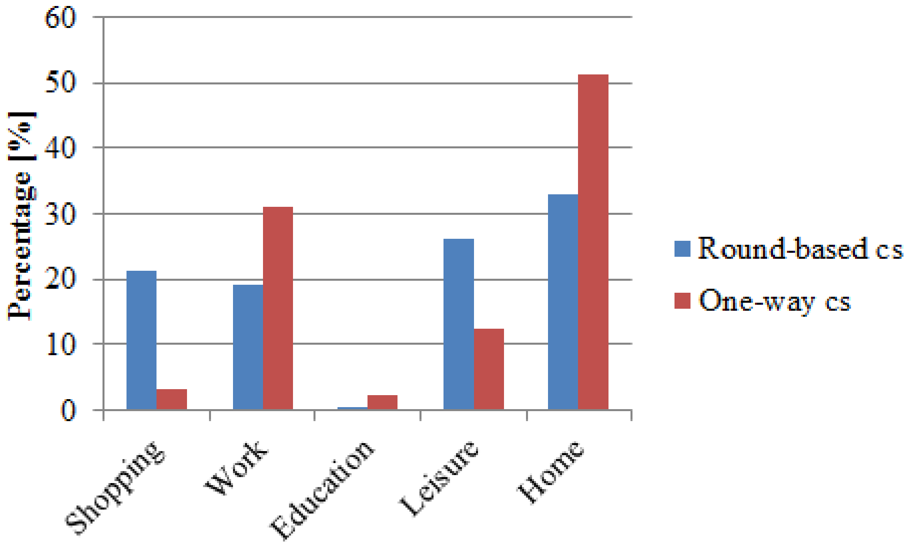
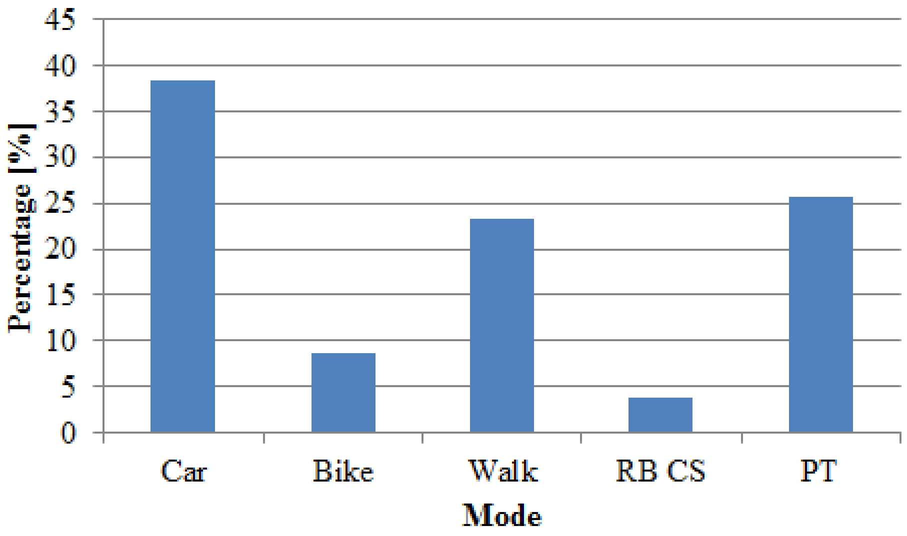


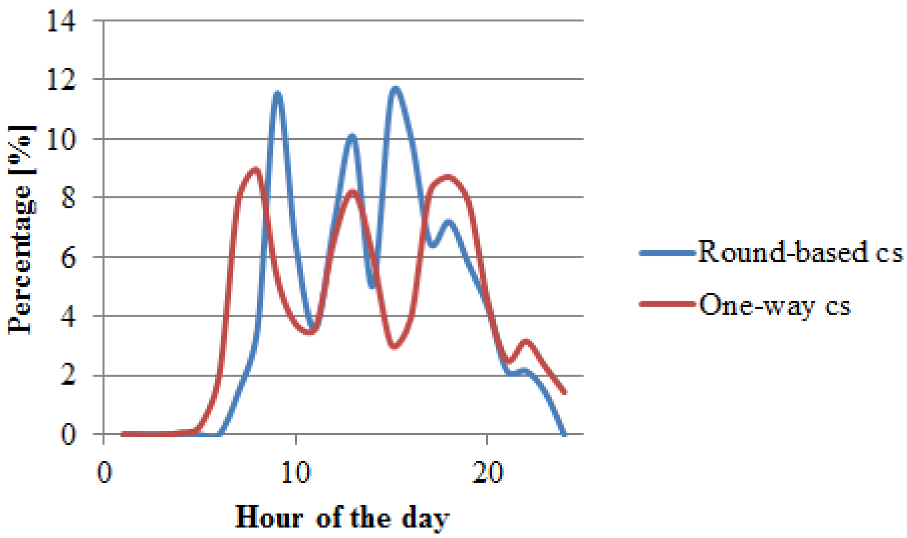
Figure 3 presents the comparison between round-based and one-way service in terms of trips by purpose. One-way is much more used for commuting and return to home trips, compared to the round-based service. This increase in the commuter trips was expected since the users don't have to pay for the rented vehicle while working long hours. It is also important to observe what modes one-way carsharing is substituting. The comparison is performed for scenarios I and II and it is shown in Figure 4. Car is actually the mode which is substituted the most, followed by PT and walk. Round-based carsharing is the least substituted mode and having in mind that the round-based rentals dropped only 10% in scenario II, it can be inferred that these two modes are rather complementary. Even though one-way station based carsharing provides more flexibility it seems that both modes are used for different situations. Similar findings were reported in a work on free-floating carsharing in Berlin, Germany (Ciari et al. (2014)).

Figure 4: Modes substituted by one-way carsharing.



Taking a look at the starting time of the rentals for both services (Figure 5) it can be observed that for one-way service there are three main peaks - in the morning, around noon, and in the afternoon, which are the main traffic peak hours during the day. Round-based carsharing rental start times distribution also has three main peaks, with the outside peaks closer to the middle one, supporting the finding that this service is rather used for non-commuting trips.

Figure 5: Distribution of the rental start times for both carsharing options in scenario II.



Scenario III: Having a good accessibility to carsharing stations is one of the critical parts of becoming a member of the carsharing service. Using an algorithm developed earlier, carsharing stations are relocated in an attempt to increase the number of members. After the relocation, the number of members was 3339 (26% increase over the original), with 26 stations relocated to new locations and with 92 stations that had their vehicle fleet switched with one of the other stations. Using these new locations and increased number of members, demand for round-based carsharing is observed. Table 3 shows the most important rental statistics for this mode.

Table 3: Rental statistics for round-based carsharing in Scenario III.

Scenario	# of Rentals	# of Trips	Avg. # Trips per Rental	# of Different Users
III:	192	550	2.86	185

The increase in the number of rentals over the scenario I is 25.4%. Taking into account that the increase of the number of members was 26%, suggests that new station locations bring not only more members, but also significantly more users. In Figure 6 the distribution of round-based carsharing trips by purpose can be observed. The distribution is similar to one of the scenario I, however percentage of commuting trips is now a little bit higher than the percentage of shopping trips.

Figure 6: Distribution of round-based carsharing trips by purpose.

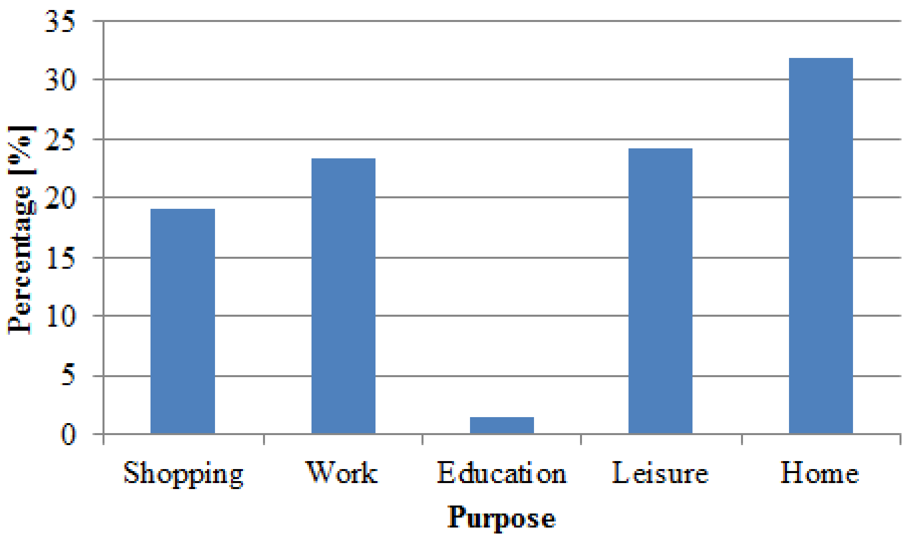
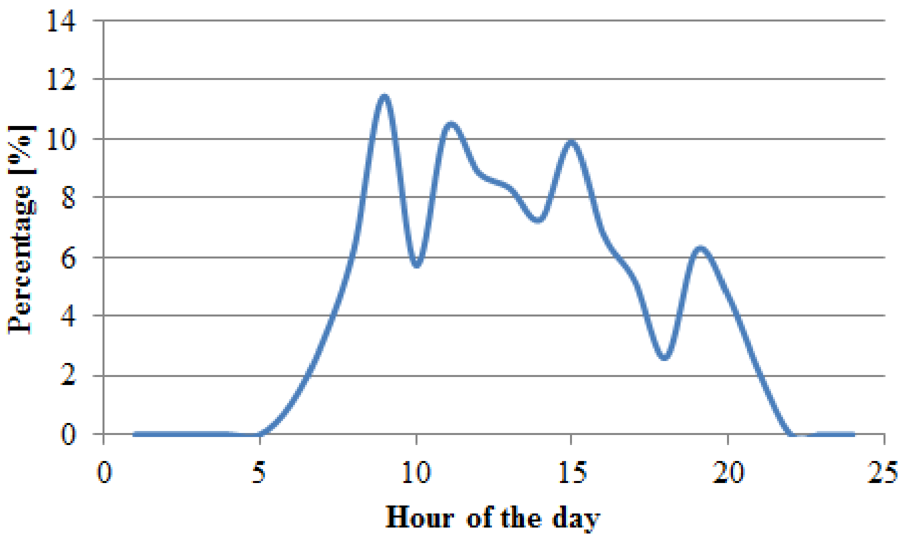


Figure 7 shows the distribution of the rental start times for carsharing service in scenario III.

Distribution is similar to the one before the relocation of stations. However, there are two observable changes. The first one is that now the first, around 9:00, peak is the largest one and there is now an additional smaller peak at 19:00. This changes are probably due to the fact that the relocated stations and different set of members forces users to use this service in a slightly different way.

Figure 7: Distribution of rental start times of round-based carsharing in scenario III.



Scenario IV: Following results for the Scenario III, scenario IV has both carsharing modes available, with the relocated stations and increased number of members. Demand for both modes in this scenario is summarized in Table 4.

Table 4: Rental statistics for round-based and one-way carsharing in Scenario IV.

	Round-based	One-way
# of Rentals:	163	17.2
Inc. over Sc. II [%]:	1871	34.8
# of Trips:	1871	34.8
Avg. # Trips per Rental:	1871	34.8
# of Different Users:	1871	34.8

If we compare the results from Table 2 and Table4 we can observe that the core of the behaviour of the users did not change with the increase of the number of members. However, number of rentals significantly increased. Number of round-based rentals increased by little bit over 17% which is lower than the increase in the number of members (26%), but one-way rentals increased by a little less than 35%. Much bigger increase in the number of one-way rentals suggests that the new stations locations might be much more suited for this kind of service. The small decrease in the number of round-based rentals following the introduction of the one-way service (with only 1 user using both services), supports previous conclusion that these two services are complementary and that they serve to provide transportation for different daily situations.

Figure 8 shows the distribution by purpose of trips for both carsharing options. Again, the distribution is similar to the one in scenario II. With round-based service, users tend to go to shopping, leisure and work activities with the similar percentage, while with the one-way service commuting trips are prevailing.

Figure 8: Distribution of carsharing trips by purpose in Scenario IV.

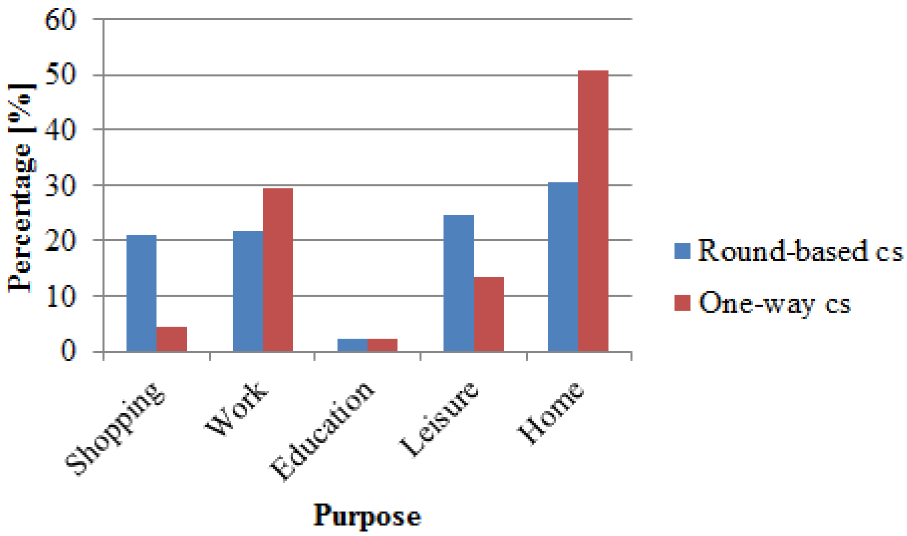
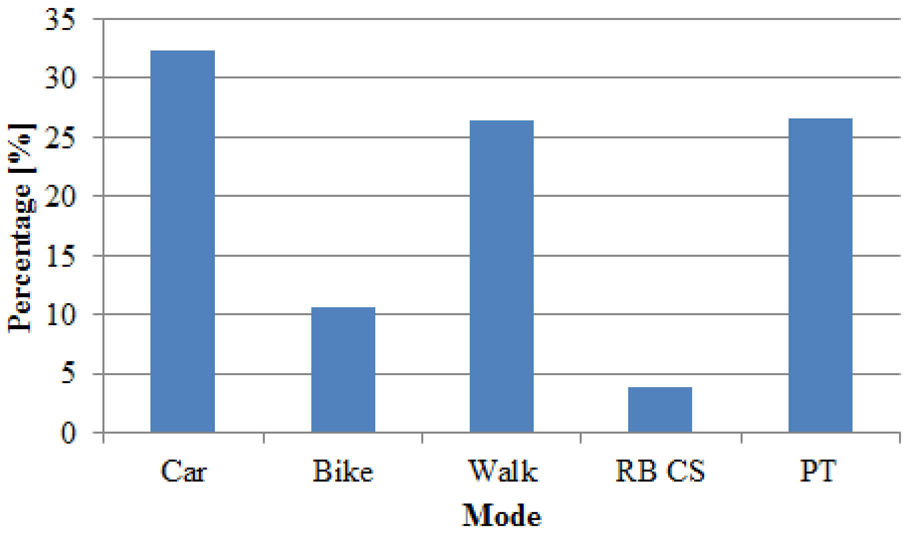


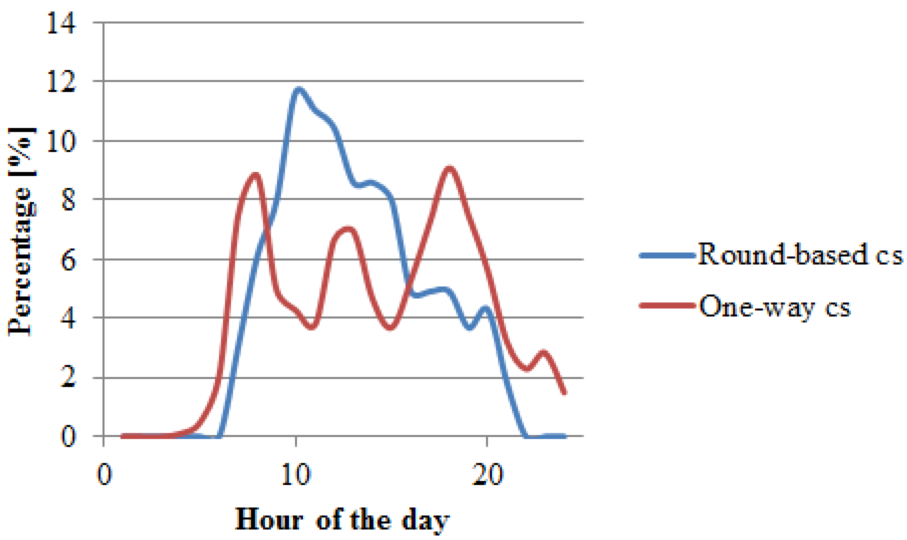
Figure 9 shows the modes in scenario III substituted by one-way carsharing service. Car and walk dominate as the modes substituted, similarly as in the Scenario II.

Figure 9: Modes in Scenario III substituted by one-way carsharing in Scenario IV.



Finally, Figure 10 shows the distribution of rental start times for both services in scenario IV. The distribution of the one-way service still has three main peaks, but round-based service has two distinguishable peaks which are now around 11am and 5pm. Basically two peaks around 10am and noon have merged into one around 11am, which is right in the middle of the two one-way service peaks.

Figure 10: Distribution of rental start times of both carsharing services in Scenario IV.



4 Conclusion and Outlook

The analyses in the previous section, presented the available and potential carsharing alternatives in the Zurich area. It is clear that the traditional, round-based, carsharing service provides users an option that is rather used for shopping and leisure activities, rather than for commuting trips. Even though the addition of the one-way carsharing alternative captured more than three times more trips than round-based service - in terms of daily rental per car - , showing its great potential, it did not substitute a large number of round-based trips. Moreover, it seems that these two carsharing options are rather complementary, thus serving different individuals daily needs. Relocating the stations, increased the number of members, and also increased the number of rentals for both carsharing options. It happened, however, in a different manner. While the round-based service did not increase as much as the number of members, one-way service rentals had a large boost. This shows that new stations locations, even though providing larger number of members, might be much more convenient for one-way alternative users.

Another significant finding is that one-way carsharing cars mostly substituted usage of cars and walking. While from the sustainability perspective, which is one of the driving forces of carsharing, replacement of car is good, the substitution of walk is not because this might lead to more car travel than before. However, this is based on a simulation and this should not be considered as a fact, but should be rather handled with care, until more detailed analysis will be performed.

MATSim as a simulation tool is definitely able to perform the necessary analysis and to test new modes and scenarios, on both spatial and temporal level, which is very important for policy analysis. Having more empirical data on both round-based carsharing in Switzerland, but also on one-way carsharing in other countries would definitely help improving the models and provide more reliable results in the future. Furthermore, investigating other areas for potential introduction of the one-way carsharing service and simulating larger (100%) scenarios is very important.

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