Concepts for a large scale car-sharing system: Modeling and evaluation with an agent-based approach

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ABSTRACT

This paper is aimed to renew the debate on car-sharing and its future development. The recent worldwide success should not hide the fact that car-sharing is still a niche product. There is agreement that car-sharing produces benefits for the transport system, the environment and the society. However, the scale of such benefits is minimal. This is a reason to attempt the implementation of a system at a much larger scale. A car-sharing scheme of this type is sketched and some concepts on which the system would be based are suggested. They are the capillarity of the system, its flexibility and its integration with other urban mobility tools. For the future implementation of such a scheme it is crucial to find a methodology which would be able to realistically assess its potential. Reviewing the methodologies used so far to investigate car-sharing potential suggests that the adoption of an agent based approach might be the right answer. A framework to model a large scale car-sharing scheme with such methodology is proposed in the context of MATSim-T, an existing agent based traffic micro-simulation tool.
INTRODUCTION

The car as an individual transport mode can be interpreted at least in two ways. It is individual because one is free of using it individually and has a complete control over the destination and the route, or because it is individually owned; both 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 individually use a transport mode - one needs to own a vehicle. This partially explains why car ownership is so common in our society. Simply to walk around in a western city should be enough to make us aware of the high inefficiency of this approach. Parked cars are - in principle - mobility instruments waiting on the curb side for someone who finally will 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 to share cars among a group of users is not new. The concept of car-sharing has been around for decades before first successful and durable practical implementations of car-sharing appeared. The Swiss operator Mobility and the German Stattauto, are not older than 20 years (1, 2). Nowadays, car-sharing schemes are increasingly popular and their number is growing around the world (3). Still, all these applications, even if producing appreciable results, are working at a completely different, smaller, scale than the problems they are supposed to confront. This paper is aimed to renew the debate on car-sharing and its future development. In particular this paper addresses two problems. The first is the scale of a car-sharing system arguing that most of the benefits usually attributed to car-sharing would be tangible only with implementations of the system at a much larger scale than those current now. For this reason a car-sharing scheme appropriate to that much larger scale should be envisaged. Aiming to investigate both the potential and the feasibility of such a large scale car-sharing, there is a second issue; a methodology needs to be found which can be successfully used for the planning and evaluation of this task. Traditional transport modeling methods have
already been found to have drawbacks forecasting car-sharing potential or, more in general, the public’s reaction to a new mobility option (4, 5). Here an agent based simulation approach is proposed in order to overcome such problems. With such an approach it is possible to predict the potential of a large scale car-sharing system for a given scenario, and evaluate its operational feasibility. Moreover as this approach is modular and thus flexible, other analyses can be performed in the future, like the evaluation of policy impacts or the estimation of societal costs and benefits of different car-sharing scenarios.

The paper is organized as follow. In the next section the state of the art of car-sharing will be shortly presented and the scale of benefits attributable to car-sharing discussed. It is followed by the design of a large scale car-sharing system. Section 4 is dedicated to a reflection on methodologies already used to evaluate car-sharing. In Section 5 the reasons for using an agent based approach are discussed and a possible modeling framework of the system is outlined. This draws on the multi agent traffic simulation toolkit MATSim-T (6). The paper closes with conclusions and an outlook on the future work.

BACKGROUND

**Car-Sharing: short History and state of the practice**

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 (1). Various other schemes were implemented during the ‘70s and the ‘80s, but most of them were at a very small scale and none of them survived (7). Only at the end of the ‘80s the concept eventually found its way to a larger public with new programs which are still operative today. The basic concept of car-sharing has evolved in many different ways throughout the world. However, there are characteristics which are recurrent in most of car-sharing programs. Over time for profit organizations have emerged as the prevalent form, non profit organizations are less common but still existing, notably when some kind of public authority
is directly involved. “Neighborhood car-sharing” (8) is the predominant operational model. Vehicles are located at parking facilities which are distributed throughout a region. The core idea is to conveniently serve a set of members living in the neighborhood of the station. The concept is usually coupled with the obligation for the customer to return the car to the same spot. Services like instant access, one-way trips, open ended reservation, etc., go beyond this basic scheme, but they have found only sporadic applications (9, 10). Private users still constitute the bulk of the customers of car-sharing, but business users are considered by some (11) 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 which 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. But in most cases the type of fuel is not an important attribute of the car. In North America and Asia the combination of the car-sharing with LEV (low emission vehicles) is more common (12). 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 by phone.

Car-Sharing impacts
The following discussion is meant to give an idea of the order of magnitude of the benefits which can be imputed to existing car-sharing systems. There is already an important corpus of literature assessing the benefits of car-sharing for individuals, the transport system, the society and the environment. Some of the assessed benefits are based on direct evidence, others are more speculative. The issue is widely discussed in the car-sharing literature (e.g.
The scale of the benefits depends on the scale of the car-sharing operators (in terms of car fleet and users). For example, consider Mobility Carsharing in Switzerland, the biggest operator in Europe (14). Mobility is operating across the whole Swiss territory with a fleet of about 2000 cars, which is 0.05% of the global Swiss car fleet. 1.2% of driving license owners are customers. The share of travelled kilometers for car and public transport in Switzerland are 50% and 20% respectively (15). The average consumption of its fleet is about 20% below the Swiss average. In accord with evidence collected in other studies (13) a substitution rate of 5 (one Mobility car substitutes 5 privately owned cars) is assumed. The balance between induced trips and avoided trips is assumed to result in a reduction of 20% of car trips in the car-sharing/no car-sharing scenarios. It is also assumed that substituted cars had an average gas consumption and that customers were using the car at Swiss average before to joining the program. Finally, average parking construction costs are supposed to be 10% of housing development costs. With these assumptions, simple computation results in the estimates reported in Table 1. Note that such values are not intended as the best estimates of benefits due to Mobility in Switzerland, even if probably they are near to that, but as indicative of the benefits that a car-sharing scheme of this size produces. In this sense note also that local effects are in general bigger.
TABLE 1
Quantification of car-sharing benefits

<table>
<thead>
<tr>
<th>Category</th>
<th>Type of Benefit</th>
<th>Main Assumption</th>
<th>Relative change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport System</td>
<td>Lower parking demand</td>
<td>Fleet = 0.05% of global fleet</td>
<td>- 0.20%</td>
</tr>
<tr>
<td></td>
<td>More fuel efficient vehicles</td>
<td>&quot;</td>
<td>+ 0.05%</td>
</tr>
<tr>
<td></td>
<td>Less vehicle travel</td>
<td>Before joining car travel in the average</td>
<td>- 0.24%</td>
</tr>
<tr>
<td></td>
<td>More public transport ridership</td>
<td>&quot;</td>
<td>~= + 0.5%</td>
</tr>
<tr>
<td>Environment Society</td>
<td>Lower Emissions</td>
<td>Efficiency = +25%</td>
<td>&lt; - 0.5%</td>
</tr>
<tr>
<td></td>
<td>Cost saving for housing development</td>
<td>Cost Parking = 10%</td>
<td>- 0.02%</td>
</tr>
<tr>
<td></td>
<td>Less Congestion</td>
<td>-</td>
<td>Not detectable</td>
</tr>
<tr>
<td></td>
<td>Better urban design</td>
<td>-</td>
<td>Not detectable</td>
</tr>
<tr>
<td></td>
<td>More compact development</td>
<td>-</td>
<td>Not detectable</td>
</tr>
</tbody>
</table>

Based on (13) and (14).

Scaling up car-sharing?
Positive effects of car-sharing systems at the scale they are operating now are minimal. Intuitively, that speaks in favor of an implementation of the idea at a much larger scale; with matching benefits. Note, however, that at this point one cannot be sure that all effects are scalable. The increase of some effects could be more or less than proportional to the size increase. For example the reduction of parking needs is related to the fact that some customers joining car-sharing generally sell the car they owned. The decision to give up the car because of joining car-sharing is basically a personal decision and the idea that the substitution rate shared car/private car does not depend on the scale seems sound. But if the
reduction in car ownership would become more visible in the community, it might be that more persons would be ready to do the same. In this case an increase of the benefit would results. For other benefits the opposite might happen, or the result might be simply ambiguous. For example it is hard to imagine which effect car-sharing implemented at a large scale would have on the balance between avoided/induced car trips. However, what is important to point out here is that car-sharing impacts, even those based on well documented data, are small and depend on the scale of system, be that the number of shared cars, the number of customers or the distances travelled with shared cars. This strongly supports the idea that car-sharing should be implemented at a much larger scale in order to obtain noticeable benefits for the transport system, society and the environment. To define what “large scale car-sharing” means is somewhat arbitrary since the main concept remains the same. Here it will be defined as a scheme whose fleet would account for at least 5% of the relevant global fleet, that is a factor $10^2$ bigger than the current biggest scheme. Similar definitions, also arbitrary, could be made in terms of distance travelled or number of customers. Such a large system might seem hard to realize. The investment would be huge. But the necessity of a substantial shift in people’s travel behavior might become ever more urgent. The success of the bike sharing experience in Paris (16), however, is encouraging. Even if the transferability of such results to car-sharing must be assessed cautiously, it demonstrates that if a system of large size is put in place and appropriately advertised a dramatic and rapid shift in travel behavior may happen.

A LARGE SCALE CAR-SHARING

In this section some ideas for a large scale car-sharing system are presented. Issues related to the scale of the scheme are also discussed here.

Concepts

Three concepts are proposed on which a large scale car-sharing system would be based: *capillarity, flexibility and integration* (with other modes).
Capillarity
A convenient access to the system is overall one of the most important factors behind the satisfaction of car-sharing customers (13). A higher capillarity of the system can better capture all the potential demands by increasing the number of potential users having convenient access. At its extreme, every single shared car would be a station. A similar concept is already suggested in (9), where the possibility to return the car within a given zone is called “Floating Fleet”. The access time to the system is part of the generalized cost of a trip, and a dense distribution of shared cars throughout the service area would reduce this part. This will make car-sharing more competitive with privately owned cars which are generally available at the home end of the trip. Note that capillarity is not to be confused with the scale, in terms of number of cars and stations of the car-sharing system. It is rather assumed that for a given scale a higher capillarity would help the system to meet demand. In practical terms, this translates in trying to reduce the size of stations, i.e. the number of cars parked in the same slot - in particular for residential areas - and distribute them in order to match the demand from as close as possible.

Flexibility
Car-sharing has already been called the “missing link” of transport supply in terms of flexibility (17). Nevertheless, the system is less flexible than private cars. Some constraints apply like returning the car at the pick-up station or the need to schedule the time interval prior to usage. New services can increase its flexibility and make car-sharing become attractive for different trips purposes and customers groups. The flexibility should be improved along the space and time dimensions. Space means, that the constraint to return the car at the pick up station would be relaxed. The most obvious policy is to allow the return to another station, which may be or not fixed in advance. The concept of station would dissolve in a system where it would be possible to pick up and return a shared car everywhere in the area served. On the temporal side the flexibility could be enhanced by instant access of an available car, and open end, i.e. without advance temporal limits. Both these services where
successfully tested in an experiment in Berlin (9). A similar experience, which lasted six years, ended recently in Singapore because of management problems (18). In both cases the network was relatively small, making hard to draw conclusions about an eventual application at a much larger scale. To the best of our knowledge such services are currently not available in other existing car-sharing schemes. Combining extreme flexibility with extreme capillarity would result in a system of “public cars” which could be picked up and returned at every point of the service area and without time constraints.

Integration with other modes

It is implicit - behind the idea of a large scale car-sharing system - that car-sharing should substitute a considerable part of private car use. Flexibility is one of the most recurrent arguments when it comes to justify the use of private cars against other modes of transport. It has already been discussed how the flexibility of car-sharing might be improved. But not all trips made with a car actually need the corresponding degree of flexibility. In order to make the car-sharing more attractive, but also in order to limit the use of a shared car only when really needed, the scheme should be integrated in the transport system and not only seen as an alternative form of car use. The transport system should be conceived in a way that all mobility needs of the population can be met without making use of private cars. This can be realized if the different operators of the transport system collaborate to create a mobility supply which gives seamless access to different modes. The possibility to include car-sharing in “mobility packages” has already been discussed (19), and some attempts to go in this direction already exist, especially in Europe (11, 20) where public transport usage is traditionally higher than in North America. The literature documents that car-sharing customers tend to switch from car use to other modes, in particular to public transport. It was shown above that at present scale, the increase in public transport ridership is minimal, and the additional demand can be absorbed by the system easily. However, if the scale of car-sharing increases and the increase in public transport use becomes significant, this transfer can work only if the public transport supply is increased when and where needed.
In order to meet the demand better, car-sharing could be integrated also with other systems than public transport. Since car-sharing does not improve the occupancy rate of cars in principle, customers could be incentivized to car pool through tariff reductions. That would reduce the system needs in term of cars and would have beneficial effects if car-sharing is used for commuter trips, reducing imbalances which otherwise would occur. For such type of trips collective taxis can be also envisaged as a solution further reducing the risk of imbalances. Bike sharing - a system which is becoming increasingly common in Europe in recent years, is also complementary to car-sharing. Their use might be combined for some commuter trips, especially if the trip passes both through suburban and urban environments. Or they might be used for shopping trips, where the trip back could be with car-sharing to carry any heavy load. Integration possibilities with other traditional systems, like taxi and rental car have already been discussed elsewhere (21).

To resume, a large scale car-sharing system should be well integrated in the transport system exploiting the possibility of complementary use of different modes, be that in the sense of multimodal travel or different modal choices for different purposes. This use should be incentivized facilitating the access to the whole transport system, for example, employing a single smartcard which would provide access for all modes and would be charged according to use.

**Operational issues**
The implementation of a large scale car-sharing scheme raises new issues which were only marginal for traditional car-sharing schemes. Albeit the location of stations was already an important theme before, the methodology of their location was relatively simple (13). Basically a promising area was identified and a station location was picked opportunistically (i.e. where some free space was available, where it was possible to obtain dedicated parking, etc.). No particular thoughts were needed regarding the distribution of stations throughout the whole service area, since each station’s operations were self containing and operations at other stations were not a real concern. In a system which has the ambition to be ubiquitous
this approach is no longer possible. The distribution of stations throughout the area is a key aspect for its success because it influences its capacity to effectively capture the whole potential demand. Moreover, some operational aspects are depending on this; the introduction of one way service potentially causes imbalances at the stations during operations. In order to maintain the system operative such imbalances need to be managed by the operator trying to limit them with appropriate price policies and by relocating cars. This latter operation may imply substantial costs and make the profitability of the one way service doubtful (22). Some solutions for this problem have been already proposed (23, 24, 25). Ideally the distribution of stations should be such that these costs are minimized. Overall the distribution of stations should be optimized according to the two criteria discussed.

EVALUATION OF CAR-SHARING: METHODOLOGICAL ASPECTS

The car-sharing scheme sketched above is assumed to have characteristics which would permit its development at a large scale. The implementation of such a scheme in the real world would imply substantial investments and a central question would be the assessment of its real potential. There is also a more general question of the assessment of car-sharing potential, since many studies have already dealt with this topic but none of the proposed methodologies has proven reliable so far. In fact car-sharing had an impressive growth in the recent years (and still has in many countries) but it is still a niche product and it is yet unclear how large the diffusion of the system could be in the future. The majority of past estimates of its growth potential were too optimistic and used very simple methods indeed (for a comprehensive discussion see 13). In recent years some more sophisticated approaches have been proposed (see 4, 14, 26). Such studies use cost considerations in order to assess the utility of car-sharing against other options. They constitute a considerable step forward compared with previous approaches, nevertheless, Shaheen and Rodier observe that a tool allowing for the evaluation of more complex scenarios would be a priority in order to obtain more reliable results. They also suggest that a more precise representation of the services
would be desirable, and that the lack of tools to evaluate innovative mobility service/policy effects could be a barrier to their implementation on a regional level. A more precise representation of the service means, for example, high spatial and temporal resolution because access time to the service is a fundamental parameter in customer choice. An explicit representation of trip chaining of individuals would allow detecting who could meaningfully use a shared car in his/her out-of-home tour. For this, a representation of travel at the individual level with explicit modeling of modal choice would be necessary. The representation of individual travel needs would further increase the precision of the model (shopping, work, leisure, etc.).

Another important aspect is that car-sharing is not a new concept anymore, but also far from being a familiar one to many people. It has already been shown that even in areas where a car-sharing operation is active a lack of information can substantially reduce the potential of the system (27). This last issue is even more relevant when it comes to the modeling of an innovative implementation of the concept. A possible way to overcome those problems would be to broaden the range of instruments searching beyond the set of tools traditionally used in transport sciences. This is suggested for example in (28), where it is pointed out that some social science concepts could help understanding the customer’s reasons to adopt car-sharing. Of particular interest is the idea that the diffusion of car-sharing could follow the general diffusion paths of new products. The likelihood of adoption of an innovation would depend then on the potential adopters’ perception. The individual evaluates the advantages of the adoption, the soundness of the product against the individual’s needs and self perception, its complexity and the possibility to try it without costs. Finally, the speed of diffusion of the innovation is in itself an important consideration, because it demonstrates its longer-term viability. This is in accord with the classic work of (29), where the S-shaped curve for the diffusion of innovations is introduced. In this literature the existence of a critical mass in the diffusion of innovations is discussed. The presence of this critical mass is related to the idea of network externalities. That is an additional utility for the persons using a new product,
directly or indirectly, if the diffusion of the product continues. The utility of car-sharing adoption by a single individual does not depend directly on the global number of adopters. However, it can be argued that indirect externalities do exist since a higher number of adopters correspond to a possible increase in the number of services and in their quality. One additional useful concept can be drawn from the literature about product service systems. In (30) is observed that the socio-cultural situation in which a sharing system takes place is a crucial aspect for its success and thus the scale it can reach. In many society renting and sharing is associated with low socio-economic status, personal sacrifice in freedom and excessive complications in scheduling of daily life while in other society it is very common. Thus, the socio-cultural situation is important for understanding if individuals are ready to modify their behavior and suggests the predisposition of a society to adopt new products or services.

The list of concepts drawn from other disciplines which are useful in assessing car-sharing potential could be even longer. Indeed, the goal here was to show that an ideal tool to achieve this task should allow for a very rich description of both, individuals and the car-sharing scheme, as already suggested in the car-sharing literature, but should be also flexible in order to account for other aspects, which are usually not considered and hard to model with traditional approaches but might be important obtaining a reliable forecast of the diffusion of a large scale car-sharing and of car-sharing in general.

AGENT BASED MODELING OF CAR-SHARING

It is suggested that agent based simulation might be the tool which permits to address most of the issues discussed in the previous section. Agent based simulations are computer based approaches where the actors of a system are encapsulated software entities capable (in various degrees) of acting in an environment, communicate with other agents, pursue a set of objectives, perform goal-directed learning, behave autonomously (31). In transport their use is becoming more popular and quite a few examples of agent based approaches can be found
in the literature (32, 33, 34, 35, 36). The main advantage that agent based modeling has against traditional modeling is the fact that each traveler is simulated individually permitting a rich description of the demand side. The agent paradigm can be extended also to the supply side of the transport system allowing for an even richer representation of the whole system. Agent based modeling is suitable for modeling rational choices. But agent based modeling has the advantage to be a bottom-up approach. Behavior rules for the agents are defined at the individual level but the global response to different scenarios is the result of both the individual reaction to such measures and of the interactions among individuals. The objective function can be modified in order to take into account other aspects which are not of economic nature. Social contacts may be also modeled, and can bring new knowledge to the agent, modifying its behavior. In conclusion, agent based modeling is suitable for a rich and high resolve description of the whole system, is suitable capturing complex interactions if they occur and can also model aspects which are not considered in traditional approaches. All this allows for the test of many different, eventually complex, scenarios.

This section describes how individuals and the car-sharing system can be modeled in an already existing agent based traffic simulator in order to obtain a convenient tool for the assessment of car-sharing potential. The simulation tool is MATSim-T (6, 37, 38). So far, MATSim-T is a fast dynamic microscopic transport model. Its most prominent application is a simulation of the travel behavior of the whole Swiss population, where 7.6 millions of individuals are travelling on a network with 24,000 nodes and 60,000 links. 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 for individuals a derived necessity, in relation with the primary need of individuals to perform certain activities during the day. Therefore, for each agent a plan (daily schedule) is generated. 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 activities are listed, but 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. More details can be found in (39) and (40). 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, while creating new plans based on their previous experiences. Trying to improve their score, the agents can choose the time when to leave from home and the route to concatenate all activities. The system iterates between plan generation and traffic flow simulation until a relaxed state is reached. The core idea of MATSim-T is that each single actor of the transport system, both on the supply and the demand side, can be simulated according to the agent paradigm. In the current version each traveler of the real system is modeled as an individual agent while the supply side is modeled as fixed constraints of the system. Both representations need to be updated in order to model the large scale car-sharing system.

**Individuals**

The agents’ objective is to maximize their score, where the only variable taken into account is time, with a positive value when it is spent in an activity and with a negative value when it is spent for travel. Presently the mode choice module simply assigns a transport mode to each agent using a logit model which depends on the socio-demographics characteristics of the agents and the distances involved in turn. Car-sharing is not considered as an option. Agents are not allowed to modify the choice of the mode when trying to improve the score. In other words mode choice is not optimized but fixed at the start of the simulation. A new mode choice module needs to be introduced during the optimization stage of MATSim, where monetary costs are explicitly considered and agents seek for the maximum satisfaction within the budget constraints. Such modifications would allow assessing the car-sharing potential in terms of a rational economic choice. MATSim agents optimize their scores retaining some old plans, comparing them, and choosing the best one. Other aspects of the decision process, not strictly of economic nature, can be also accounted for integrating models coming from other disciplines in this base framework. In the case of car-sharing, as
an innovative product, things like the contact with other persons already knowing/using the scheme and the level of advertising for the scheme might be modeled. The probability to choose an option or another can be set to reflect socio-cultural conditions and socio-economic attributes. A last aspect which needs to be considered is car ownership. The car-sharing literature agrees that car-sharing customers’ disposal of the private car is not simply related to the participation in the program but often triggered by a personal event (divorce, move, changes of employment). In the actual implementation of MATSim the car ownership is fixed, as the other socio-demographic attributes are. A module is needed which would, after a given number of iterations, modify socio-demographic attributes of persons and car ownership accordingly.

**Car-sharing operators**

A new agent representing the car-sharing operator has to be introduced in MATSim. The car-sharing operator agent is the decision maker having the control of the whole car-sharing system and is able to modify its characteristics. The agent does not necessarily represent an individual. For example it might also be the board of the company. The car-sharing operator’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, or its profit or the 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 the financial feasibility of a solution would have to be evaluated a posteriori. The dimensions on which the agent will be allowed to act are:

- the fleet (number of cars and composition)
- the stations (number and location)
- the price schedule (price level; distance and time dependency)

The type of services offered (open end, instant access, etc.) is considered fixed for a given scenario and thus not modifiable by the agent from iteration to iteration. The pricing
structure (prices for the different services, special conditions, etc.) will be also part of the scenario constraints and not be managed by the agent. This is basically to avoid excessive complexity of the system.

The composition of the fleet has an influence on the type of demand which can be satisfied, in particular regarding the activity which the individual wants to perform. In the current MATSim implementation only four different out-of-home activity types are distinguished which are work, education, shop and leisure, which means that agents could only marginally appreciate this aspect. However, it is logical, activity of different types, i.e. leisure and shop, might call for the use of different car models, but also within a same activity category, i.e clothes shopping downtown and furniture shopping in the city outskirts, different car models would be necessary. With a finer specification of activities agents will be able, at least to some extent, to choose the car which fits the planned activity better. The locations of stations determine which part of the demand can be conveniently served, but also the generalized cost of the walking to the station. If one car of a given station is used below a given threshold the operator in the next iteration will displace the car to another station, or will open a new station with this car. The concept of capillarity can be approached giving limits to the size of stations in residential areas. In this procedure it might be considered that the opening of a station generates costs. The price level will be also an important switch for the operator. The logic behind is clear; the operator will try to attract more customers lowering the price within the limit, at least, to recover operating costs. 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, annulling the possibility to modify the others.
CONCLUSIONS AND OUTLOOK

This paper discussed the issue of car-sharing benefits. Even if their existence is undeniable it has been shown that car-sharing schemes at the scale they are working now have only very limited impacts on the transport system, the environment and society. This is the reason to reflect on the realization of car-sharing schemes able to capture a much larger number of customers or - as it is called here - a large scale car-sharing system. A system of this type has been sketched describing the concepts on which it should rely. The problem of its evaluation was discussed, both in terms of the assessment of the concrete potential and the representation of the operational side. It became clear that new methodologies are needed in order to conveniently evaluate large scale car-sharing, but also more in general, to overcome the drawbacks of the approaches used until now. It was argued that an agent based approach would be the right instrument for the evaluation for car-sharing systems. The section on agent based modeling presented first the basis of this approach and the reason of the appropriateness of the approach evaluating car-sharing in general and the large scale car-sharing in particular. Successive to this, more detail was given on which aspect of car-sharing can be modeled using the agent paradigm and, finally, an insight into the implementation of the agents. This part was sketched building on, conceptually, an existing agent based simulation tool: MATSim. This sketch was intended as a broad, even if not exhaustive picture, of what could be achieved modeling car-sharing within an agent based simulation tool. The choice of MATSim is explained with some of its most important features. It is flexible in the spatial resolution, any number of activity types can be represented, the consistency over activity chains during the whole computation is maintained, the modular approach makes it easy to add other agents to the system, and the optimization process is flexible to new aspects in the objective functions of the travelers. The next step will be a programming effort, aimed to obtain a first working version of MATSim where car-sharing is available for individual agents, and the system is modeled as fixed service. Even in this simple form the approach to car-sharing assessment is
substantially more sophisticated than most other approaches used so far. Next to this a fully
gagent based approach will be implemented. The car-sharing agent will optimize costs and
revenues, stations, number of vehicles etc., and customers react to the changing service. The
long term goal of this research is to evaluate the potential demand for a large scale car-
sharing scheme for the Zurich area using the fully agent based approach.
LITERATURE


