ESTIMATING THE POTENTIAL OF A LARGE SCALE CAR-SHARING SYSTEM WITH AN AGENT-BASED MICROSIMULATION APPROACH

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ABSTRACT

This paper reports on ongoing work aimed to estimate the potential use of car sharing at large scale in urban areas as a mean to mitigate congestion and social exclusion. The methodology used to assess the potential of the system is agent based modelling. An existing open source software, called MATSim-T (Multi-Agent Transport Simulation Toolkit, http://matsim.org), has been enhanced within this project to allow the modelling of the car sharing mode. In order to add the car sharing mode to the simulation toolkit a cost structure reflecting the implementation scheme of the system has been defined. The simulated individuals (agents) will have this additional option and will choose it, or not, according to the generalized cost it generates for their schedules (plans). The travelling time for this mode, is analogue to that for car and it is calculated on a congested network, where all cars are simulated, adding realism to the model. The results of a test case for the city of Zurich, a scenario with about 160’000 agents, are reported and discussed.

Keywords: car sharing, microsimulation, agent based

INTRODUCTION

The car, in the transportation literature, is commonly referred to as an individual transport mode. It is individual because one is free to use it individually and has complete control over both destination and route. But it can be interpreted as individual also because it is individually owned. Both these aspects are in contrast to public transport. In the common perception, these two aspects are indissoluble, making it obvious that in the large majority of cases, in order to use a transport mode individually, one needs to own a vehicle. This partially explains why car ownership is so common in our society. In most of our cities, along most of their streets, the large amount of cars parked on the curb side should make us aware of the high inefficiency of this approach. Parked cars are, in principle, mobility instruments just waiting for someone to need the mobility they are supposed to provide. An obvious way to improve the efficiency of the system would be to decouple ownership from use, that is, to share the resource among potential users. Actually, the idea of sharing cars among a group of users is not new; the concept had been around for decades before the first successful and durable practical implementations of car-sharing appeared. The first two examples of this kind are probably the Swiss operator Mobility and the German Stattauto, which are no older than 20 years (Harms and Truffer, 1998; Britton, 1999). Today, car-sharing schemes are increasingly popular and their number is growing around the world (Shaeen and Cohen, 2007; Shaeen *et al.*, 2009). Much literature has been consecrated to the potential benefits of such car sharing schemes (Millard-Ball *et al.*, 2005; Haefeli, 2006), however, all these applications, are working at a much smaller scale than the problems they are intended to confront. Most of the benefits usually attributed to car-sharing would be tangible only with implementations at a much larger scale than those in use now (Ciari *et al.*, 2009). Aiming to investigate both the potential and the feasibility of such large-scale car-sharing, an important issue is to found a methodology that can be used for the planning and evaluation of this task. Here, an agent-based simulation approach is used. The implementation proposed here is to be intended as a first step introducing a new generation of modelling tools which are expected to overcome some of the drawbacks encountered by traditional transport modelling in forecasting the reaction of the public to a new mobility option. In this sense the main goal of this paper is to show the first functioning version of this effort and discuss it, indicating in which direction the future work will go and which improvement will be possible in the near future and in the longer run.

The paper is organized in six sections. In the next section, some of the motivations behind the idea of implementing car sharing at large scale are introduced. A short section on the state-of-the-art of car-sharing is following. The fourth section is describing the modelling framework and the possible modelling options within it. The fifth section deals with a test case, the evaluation of car sharing in the metropolitan area around Zurich, in Switzerland. That contains also the presentation of some preliminary results of the simulation for this scenario and their discussion. The paper ends with conclusions and an outlook for future work.

MOTIVATIONS

It is well known that the current transportation system imposes a heavy burden on society in terms of energy consumption and external costs such as accidents, noise emissions, pollution, space consumption etc. But it is often neglected that this system also entails social exclusion, and that it is for different reasons inaccessible to various categories of people. The idea of car sharing at large scale should be seen as a part of an effort to rethink urban travel and try to mitigate both problems. In particular, the goal is to find ways to substitute private car travel in a way which is more environmentally friendly and more democratic. The car sharing system would be part of a global system where also other services, like collective taxis, car-pooling, bike sharing, etc., are also deployed at large scale. The integration of such systems should be a contribution to a major shift from private oriented, individually driven, urban transport; to more sustainable multi-modal shared transport.

Pollution Reduction

There is already an important corpus of literature assessing the benefits of car-sharing for individuals, the transport system, society and the environment (for example Millard-Ball *et al.*, 2005). Some of those usually claimed include: more fuel efficient vehicles, less vehicle travel, lower emissions, and more compact development. Probably even more important than all this, such a large scale car sharing system could induct a reduction of the number of circulating cars overall. In fact, the current discussion on car pollution mainly focuses on car emissions, in particular on carbon dioxide emissions. This is sound with many of the current studies on the topic since road transport is one of the major causes of this kind of pollution. According to the United Nations Framework Convention on Climate Change (http://unfccc.int/2860.php), the transport sector in western countries accounts for about 40% of CO2 emissions. By far, the largest part of these emissions is related to road transport (in the USA for example 84%). However, if one looks to a broader definition of pollution and speaks more in general of environmental costs (other pollutants, the waste of materials, etc.), it has been assessed that a large part of the costs related to the use of the car are coming from its production, and not depending on travel. In fact according to some researchers (Umwelt und Prognose Institut Heidelberg, 1993), the largest part of the pollution related to a car life cycle is coming from its manufacturing, while a smaller, but not negligible, contribution comes from car disposal at the end of its life cycle. This is a good reason to focus not only on emissions reduction (either directly producing cleaner car engines or indirectly reducing car travel), but also on the reduction of the number of cars overall.

Social Exclusion Mitigation

Social exclusion means that people or areas are suffering from a combination of linked problems such as unemployment, poor skills, low incomes, poor housing, etc. (Pickup and Giuliano, 2005). In our societies mobility is perceived as a fundamental personal freedom and considered one indicator of the quality of life we experience. But transport is also a tool for living and working; it provides a level of mobility and accessibility to meet activity requirements. The lack of mobility is recognized as one of the possible factors of social exclusion. Links between trans-port and social exclusion has been extensively discussed, among others, by Hine and Mitchell (2003). Such problems are much stronger in North America, due to a development style implying private car mobility and, consequently, weak public transport system. However such problems are not unknown to European societies either (see for example: Pickup and Giuliano, 2005, Church et al., 2000) and could be addressed by a system like the one proposed in this paper.

CAR SHARING: SHORT STORY AND CURRENT STATE

The basic concept of car-sharing is that individuals participating in a specific program are allowed to use vehicles from a fleet on an hourly basis. The first implementation of the car-sharing idea dates back to 1948, with the Sefage development project in Zurich (Harms and Truffer, 1998). Various other schemes were implemented during the 1970s and 1980s, but most of them were at a very small scale and none of them survived (Shaheen *et al.,1998*). Only at the end of the 1980s did the concept eventually find its way to a larger public with new programs that are still in operation today. The basic concept of car-sharing has evolved in many different ways throughout the world. However, there are characteristics that are recurrent in most car-sharing programs. Over time, profit-making organizations have emerged as the most important actors in the car-sharing market, catching the largest market share, even if non-profit organizations are still predominant in terms of number of organizations. “Neighborhood car-sharing” (Barth and Shaheen*, 2002*) is the predominant operational model. Vehicles are located at parking facilities that are distributed throughout a region. The core idea is to conveniently serve a set of members living in the neighborhood of the station (the location of the car). The concept is usually coupled with the obligation for the customer to return the car to the same spot. Services such as instant access, one-way trips, open-ended reservations, etc., go beyond this basic scheme, but they have only found sporadic applications (*Schwieger, 2002; ICVS, 2008*). Private users still constitute the bulk of car-sharing customers, but business users are considered by some (Mobility*, 2010*) the most promising market for further expansion of car-sharing. Private trips are mostly leisure trips or cargo trips (i.e., shopping trips resulting in heavy or large purchases); trips to and from work are almost absent. Business car-sharing, where a firm offers its employees access to car-sharing for business trips instead owning a car fleet, is growing faster than private use, but still accounts for a small portion of global car-sharing use. Most car-sharing operators require that customers pay a membership fee. Sometimes this is a sort of deposit that is refunded when membership ends. The rates are usually a combination of per hour and per km rates; maximum rates for daily rental sometimes apply. In Europe, most operators offer a relatively wide range of vehicles, from small city cars to relatively large cargo vehicles. However, in most cases the type of fuel is not an important attribute of the car. In North America and Asia, the combination of car-sharing with LEV (low emission vehicles) is more common (Shaheen and Cohen*, 2007*). For the time being, most established car-sharing schemes offer access to cars via smart card or PIN (personal identification number), and reservations are made by Internet or telephone. This is the way car sharing as established itself in the last decade, but some new approaches to car sharing are already appearing at the horizon. The most interesting one is probably the idea of peer-to-peer car sharing systems, where private auto owners are making their car available to other members of the association who want to rent the car for a short period (Brooks, 2010).

MODELING FRAMEWORK

The modelling of a large scale car sharing system is challenging. A crucial step to overcome limits usually encountered with traditional modelling frameworks in the forecasting of new transport options is to have a more precise representation of the service (Shaheen and Rodier, 2004). An explicit representation of trip chaining of individuals, for example, allows detecting who could meaningfully use the car sharing in his/her out-of-home tour. For this, a representation of travel at the individual level with explicit modelling of modal choice is necessary. The representation of individual travel needs increases the precision of the model (shopping, work, leisure, etc.). High spatial and temporal resolution would be also important, since access time to the service is a fundamental parameter in customer choice. Here, an agent-based micro-simulation approach is proposed. This technique allows to model the system at high spatial resolution, but also to consider the behaviour of single individuals. An already existing simulation tool, MATSim-T (Multi-Agent Transport Simulation Toolkit, http://matsim.org) is the basis for this work. MATSim is an agent based and activity-based travel microsimulation tool, which produces individual daily transport demand as output.

The MATSim toolkit

MATSim-T is a fast, dynamic microscopic transport model. Results are completely disaggregated and analysis can be performed at any level of resolution in space and time, and for any individual agent. Transport is assumed to be a derived necessity for individuals, in relation to the primary need of individuals to perform certain activities during the day. Therefore a plan (daily schedule) is generated for each agent (a synthetic person). A plan contains information on the activities planned by an agent for a certain time span, typically one day, assigned according to its socio-demographic profile. Not only are activities listed, it is also specified where and when those activities will be performed, and which mode of transport will be used to reach the different locations. The plans are executed simultaneously during the traffic flow simulation. Several plans for each agent are retained, given a score, and compared. The plans with the highest scores are kept, and used to create new plans based on their previous experiences. Trying to improve their score, the agents can choose when to leave home, and the transport mode and the route to concatenate all activities. The system iterates between plan generation and traffic flow simulation until a relaxed state is reached (Fig.1). MATSim's most prominent application is a simulation of the travel behaviour of the entire Swiss population, where 7.5 millions of agents are simulated, and about 2.3 million individuals are travelling by car on a network with 882,000 links. More information on the data needed to set up and run the simulation can be found in Ciari et al. (2007) and in Meister (2008), while in Meister *et al.* (2008) and Balmer *et al.* (2009) it is demonstrated that the toolkit is able to deal with large-scale scenarios, producing results that are consistent with observed traffic data. In the current version, each traveller of the real system is modelled as an individual agent, while the supply side is modelled as fixed constraints of the system. However, in MATSim-T, each single actor of the transport system can be simulated according to the agent paradigm on both the supply and demand sides.

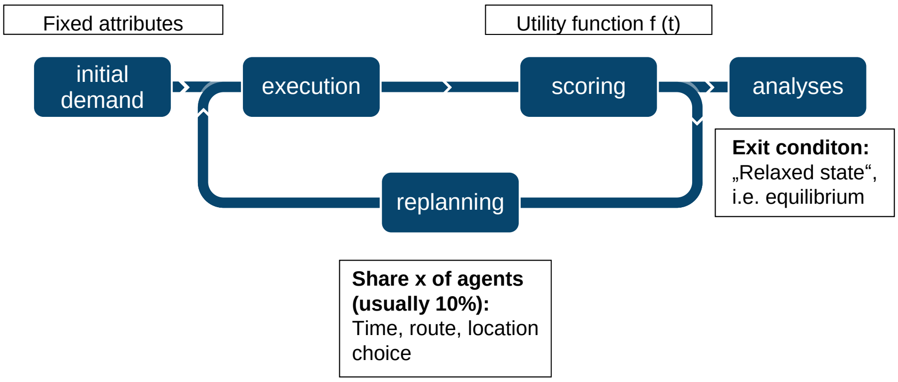

Figure 1 – Graphic representation of the MATSim simulation framework

Modelling options

In the most recent version of the MATSim toolkit the available modes were Car, Public transport, Bike and Walk. Car sharing was not considered as an option. The optimization process, described above, is based on the evaluation of the plans using a specific scoring function. The MATSim scoring function (Charypar and Nagel, 2005) is currently based on two ideas: logarithmically decreasing marginal utility of the activity duration and a Vickrey (1969) inspired valuation of the timing of the activities. Its general form is

$$(1) \quad U_{plan} = \sum_{i=1}^{n} (U_{act,i} + U_{travel,i}) .$$

Travel produces a negative score, and the value of this score depends on the length of the trip, both in terms of time and distance, and the type of transport mode used. The elements included in the second term of equation (1), which is basically the utility function of traveling, are access/egress time, traveling time and the cost of the trip with a given mode.

$$(2) \quad U_{travel,\mathrm{mode},i} = \sum_{i=1}^{m} \alpha_{\mathrm{mode}} + \beta^{1}{}_{\mathrm{mode}} * TT + \beta^{2}{}_{\mathrm{mode}} * Cost_{\mathrm{mode}} * Dist$$

Access and egress time are not calculated but assigned for each mode in the form of a negative constant α. Other kinds of out-of-pocket expenses (like parking costs) can be added in this same way. Travel time (TT) is calculated knowing the distance (which is calculated in turn with different methods according to the mode) and the speed of the mode (it is assumed a specific average speed for each of the modes, based on mobility census data). With Cost is intended the kilometric cost for the considered mode, Dist is the distance for the trip. The constant α and the parameters β^1 and β^2 are different for each mode, meaning different attractiveness of travel, and have been estimated with a stated preferences survey (for more details on this topic see Balmer *et al.*, 2009; Kickhöfer, 2009; and Vrtic *et al.*, 2008). Within this approach it is possible to vary the characteristic of different modes and observe the reaction of agents to such variations. For example it is possible to vary the cost of a given mode and see what happens to this mode’s share of global trips. Note, however, that currently the only mode which is properly simulated, the only which is “physically” represented in the model, is the car option. Through the use of this mode agents are interacting, in the sense that the real cost (intended as generalized costs) of one car trip will depend also on the congestion of the network, and thus on the mobility behavior of other agents. In other words, for one agent, travel with car mode from point A to point B has not a constant cost, but depends on other agents’ decisions (if they are traveling with the car or not, when they are traveling, along which route, etc.) For all other modes currently simulated (public transport, bicycle, walk) the utility of travel is independent of other agents’ behavior, the route followed and the travel time are fixed for any two points of the network, and the trip is not “executed” in the simulation. According to what explained above, it is possible to introduce a new mode, the car sharing mode in this case, in various forms and with a different level of accuracy. The first possibility is to simply define a cost structure for the new mode. The agents will get this new option, which mean that in the re-planning part of the simulation agents can get a plan where the car sharing mode is used. The plan is evaluated as usual and, within this process, the trip with the new mode is evaluated according to the introduced cost structure. According to the type of service that we want to introduce we can give to the relevant variables different values. Parameters can be estimated with the help of an appropriate SP survey, or more simply, imputed with the help of parameters of existing modes; for example in the case of car sharing it seems reasonable that the attractiveness of travel (the parameters of the travel time variable) will be between the one of car and the one of public transport. This modeling option is not only the simplest possible in order to introduce a new mode, but also a necessary premise for any more sophisticated approach. If no new cost structure is defined, no new mode will be available to the agents.

Simulated Car sharing

The simple solution presented above does not include yet the simulation of the car sharing mode. In particular in this way, it is implicitly assumed that the car sharing service is always available at any time and in any point of the network. It is a system with infinite capacity, and all the demand for this mode can be always satisfied. Of course this assumption is not very realistic and, indeed, an important advantage of the agent based approach versus other methodologies relies on the possibility to simulate the access to the vehicle for each passenger, and to put in relation the number of car assigned to the service and the effective number of customers. Moreover, this way, travel distances and times will be not realistic because they will be not taking into account the interaction of car sharing vehicles with other vehicles. Moreover, currently, the problem of the coordination of the schedule of different agents which need to use the same vehicle does not exist. The solution to such issues is the explicit simulation of the car sharing mode and of the reservation system. In some parallel work (Rieser *et al.*, 2009) the tools to introduce new types of vehicle in the simulation have been created. This allows for the representation of vehicles different than private cars, and creates a direct interaction between car and other modes. A solution for the representation of the reservation system is not yet available within the MATsim framework and should be introduced to solve this problem. This is probably the most problematic part of explicitly simulating car sharing travel.

Agent based supply side

A further refinement step for the model, and an attractive option for the modelling of car sharing, is the introduction of a car sharing operator agent. Every actor of the transport system, both on the supply and the demand side, can be simulated in MATSim-T according to the agent paradigm. In the current version each traveller of the real system is modelled as an individual agent while the supply side is modelled through fixed constraints. A first effort introducing an agent modelling for supply side actors of the system is Ciari *et al.* (2008). The operator agent is the decision maker having the control of the whole car sharing system and is able to modify its characteristics. It can be provided with attributes, knowledge, objectives, a strategy to pursue, a methodology to implement this strategy and a group of allowed choices. The operator agent’s objective function can be assumed to be more or less complex. In the simplest case the agent would seek to maximize the number of customers, but other possibility could be the maximization of profit or of social welfare. The knowledge of the agent - similar to those of individuals - is the memory of some previous score and the corresponding configuration of the service. In the case that costs are not part of the objective function of the operator a posterior evaluation of the financial feasibility could be performed. The dimensions on which the agent could operate are for example the fleet (number of cars, dimensions) and the price scheme (price level, distance and time dependency). The whole system can be optimized with an evolutionary approach. The operator would change some of the characteristics of the car sharing scheme in order to try to obtain a better score. It would be possible to isolate also the effect of a single decision dimension, blocking the possibility to modify the others. This way the characteristics of the service would be not fixed anymore, but would emerge as equilibrium depending on the behaviour of the operator and those of individual agents. This approach is much more sophisticated than the other proposed above and also really challenging. One of the greater difficulties is the right interpretation of the results (Ciari and Loechl, 2008). If the price of the service and its extension are not an input anymore but become a result of the simulation, these results are dependent on the number of agents using collective car sharing which depends on the characteristics of the system in turn, and so on. With only one type of agents the relaxed state of MATSim is considered to be reached as soon as the average score of agents is not changing anymore (or changes observed between two successive iterations are less than a given threshold value). Off course this get more complicated if two types of agents are there, and little is know about the type of equilibriums that can be obtained. This approach can be seen as a development of the model further than the explicit simulation of the car sharing mode. Theoretically, this approach can be used even coupled with the simplest representation of the car sharing system, since the existence of the car sharing mode with its cost structure is a sufficient condition to implement it. However, it would probably make the interpretation of the results even more difficult, since the characteristics which could be varied by the operator agent would not be directly something like the number of stations, or cars, of the scheme, but the variable and/or the parameters of equation (2). If with such values a description of the model is definitely possible, the level of approximation implicit in this description make this more suitable to a qualitative discussion than to an optimization process.

A TEST CASE: THE AREA AROUND ZURICH

The work presented in this paper is part of an ongoing project which final goal is to assess the potential of a large scale car sharing system for the city of Zurich and the area around it. The project is not yet finished, and the car sharing mode has been introduced only in a simple manner. The way this has been done, will be explained in detail here below. Nevertheless, some test simulations have already been run and from the available output, even preliminary, some interesting results have already emerged.

The implemented Car Sharing System

The one presented here is the first implementation of car sharing within the MATSim framework. However some previous work (Ciari *et al.*, 2009) has already been achieved to introduce a new transport mode in the framework. In that case the newly introduced mode was collective taxi. This was modelled in the simplest possible of the above presented modelling options; this is, by introducing a cost structure for the taxi mode to which agents are able to react. The vehicles where assumed to be available to everybody, always, and everywhere. A system like this is able to capture consistent shares of the simulated travellers, but obviously is not much realistic. For the representation of car sharing it has been possible to accomplish some further steps, obtaining a more realistic model. The main features of the modelled system are:

1. Car sharing is available to everybody having a driving license (no membership is needed)
2. Agents can pick up and drop off car sharing cars only at predetermined spot
3. It is assumed that agents are walking to the pick-up point and from the drop off point
4. This is a one-way system; agents need to drop off the car they used at the nearest station to their destination
5. An unlimited number of cars are available at stations (no reservation system, every agent trying to use car sharing will find a car at the station)

These system's features translate in the following model's features:

1. During the simulation all agents with a driving license may try to use car sharing on any leg
2. Car sharing Stations with, a precise location, are added in the system
3. A car sharing leg is made up of three sub legs, two walk legs (from the start link to the starting station and from the arrival station to the destination link), and a car leg (from the starting station to the arrival station)
4. Car sharing cars are not properly simulated. However, the route is assigned with the same router as for the mode car, and the travelling time is calculated on the congested network.

The choice of assuming a one way system was necessary because of the absence of a reservation system.

The simulation scenario

The set up of a simulation scenario is a complex task, involving the integration of different data sets. The description of this process is beyond the scope of this paper, more information on it can be found in Ciari *et al.* (2007). The scenario used here is a "Greater Zürich" scenario. The scenario is a subset of the Swiss scenario, and covers and area of about 2800 km^2, obtained drawing a 30 km circle around the "Bellevue" place in the centre of Zurich. This scenario is built with geo-coded data from the year 2000 census of population (agents, households, commuting matrices), the year 2000 census of workplaces (facilities by type and capacity) and the national travel survey for the year 2005 (477 types of activity chains / 9429 types of activity chains with duration classes; eight classes of agents by age and work status are distinguished). This area has approximately 1 M inhabitants, note, however, that in the scenario are included also all agents having plans where an activity within the area is scheduled or agents simply crossing the area. Also transit traffic through the country is included; it was generated with the relevant border survey data. Those crossing the study area or entering/leaving it are represented by agents with a plan including either the single observed trip (for transit traffic) or two trips (for e.g. commuters from outside Switzerland). A map of the scenario is presented in Fig. 2.

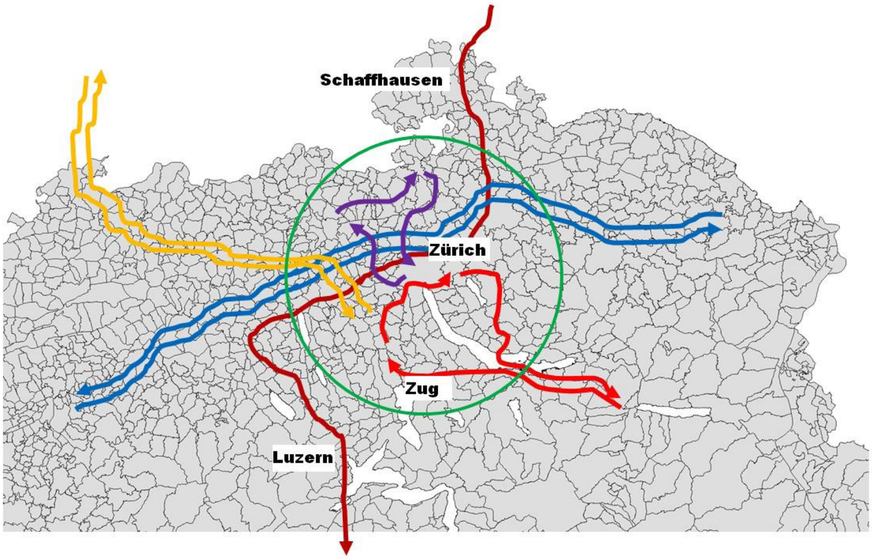

Figure 2 – Map of the Greater Zurich scenario (green circle) with graphic representation of examples of the plans included in the scenario.

The road network model has more than 236.000 directed links and more than 73.000 nodes; it is obtained from the data of the Teleatlas navigation network. The number of facilities for out-of-home activities is 373.155. MATSim specific subdivision of activities, including 17 different types is used. Those activities are basically all the activities which are possible entries in one agent’s plan, and are subcategories of the four main categories: work, education, shop, and leisure. The transport modes allowed are: car driver, public transport, bicycle, walk, and car sharing. To this scenario have been added 276 car sharing stations, representing the locations where an agent is allowed to pick up a car sharing car. The locations are actually the real locations of the Swiss car sharing operator Mobility in the concerned area. Mobility car sharing is the only operator in Switzerland and one of the leaders worldwide in terms of number of customers. This obviously adds a lot to the reality of the simulation, even if the number of available cars at the station and the whole reservation system are not modelled. For computational reasons the simulation is run on a 10% sample of this scenario, which means that for this scenario 161.810 agents are simulated. All of the described dimensions stay the same, except the network capacity which is also scaled (each link’s capacity is set to 10% of the original capacity) in order to have realistic traffic flows on the network’s links. In this sample the number of agents crossing the study area while transiting Switzerland is 5’791, linked to 880 home facilities outside Switzerland.

With the computer used for the simulation (3 cores, 40G Ram) the 10% sample scenario takes about 10 hours of computing time for a simulation of 50 iterations.

Results and discussion

The implementation of the car sharing mode is currently still simple while, on the contrary, many parts of the model are much more refined and would invite to advanced analysis exercises. This basically means that the results presented here are by no means to be intended as an ultimate answer to the question of car sharing potential's dimension in the studied area. However, at that stage of this project, some of those analysis are a precious instrument to understand what still need to be improved in the model and what is already working fine. Moreover, since the methodology used here, agent based modeling, is quite new for the assessment of unconventional modes of transports, it is important to show which kind of analysis are possible with this tool. In this sense, the most that can be asked to the current results of the simulation is to appear reasonable and consistent with the assumptions made. To assess what is "reasonable", it is useful to estimate "ex ante" in which range the share of the car sharing mode could fall. Since the car sharing system implemented in the simulation is not the same as the real one of Mobility, a difference in this figure is to be expected. In order to understand which difference can be plausible we can try to list the characteristics of the simulated car sharing which are expected to be important factors determining the number of users.
Factors which are expected to pull up this number are:

1. The number of cars at station is unlimited. This implies that adjusting the daily schedule to the availability of the car sharing car at a certain time of the day is unnecessary.
2. All persons having a driving license can access the system, membership is not modelled

Factors which are expected to pull down this number or expected to have contrasting impacts:

1. Monetary costs of car sharing are not modelled. The station-to-station car leg which is part of the car-sharing leg is handled as a normal car leg. This means that, since two walk legs are coming in top of that, generalized costs for car sharing travel are, in general, higher than for car travel (because walk is slower than car travel).
2. The eventual necessity of using car sharing for some special transport, which would be not possible with the own car, is not modeled. This might restricts the use of car sharing to non car-owners in the simulation.
3. The obligatory one-way use of the system will allow, on the one hand, for using car sharing even in cases where a long activity is involved. On the other hand, trips with a destination which is far from any car sharing station will unlikely be car sharing trips.

All in all, it is to expect that factors implicating a higher share of the car sharing mode in the simulated world are predominant. This should push up the number of car sharing users;

however, it seems plausible that car sharing will keep being a niche product, since with the present implementation only agents starting a trip near to a station are expected to find attractive car sharing. Considering that car sharing now in Switzerland is the chosen mode in less than 0.1% of the global trips (Haefeli, 2006), a share between this figure and some few percent points can be expected.

The results, shown in Fig.3, have been obtained simulating the service scheme in the 10% sample of the Greater Zurich scenario. The shares of the transport modes for the two alternatives, with and without car sharing, are showed together with the shares extracted from the Microcensus.

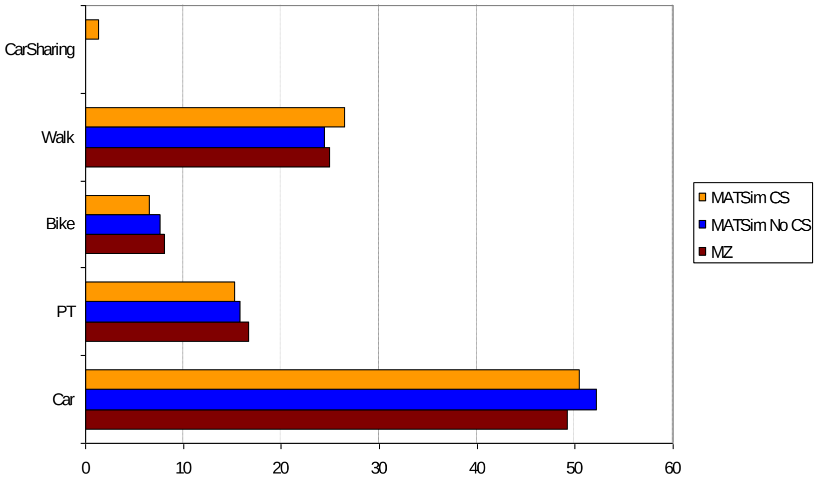

Figure 3 – Shares of the transportation modes for the simulation scenario “Greater Zurich” with and without car sharing, and real shares from the Microcensus

The shares are measured as the percentage of the trips travelled with a certain mode, disregarding the distance travelled. The share of travellers using car sharing for their travel is 1.3%, which can be considered consistent with the expectations. An interesting further insight is the typology of persons using car sharing with respect to car availability. In the Table 1 it is shown how many trips have been travelled with car sharing according to the total distance walked by the agent (distance from start point to start station plus distance from arrival station to destination point) and its car availability. Distance intervals have been chosen in a way that each interval includes 20% of total car sharing trips.

Table I – Number of car sharing trips with respect to total walk distance and car availability

	Distance (m)				
Car Availability	<270	270-390	391-512	512-692	>692
Always	817	787	784	736	733
Never	360	377	428	474	566
Sometimes	362	375	326	327	241

The number of trips made with car sharing by agents having a car always available is surprising high, but it is interesting to note that this figure is going down as the distance to be walked is going up. The opposite happens for agents never having a car available while agents having the car available only sometimes are more constantly distributed among distance classes. This seems a logical result, agents having the car always available will compare the car sharing option with the car option, and the first will be attractive if walk distances are negligible. Agents without access to a private car will compare the car sharing options with other, slower, modes (like public transport) and are ready to walk more in order to use car sharing, but if the distance is not long they will prefer cheaper modes (like walk or bicycle). In average, the total distance walked, which is 590m for agents with car availability “never” falls to 496m for agents with car availability “always”. Finally, a further confirmation of this mechanism comes from the relationship between walked distance and travel time. Most of shorter car sharing trips, of 12 minutes travel time or less, which are travelled by agents with car always available, are implying a really short walk distance. About 45% of those trips imply less than 270m walk distance and about 88% less than 512m (the marks for the first and the third distance bin of Table I respectively).

CONCLUSIONS AND OUTLOOK

This paper reported on ongoing work aimed to develop a simulation tool which should be able to assess the potential of a large scale car sharing system in an urban area. The main motivations for the implementations of such a system, which are of environmental and of social nature, has been presented. The work is still on an early stage; and the modelling and estimation of a large scale car sharing system was beyond the scope of this paper. At the moment, the focus was more on the methodological side. It has been shown that the methodology described can help in substantially improving the potential estimation for new transport modes. This is a very flexible approach and the number of modelling details which can be added is virtually infinite. It has the potential to represent the system at the microscopic level, even when simulating a large scale scenario, permitting an accurate study of the feasibility of the system, both in technical and in economical terms. Of course, what it can be hard to understand is how far the estimated potential, which could be called theoretical potential, can be effectively being exploited in a real life situation. This can be achieved only getting in confidence with the tool and testing it with different modelling options and scenarios. For the time being, it was important to show that agent based modelling is a realistic option for the modelling of such a system and to provide a first operative example of it. The introduction of the car sharing mode in the agent based simulation toolkit MATSim described in this paper, even if in a simple way, is a necessary premise for any kind of more sophisticated modelling approach, and gives the precious opportunity to test the behaviour of the system. The car sharing system modelled, a one-way system, accessible to all car license owners, and with costs equalling those of car travel, have been the chosen mode for 1.3% of all trips in the simulation. It has been shown that this result can be considered in line with the expectations, given the specifications and the level of detail of the model. This is much higher than real car sharing use, but still not properly large scale (Ciari *et al.*, 2009). The future work on this project will be focused on both, performing further analyses and improving the modelling side. The simple analyses performed so far were only considering the demand, since the goal was to demonstrate that agents in the simulation react reasonably to the characteristics of the car sharing system. However, to prove how realistic the modelled system was, it will be necessary to check the number of cars effectively picked up and returned at each station. Since the reservation system has not been modelled, it has been assumed that a station will be always able to satisfy the demand, whatever the demand will be. This means that it might be counted “ex post” how many cars has been picked up and returned to each station during the day and, consequently, compute how many cars would have been necessary to fulfil the demand, both globally and locally. This is important because it will be possible to understand how much each car is effectively used and will give a first hint on the profitability of the additional capacity provided to the system. The model could be improved in many different ways. The most straightforward one, and thus the one which will be attempted next, is the introduction of explicit monetary costs for the transportation modes. This is expected to allow for a more realistic modelling of the modal split and in particular the choice between car sharing and private car (for private car owners). In fact this will show which agents might have an interest, in an economic sense, in adopting this transport mode, for a given level of price. The simulation of the reservation system, reproducing the effective availability of a car at a given moment and station, will add further realism, but this probably the most challenging aspect to be modelled and will be considered only in a long term perspective. Another important aspect of the large scale use of car sharing would be the effect this would have on parking needs. At the moment parking is not explicitly simulated in MATSim, and its modelling is beyond the scope of this project. This is being developed in some parallel work, and will be used as soon as it will be available. However, already now it would be possible to deduce some effects from the use of car sharing, and this approach will be attempted for the next simulation experiments. Finally, also in the long term perspective, the modelling of the car sharing operator as an agent will be attempted. This is expected to help in finding new solutions for the large scale car sharing system, eventually including also counterintuitive ones, allowing for a better understanding of the interactions of the different modes in the transportation system. But it will be also an important step to have an always more complete and flexible modelling framework, enhancing the palette of scenarios which can be modelled with the MATSim toolkit.

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