Enhancement of the carsharing fleet utilization

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Abstract

Worldwide expansion of the carsharing services in recent years has increased the importance of enhancing the performance of the existing carsharing systems as well as good planning of the future ones. Some of the important segments of a good carsharing service is high availability paired with high utilization of the carsharing vehicles. The work presented here makes use of the multi-agent transport simulation tool (MATSim) to investigate two approaches in enhancing the utilization of the round-trip carsharing fleet. Presented strategies increase the utilization of vehicles up to 52%, number of rentals up to 24% and increase the turnover for the operator up to 25%.

Keywords

carsharing, MATSim, fleet utilization

1 Introduction

The presence of the "sharing economy" which is based on sharing rather than owning (Shaheen et al. (2012)), has grown significantly in recent years. In transportation, several transport options are part of "sharing economy". Among these are bikesharing, ridesharing and carsharing. Carsharing has been around for almost 70 years (Harms and Truffer (1998)) and while it still does not take a considerable portion of the modal share (Haefeli et al. (2006); Kortum (2014)) it has grown significantly in recent years (Shaheen and Cohen (2013)). Moreover, different kinds of carsahring have emerged and traditional, round-trip carsharing (where a vehicle needs to be returned where it was picked up) is not the only one offered. Different carsharing services now include:

1. One-way carsharing - where a vehicle can be returned at any station
2. Free-floating carsharing - where a car can be picked and parked on (usually) any public parking spot within the service area
3. Peer-to-peer carsharing - where privately owned vehicles are available for use by members.

Even though, one-way and free-floating carsharing provide more flexibility to the users, they are also facing new problems that need to be addressed and that are limiting the operators. Among these problems are the possibility for the system to become unbalanced during the day and also during a bigger period of time, unavailability of vehicles for the return part of the tour, legal issues with peer-to-peer carsharing etc..

As the size of these services expands, the difficulty of finding the optimal size of the fleet and also the position for stations/cars, in terms of profit, service availability and user satisfaction, is also increasing and becoming more important to the operators. The literature on the optimization of the fleet size of carsharing services is, however, very scarce. To the best knowledge of the authors only a small number of studies exists dealing with the optimization of the supply side of a car sharing service (Rickenberg et al. (2013); Correia and Antunes (2012)). They, however deal only with one-way systems and try to satisfy the current demand, thus not considering how the demand will adapt to the change of the supply. Moreover, only limited number of papers exist dealing with the optimal location of the stations. Ciari et al. (2015) suggest a genetic algorithm that searches for the optimal position of the already existing carsharing stations among the possible preselected locations. Kumar and Bierlaire (2012) present a mathematical model to identify the best locations based on the demand. They also use a real-life scenario to test their presented model.

In the study conducted previously (Balac et al. (2015)) we have observed that Zurich area still has a potential for expansion of round-trip carsharing, but that this expansion needs to be carefully conducted in order to avoid having large number of unused vehicles during the day. This implies careful planning and finding as close to optimal fleet size and their position.

The purpose of this paper is to provide an initial step towards a methodology that will supplement the current literature and the one that can be used as an initial step towards a more optimal distribution of the carsharing vehicles for round-trip service. The methodology presented also takes into account that the demand will change with the relocation of the existing vehicles, which is important if we want to have a full picture of the effects of vehicle redistribution. Therefore, the results presented here, could be used as guidance to the operators and transport planners of the carsharing services on how to increase the utilization of the available carsharing fleet.

The remainder of the paper first presents the methodology used. Next, the results are shown and finally, conclusions are made and future work lade out.

2 Methodology

For this work an open-source, multi-agent transport simulation tool (MATSim (2015)) was used to model the demand and supply for round-trip carsharing and to observe the effects of the strategies proposed for enhancing the fleet utilization.

MATSim simulates a synthetic population in a virtual world. The synthetic population is generated using the census data and daily plan (activity chains and mobility tools) for each member of the population is derived from suitable diaries. The virtual world presents the road network - in this study it is a detailed navigation road network. During the iterative process of finding the stochastic user equilibrium each agent can adapt its plan according to its preferences (change transportation mode, departure time, route, location of his secondary activities (shopping and leisure)). The advantage of using an agent-based simulation tool over the traditional four-step models is the opportunity to answer complex scientific questions regarding carsharing user behavior. This comes from the fact that to correctly model carsharing, both spatial and temporal location of vehicles is needed which aggregate four-step models can not provide.

The implementation of the carsharing services were developed previously and in short, main features of the implementation include:

1. Carsharing vehicles interact with other vehicles on the road network.
2. Carsharing stations and their capacity (fleet and parking size) are modeled based on the real data.
3. Access and egress times to each station/car are modeled.
4. Each agent in the simulation has to reserve a carsharing vehicle.
5. Cost structure is based on the fees gathered from the current carsharing operator in Switzerland and take into account both rental time and distance traveled.

A detailed explanation of the carsharing implementation can be found in (Balac et al. (2015)).

2.1 Strategies for increasing the fleet utilization

To increase the utilization of the existing vehicles and stations, we have investigated two approaches:

1. First strategy investigates how the cars are utilized with the original number of cars per station using following steps.

- **Step 1:** Place the cars according to their original distribution.
- **Step 2:** Run MATSim simulation.
- **Step 3:** Calculate the utilization of the vehicles at each station. If there is no significant improvement, stop the process, otherwise go to **Step 4**.
- **Step 4:** Remove all unused vehicles from the stations and re-distribute them among the stations that did not have any unused cars, startin with the one with the highest number of rentals per vehicle. If all the stations with no unused vehicles were used and some cars were still remaining, this process was repeated until all the unused vehicles were placed
- **Step 5:** Any stations that are left empty at this point were removed. Go to **Step 2**.

2. Second strategy combines the first strategy with the analysis of the highest potential demand for the current stations.
   - **Step 1:** Place infinite number of cars at each station, to observe the highest potential demand for the current station locations.
   - **Step 2:** Run MATSim simulation.
   - **Step 3:** Store number of rentals and used cars for each station and compute the utilization of vehicles for each station.
   - **Step 4:** Empty all the stations and fill them with the number of used cars in that station, starting from the one with the highest utilization ratio until all cars are placed.
   - **Step 5:** The stations that after this process have no cars are removed from the simulation. Go to **Step 2** of the first strategy.

3 Scenarios and Results

3.1 Scenario

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 and all members of the population are represented in the simulation by a corresponding agent. Carsharing stations and fleet size was taken from the data provided by the carsharing company operating in Zurich (Mobility (2015)). Different scenarios used to investigate the effectiveness of the optimization strategies are described below:

1. Base scenario: Only round-trip carsharing is available, with the current Mobility stations (492 stations with 911 cars in the simulated area, Figure 1) and membership assigned to agents, based on the logit model estimated previously by Ciari et al. (2015) resulting in 35,718 members.
2. Two scenarios, each using different strategy to increase the utilization of the carsharing fleet.

Figure 1: Distribution of carsharing stations.

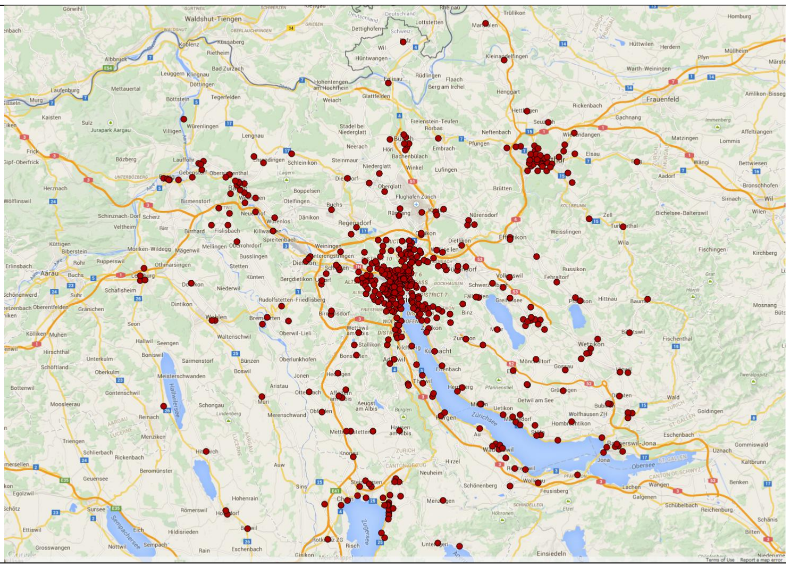


Table 1: Carsharing supply and demand.

Number of	Mobility - Canton Zurich	Mobility - sim. area	MATSim - sim. area
Stations:	379	492	492
Cars:	695	911	911
Members:	26,814	34,897	35,718
Rentals/work day:	730	~940	854
Trips:	-	-	2,157
Used cars:	475	~617	492
Unique users:	-	-	823

3.2 Results - Base Scenario

Here we will first present the statistics of the simulated round-trip carsharing service compared to the data obtained from the carsharing operator in the Zurich area (Mobility). This will be followed by the results of the two strategies proposed for the enhancement of the utilization of the current fleet size.

Table 1 shows the carsharing usage statistics for the Canton of Zurich, on an average working day, which was provided to us by Mobility from the year 2010. While we do have the number of members, cars and stations in the simulated area we did not have the full usage data. Therefore, we scaled up the booking data from the Canton of Zurich which is shown in the Mobility - simulated area column. The scaling was done by multiplying the number of rentals and used cars with the ratio of the number of cars in the simulated area and the Zurich Canton. Finally, MATSim simluation results are presented in the third column. The lower number of rentals was expected since around 10% of Mobility rentals are performed with the vehicle type "transporter" used to move bulky loads. However, current day plans of the agent population do not differentiate between different types of shopping nor does it includes moving home.

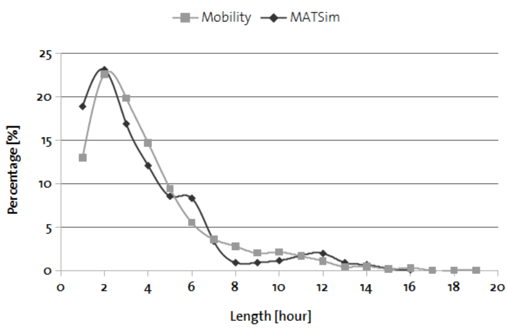
To analyze the temporal quality of the simulated results one can look at the rental length times and also rental start times distributions. These are shown in 2(a) and 2(b). The distribution of the rental length times, which is shown in Figure 2(a), resembles quite well the Mobility data (with a correlation of $r = 0.977 (p < 0.01)$), even though there is a bit larger percentage of the rentals lasting less than 1hour. This can be explained by the fact that in reality people need time to get used to the vehicle, find parking spots, access and egress the vehicle when finishing or starting their activities during the rental, which in the simulation is not taken into account.

Rental start time figure (2(b)) shows that both Mobility data and MATSim simulation results (with a correlation of $r = 0.77(p < 0.01)$) have three peaks during the day, but with MATSim having a morning peak one hour earlier . These differences between these two distributions can be accounted to the fact that in reality people adapt their schedule according to the car availability which in MATSim is only partially done (changing activity location and departure time).

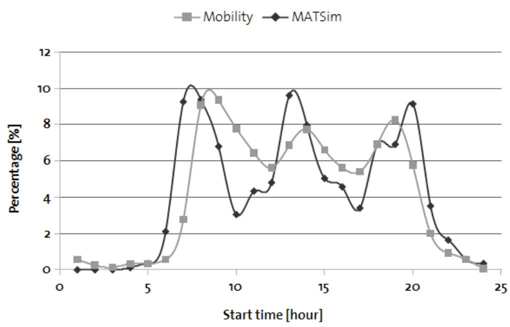
These analyses show that the MATSim simulation (even though with mentioned limitations), produces results not very different from the actual behavior of the members of the carsharing scheme.

Figure 2: Comparison of the base simlation against observed demand. a) Rental length times, b) Rental start times

(a)



(b)



3.3 Results - Enhancement strategies

Table 2 shows the fleet distribution and its utilization for base scenario and after executing two presented strategies for increasing the fleet utilization.

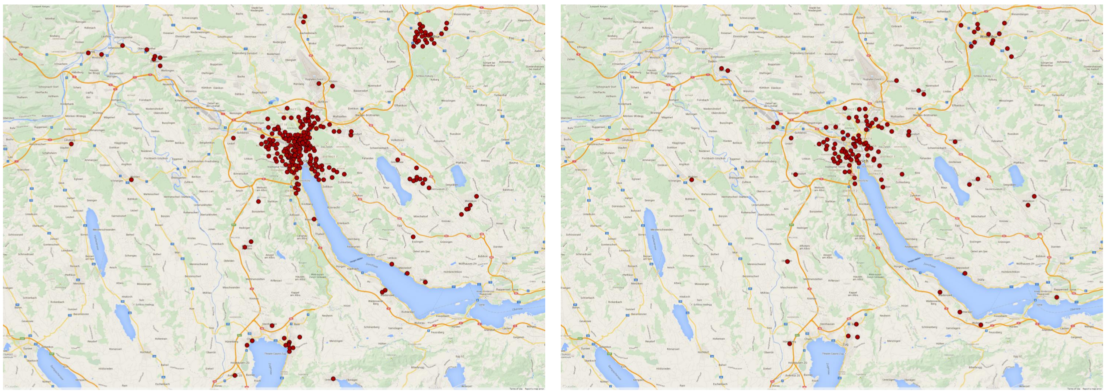
Interestingly, even though Strategy II has larger vehicle utilization than Strategy I, it generates lower number of rentals and lower turnover than the Strategy I. However, both strategies increase the number of rentals and turnover compared to the base scenario. Figures 3(a) and 3(b) show the distribution of stations after applying both strategies. It can be observed that Strategy II has a much stronger effect on the reduction of the number of carsharing stations than Strategy I. This also means that the size of each station on average is larger and requires more parking spaces. Moreover, both strategies remove some of the stations completely and some smaller towns are left with no casharing stations. This would probably imply reduction in the membership numbers and coverage, which are also important factors for the operator. Moreover, the unused cars during one day might be used on an another day. Therefore, the results presented should be used with caution.

Table 2: Carsharing demand with different fleet distributions.

Variable	Base Scenario	Strategy I	Strategy II
Number of cars:	911	911	911
Number of stations:	492	270	116
Number of rentals:	854	1,062	967
Avg. rental time[min]:	196	194	185
Number of Used cars:	492	737	749
Turnover[CHF]:	14,519	18,247	16,256

Figure 3: Spatial distribution of stations after applying a) Strategy I, b) Strategy II

(a) (b)



Figures 4(a) and 4(b) show the comparison of rental length and start times for all three scenarios. Rental start times distribution is quite similar between three scenarios. Rental length times graph shows that after applying Strategy II much more rentals are very short ones (less than 2hours) and there is a decrease in rentals lasting 4-5hours. Strategy I increases the rentals lasting less than 1hour, but decreases those lasting between one and two hours. This shows that both strategies increase the accesbility of carsharing vehicles to people renting cars for very short (<60min) rentals, which can be explained by the fact that most of the vehicles are now concetrated in the centers of Zurich and Winterthur, where most of the short trips are performed, as can be seen in Figure 3.

Looking at the crow-fly access walking distances (Figure 5) to the place where the agents picked-up their carsharing vehicles, one can see that Strategy I provides better accessibility by reducing the walking distances which is one of the important factors when deciding to rent a carsharing vehicle. This was expected since this strategy aims at concentrating vehicles at high-demand areas.

Figure 4: Distributions of a) Rental Length and b) Rental Start times for different scenarios.

(a) (b)

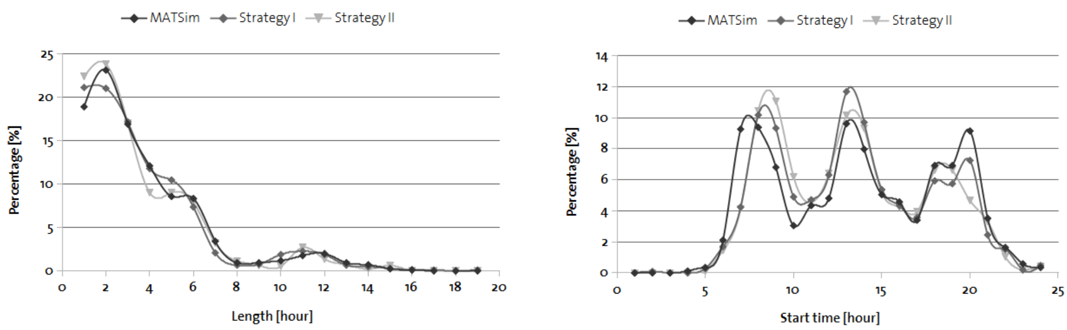
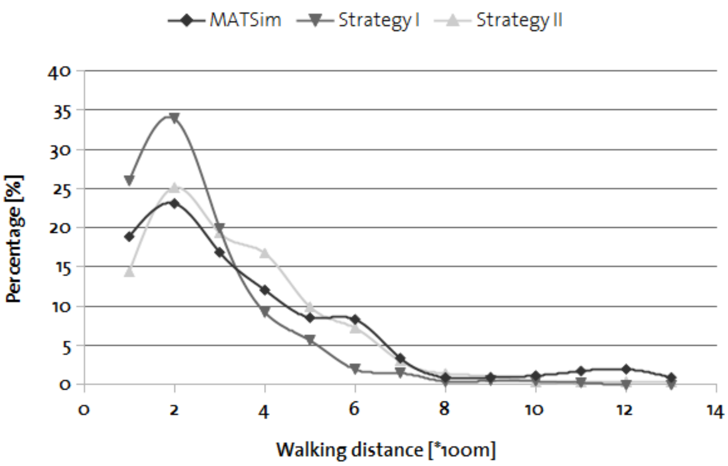


Figure 5: Distribution of access distances to the reserved vehicle.



4 Conclusion and Outlook

Increasing the performance of the existing carsharing systems as well as good planning of the future ones has become more important in the recent years, since these systems are getting larger every day. One of the important segments of a good carsharing service is a high availability paired with high utilization of the carsharing vehicles. Work presented in this paper shows two strategies for enhancement of the utilization of the round-trip carsharing fleet using multi agent transport simulation framework. MATSim framework provides us, unlike some other transport simulation tools (i.e. four step model), with the ability to observe the demand on a much higher level of detail in both spatial and temporal dimensions, which is very important when observing carsharing usage.

Analysis of the effectiveness of the proposed strategies show that the current round-trip carsharing fleet in Zurich area could be distributed in such a way that increases both its utilization and also the turnover for the operator. Both strategies increase the number of rentals, but on average those rentals are a bit shorter than with the original fleet location. Strategy II also provides the fleet distribution which increases the accessibility by providing the cars at the high-demand areas.

Redistribution of the fleet, however, can have a big effect on the size of the members pool and can reduce the coverage which are important factors for the operator. Moreover, fleet usage patterns are not the same over the week, so the increase of the usage during the working day might lead to the decrease over the weekend. These factors need to be investigated in the future work.

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