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Modeling Carsharing with the Agent-Based Simulation MATSim

State of the Art, Applications, and Future Developments

Francesco Ciari, Milos Balac, and Kay W. Axhausen

Extensive literature already exists on carsharing and other shared modes, but understanding their effect on the transportation system requires additional work. One main limit of the existing research is that such modes have been analyzed mostly as isolated systems. As these modes were niche products, it was not easy to include them in comprehensive models of transport, and, in a way, it did not even make sense. But the modes' current popularity and their expected growth completely change the picture. Transport model systems in which such mobility concepts will be explicitly modeled—along with all other modes—will be crucial in the near future to gain an insight into travel behavior effects and to assess possible future scenarios representing the effect of long-term mobility decisions. This paper describes how carsharing demand is modeled in an activity-based multiagent simulation of transport called MATSim (www.matsim.org). The paper draws from a series of papers written by the authors between 2009 and 2015 and is part of a research effort whose ultimate goal is to build a predictive and policy-sensitive model that can be used by practitioners and policy makers to test any type of carsharing scenario. This paper summarizes the work done, provides some examples of applications, addresses current limitations, and briefly reports on ongoing and planned developments.

In the past two decades, several innovative mobility concepts have been introduced or have experienced sustained popularity growth after many years of unsuccessful attempts to become a stable part of the mobility landscape. Several of them have been subsumed into the "sharing economy" (*1*). Concepts such as carsharing, bikesharing, ridesharing, or on-demand mobility services are today familiar to a large part of the population in developed countries (*2*). Several reasons have been cited as possible explanations of this phenomenon. A fundamental societal change toward an access-based economy, as opposed to ownership based, was hypothesized as early as 2000, and its (partial) realization has been enabled by successive waves of technological innovation allowing effective brokering and billing for shared resources (*3*). The diffusion of the Internet first, and then of mobile devices such as smartphones later, allowing for real-time exchange of information, certainly played an important role in this process. Such concepts can no longer be referred to as a "small niche" that is negligible in the big picture of urban transportation. Although their modal share is still modest in most of the locations where they are available, they are by now most assuredly an important and visible part of the transportation system in several cities worldwide. There is already extensive literature on modes—such as carsharing, ridesharing, and bikesharing—but the effect of such modes on the transportation system is not yet clear. One main limit of the existing research is that such modes have been analyzed mostly as isolated systems. As they were niche products—and to a large extent still are—it was not easy to include them in comprehensive models of transport, and, in a way, it did not even make sense to do so. But their current popularity, their expected further growth, and—perhaps most important—the possible integration of autonomous vehicle fleets in such concepts with all their possible implications completely change the picture. Transport model systems in which such mobility concepts are explicitly modeled along with all other modes will be crucial in the near future to gain an insight into the travel behavior effects and to assess possible future scenarios representing the effect of long-term mobility decisions. This paper tackles this issue, describing how the carsharing demand is modeled in an activity-based multiagent simulation of transport called MATSim (www.matsim.org). This paper summarizes the work done, provides some examples of applications, addresses current limitations, and reports on ongoing and planned developments.

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RELATED WORK

Carsharing has been investigated in a large number of studies, especially in the past decade, but modeling carsharing demand has been tackled only a few times. The work of Rodier and Shaheen was probably the first attempt to estimate carsharing demand and evaluate how different policies might affect it (*4*). However, they used a modeling framework that allowed only a very simplistic representation of carsharing. They observed that reliable tools for estimating innovative mobility services and policies were missing and overcoming this lack might be crucial for their success, but apparently the authors' call largely went unheeded in the carsharing community, at least until very recently. In the work of LeVine, for example, carsharing usage is forecast under different program specifications, station-based or one-way, for the city of London (*5*). On the basis of a very sophisticated stated choice exercise, he concludes that one-way carsharing would have a much larger diffusion in regard to membership and would generate more carsharing journeys. The main limitation of this work is that the model does not capture how the availability of the different carsharing options might reshape mobility patterns. A recent report by Kortum and Machemehl is a rare example of a model addressing free-floating carsharing demand estimation (*6*). The authors justify the use of rather simple regression

models based on spatial characteristics over other modeling options, that is, discrete choice models, with the low share of carsharing trips. The reasoning has some merit, and the method can likely reproduce modal share with a reasonable accuracy for the area studied and for any area in which a similar offer would be put in place. However, its application as a planning tool seems limited by the fact that it does not offer the possibility to test different carsharing schemes. A recent work by Repoux et al. used event-based simulation for optimizing one-way carsharing services with various relocation policies (*7*). And although the simulation proves useful for this kind of optimization, it suffers from the fact that the demand is fixed and not influenced by the change in the supply. Mendes Lopes et al. proposed an agent-based model for the investigation of carsharing services (*8*). They tested their method with the city of Lisbon, where the potential of one-way carsharing is estimated with a discrete choice model based on stated preference surveys. However, in the agent-based model presented, there is no learning process of the agents and it is unclear how (or even if) changing the supply side would affect the demand side. Heilig et al. proposed probably the first multiday, agent-based model for round-trip-based and free-floating carsharing (*9*). The contribution of this work is also important considering the problem of the unbalancing of one-way and free-floating fleets, which can be easily observed here. However, as they mention, high temporal and spatial resolution is still lacking to more adequately represent carsharing services.

METHOD

The modeling of carsharing demand is challenging, but necessary, for several reasons. Carsharing is one of the most well-known instances of the sharing economy and has recently experienced an extraordinarily fast evolution. The actors involved are increasingly large and include car manufacturers (Daimler and BMW), traditional car rental (Avis and Sixth), and public transport operators (DB Flinkster, owned by the German national train operator). The level of competition in the market is increasing as cities with multiple carsharing operators, once an exception, are becoming common in Europe and North America. One can therefore expect predictive models, instrumental for the optimization of operations and for demand estimation, to become more important. At the same time, the increased size and importance of carsharing suggest that it needs to be modeled as part of a comprehensive model of travel demand and not in isolation. Classic travel demand (four-step) models have evolved in a world dominated by car mobility. Public transit, buses in particular, was the only "competitor" for road infrastructure in most industrialized countries. It is no surprise that these models were typically taking only two modes into account: cars and public transport. Recent efforts account for other modes, that is, bicycle and walk, but integrating carsharing has not yet been attempted, not to mention free-floating carsharing. This approach is reasonable since despite its impressive growth, carsharing still accounts for a very low proportion of overall travel. This fact should not, however, hide the inherent limitations of traditional modeling tools to represent carsharing. The very nature of carsharing, the importance of its availability at precise points in time and space, does not fit with models using vehicles per hour flows, even more so for more flexible forms of carsharing. It is crucial to represent the availability of vehicles at the local level and therefore represent individual travel with high spatial and temporal resolution. In transport modeling, when it is important to represent time-dependent mobility patterns at an individual level, models are based on activity data. Travel is the result of an individual need to perform out-of-home activities at different locations. Agent-based modeling is a natural way to implement this paradigm. Agents are software abstractions acting in an artificial environment; they have learning capability and are goal oriented. Through this mechanism, multiagent models can deal with complex research questions concerning time-dependent spatial demand or variations in transport supply. This ability comes at the cost of being computationally intensive. In addition, the richness of detail does not imply the accuracy of the model, in particular at the microscale. It is important, however, that such a level of detail be possible because it allows introducing at the microlevel simple behavioral rules that determine the macrobehavior of the system. The key is to use behavioral rules that can be observed easily in the real world but are also fundamental enough to induce a plausible behavior in the agents, not only for a particular activity or for a particular mode of transport, but in general. This approach results in the important feature of showing an emerging behavior at the macroscale that is caused—but not directly implied—by the rules at the lower level. This property is the main reason that agent-based simulation is a suitable tool for modeling innovative transport systems in a situation in which a solid behavioral knowledge does not yet exist.

MODELING CARSHARING WITH MATSim

MATSim: A Short Overview

MATSim is a fast, dynamic, agent-based and activity-based microscopic transport modeling tool kit (*10*). The basic idea is to let a synthetic population of agents act in a virtual world. The synthetic population reflects census data, and the virtual world reflects the infrastructure, such as the road network, land use, and available transport services and activity possibilities. Each agent has its daily activity plan, which describes the chain of activities that it needs to perform in the virtual world. Each agent tries to perform optimally according to a utility function that defines what is useful for an agent. One virtual day is iteratively simulated. From iteration to iteration, a predefined number of agents are allowed to change some of their daily decisions to try to obtain a higher utility. The iterative process continues as long as the overall score of the population increases. The equilibrium reached represents what real individuals do in the real world. MATSim is a tool kit composed of different modules. Each module is responsible for one part of the whole process. A module can have an underlying model (e.g., the traffic simulation and the mode choice) and can work together with—but also independently from—other modules. In this sense, MATSim can be seen as a comprehensive, flexible framework that simulates the daily life of people and produces travel demand as a side product. Each agent has sociodemographic attributes, such as age, gender, occupation, home location, and car availability. Its plan contains information on the daily activities, such as where and when those activities will be performed and which mode of transport will be used to reach the locations. The underlying activity chain is assigned to each agent according to its sociodemographic attributes. 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 the agent's previous experiences. To improve their score the agents can, for example, vary their departure time, transport modes, and routes. The system iterates between plan generation and

traffic flow simulation until a relaxed equilibrium state is reached. The schematic representation of this iterative process is shown in Figure 1. MATSim can be applied to large-scale scenarios in which millions of agents representing the population of a predefined study area are modeled. It produces complete daily schedules for all individuals in the scenario, which comprises various types of activities and travel with several modes.

Simulation of Carsharing

The work to integrate carsharing modeling in the MATSim simulation framework started in 2009 and is ongoing (*11, 12*). The first implementation was very simple and limited to round-trip-based carsharing, but in the meantime three forms of carsharing can be simulated in a fair amount of detail: round-trip based, one way, and free floating (*13*). These are also the forms to which the large majority of currently operational schemes worldwide belong. Carsharing vehicles are all physically simulated, as well as stations and their parking constraints. More details follow on how carsharing usage is modeled.

Behavioral Model

The behavior of MATSim agents is expressed by a function that evaluates all components of their daily activity plan. In principle, activities are evaluated positively (provide utility) and travel, negatively (generates negative utility). The utility of activity is defined as follows:

$$U_{\text{act},i} = U_{\text{dur},i} + U_{\text{wait},i} + U_{\text{late.ar},i} + U_{\text{early.dp},i} + U_{\text{short.dur},i} \quad (1)$$

where

$U_{\text{dur},i}$ = utility of performing activity, in which opening times of activity locations are taken into account;

$U_{\text{wait},i}$ = disutility for waiting (e.g., for store to be opened);

$U_{\text{late.ar},i}$ and $U_{\text{early.dp},i}$ = disutility for being late and early, respectively; and

$U_{\text{short.dur},i}$ = penalty for performing activity in too short a time.

For each mode, a function includes all elements characteristic of the mode. The function representing the generalized cost of travel for carsharing travel from activity $q - 1$ to activity q is

$$U_{\text{travel},q,\text{cs}} = \alpha_{\text{cs}} + \beta_{c,\text{cs}} * c_t * \text{RT} + \beta_{c,\text{cs}} * c_d * d + \beta_{\text{tt,walk}} * (\text{AT} + \text{ET}) + \beta_{\text{tt,cs}} * \text{TT}_{\text{travel},q,\text{cs}} \quad (2)$$

Other terms can be added or removed according to the peculiar characteristic of a particular carsharing scheme. The first term, α_{cs}, is a constant that can be used as a calibration parameter and will also, generally, be different for different types of carsharing (and for different contexts). The second and third terms refer to the time-dependent and the distance-dependent part of the fee, respectively (they are set to zero if the carsharing scheme modeled does not contain this element). RT is the total reservation time, c_t represents the monetary cost for the reservation time (can be per minute or per hour), d is the total vehicle distance, and c_d is the monetary cost for 1 km of travel. The parameter $\beta_{c,\text{cs}}$ represents the marginal utility of an additional unit of money spent on traveling with carsharing. The fourth term includes the walking time to and from the station (with AT the access time and ET the egress time) and is evaluated as a normal walk leg. The parameter $\beta_{\text{tt,cs}}$ represents the direct marginal (dis)utility of an additional unit of time spent on traveling with carsharing, where TT is the actual (in-vehicle) travel time. In practice, however, in the absence of a specific logit model, the β's can be set to a default value, which is typically the same for the other modes. The result is that agents value travel time the same for all available modes, and the same is true for monetary costs. That result is clearly a limitation of the current implementation (but not of the model as such) and will be discussed below in more detail. One could argue that one peculiarity of carsharing is the uncertainty of actually finding a car. In reality, it can obviously happen that one plans to use carsharing but does not find a car available. According to the purpose of the trip, the person might reschedule the activity to another

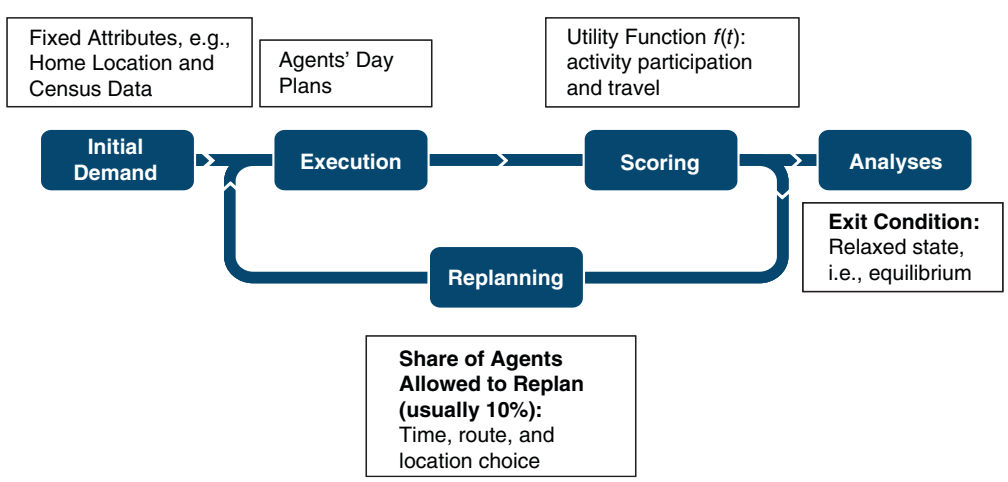

FIGURE 1 Graphic representation of MATSim simulation framework (*10*).

time of the day or to another day or use another mode. It is intuitive that to capture this kind of behavior, one should render agents capable of adapting on the fly. Even though MATSim can simulate short-term adaptation triggered by an unexpected event [see Dobler (*14*)], this ability is not used for carsharing. Carsharing is treated in the simulation as the other modal options are. Agents try out carsharing and keep it in their plans over the iterations if it provides a good fit for their needs. If they are not able to use it in the next iteration because other agents obtain the vehicle before them, the plan is heavily penalized and the probability of carsharing being tried again in successive iterations is rather low. In the iteration, however, agents do not try to use another mode on the fly. It is argued that it is not necessary to represent the competition for carsharing vehicles as it is represented anyway by the coevolutionary process.

Round-Trip-Based Carsharing

In the case of round-trip-based carsharing, the simulation of carsharing travel is subtour based. A subtour is a sequence of trips starting and ending from the same location but not necessarily from home. The following steps are simulated:

1. Agent finishes its activity, finds the closest available car, and reserves it (making it unavailable for other agents).
2. Agent walks to the station where it has reserved a vehicle.
3. Agent drives the car (interaction with other vehicles is modeled).
4. Agent parks the car at the next activity.
5. After finishing the activity, agent takes the car and drives to the next activity.
6. Before reaching the last activity in the subtour, agent ends the rental and leaves the vehicle at the starting station, making it available to other agents.
7. Agent walks to the activity.
8. Agent carries out the rest of the daily plan.

One-Way Carsharing

In the case of one-way carsharing, the steps are similar but have a few significant differences:

1. Agent finishes the activity, finds the closest station with an available car, and reserves the vehicle (making it unavailable for other agents).
2. Agent walks to the station where it has reserved the car (takes the car and frees a parking spot at the station).
3. Agent finds the closest station to the destination with a free parking spot and reserves it (making it unavailable for others).
4. Agent drives the car to the reserved parking spot (interacting with other vehicles in the network).
5. Agent parks the car on the reserved parking spot and ends the rental.
6. Agent walks to the next activity.
7. Agent carries out the rest of the daily plan.

Free-Floating Carsharing

The use of free-floating carsharing by an agent is simulated with the use of similar steps, but the rental ends with the end of one trip:

1. Rent the nearest car.
2. Walk from start activity to the rented car.
3. Drive to the next activity (interaction with other vehicles is modeled).
4. Park the car close to the next activity.
5. End the rental (and make the car available for other rentals).

Carsharing Membership

Carsharing is a membership program. To be able to access a specific carsharing service individuals need to become members of that carsharing program, and the simulation should take that aspect into account to limit the number of potential users appropriately. Realistic primary locations (home, work, and education) of the members will improve the adherence of the simulation to the observed spatial usage patterns. Realistic sociodemographic characteristics ensure that activity chains of members in the simulation are plausible, which affects the realism of the types of trips made with carsharing. Assigning carsharing membership in the simulation is challenging because there is not enough evidence that membership can be described by a valid model. There is evidence that different carsharing forms are capturing a different public (*15, 16*). Therefore, models for the area studied need to be developed unless a random membership is acceptable for the problem at hand (that can be the case if the focus is on operations and not on demand). In all of the most recent studies on carsharing carried out with MATSim, specific membership models were used. For round-trip-based carsharing, a logit model has been estimated for the whole of Switzerland and implemented in MATSim (*17*). The variables of the models are mainly individual sociodemographic characteristics. An important feature of the model, however, is that carsharing accessibility is explicitly considered, both from home and from work. So accessibility A of person p is calculated with the following formula:

$$A(p) = \ln\left(\sum_{i=1}^{n} X_i * e^{-\beta * \mathrm{dist}_{ih}}\right) + \ln\left(\sum_{i=1}^{n} X_i * e^{-\beta * \mathrm{dist}_{iw}}\right) \tag{3}$$

The weight parameter for distances β is set to 0.2 as in Weis (*18*). Assuming n as the number of stations in the system, dist_{ih} and dist_{iw} are calculated for each station as the distance between the station i and the home and work location of person p, respectively; and X_i is the number of cars at station i. Using this accessibility measure is an important improvement over other models that have been used in the past to estimate carsharing potential because it takes into account the availability of the system at the microlevel. In the case of applications in which one-way carsharing was modeled, the above model has been used as a proxy as no specific data were yet available (*12*). To model free-floating carsharing membership in the simulation, a specific model—such as the one used for round-trip carsharing [see Kopp for such models for Berlin and Munich, Germany (*16*)]—has not been estimated yet. However, it is possible to use data on the existing customers from the area of study if there is a free-floating operator present or from a different area if the free-floating service does not exist in the simulation region. Membership was then assigned (or not) to agents with iterative proportional fitting to obtain a distribution close to the real one. In the iterative proportional fitting, the variables used were age and gender. For the case study of free-floating carsharing in Berlin, the customer data used were from DB Flinkster operating free-floating carsharing in

the Berlin area (*19*). Membership of free-floating carsharing was assigned according to the observation that the number of approximately 100 customers per vehicle is stable since the service is available in Berlin, independent of increases in the number of cars. In other words, the size of the service was established and the number of customers set accordingly. Indeed, the total number obtained is fairly consistent with studies estimating the potential for free-floating carsharing in Germany (*20*). Membership was then assigned with a process similar to that used for traditional carsharing. Some of the agents were found to have access to both services, which reflects the current situation (*21*). A similar approach was used for the Zurich, Switzerland, area case study, but since there is no free-floating service available in this area, the customer data from the city of Munich (DriveNow) were used [see Kopp (*16*)] (*22*).

CALIBRATION, VALIDATION, AND APPLICATIONS

The current section provides an overview of the possibilities offered by the tool in its current form and suggests possible ways to improve it. A more detailed discussion on current limitations and future work can be found in the next section. MATSim has been used in several carsharing studies, mostly—but not exclusively—focusing on Switzerland and specifically on the Zurich region. The choice is motivated mainly by the fact that MATSim is being developed in Zurich and the scenario representing this region is one of the most well tested in the MATSim community. However, from a shared mobility standpoint, Zurich features a very large round-trip-based carsharing fleet. In addition, data on both membership and usage were to some extent available for this region, making it an ideal (virtual) playground to further develop the simulation. Possible applications are by no means bound to this region, nothing related to the scenario is hard coded, and the simulation could be used easily in any other region. The first applications were actually aimed at validating the model for round-trip-based carsharing (*13*). Carsharing usage was calibrated to actual usage levels in the region with the constant in the utility function mentioned earlier. The calibration of MATSim, as such, is done according to traffic count data, so at a much more disaggregated level. For an analogy, an attempt could be made to do the same with carsharing if disaggregate data of vehicle usage were available. Unfortunately, only incomplete data of this kind have been available to the authors so far. To check the validity of the model two main dimensions that are known to be important to define carsharing usage were used, the temporal length of the reservation and the starting time of the rental. Figure 2 shows how well the actual data (from the Swiss operator Mobility) compare with that obtained from the simulation along these two dimensions.

Successive applications have been focused mainly on one-way and free-floating carsharing. The first of this series looked at the potential to further enhance carsharing supply in Berlin (*19*). Several scenarios with different levels of carsharing supply (both station based and free floating) were simulated. It was found that a large untapped potential for round-trip-based and free-floating carsharing existed in the city and that these two carsharing forms complemented each other. Recent developments in the area, with a massive increase in carsharing supply, seem to confirm the outcome of the study. Another recent study looked at the problem of how carsharing demand varies with different pricing strategies (*22*). The metropolitan area of Zurich was used as the case study.

Based on this analysis, findings suggest that pricing strategies may induce structural changes in the spatial and journey-purpose profiles of carsharing usage and affect aggregate demand levels and how they are distributed diurnally.

Balac et al. also focused on the Zurich area and aimed at gaining insight into the complex relationship between different levels of supply and demand (*12*). Results indicate that there is still untapped potential for round-trip carsharing. Increasing supply will generate more demand, but no linear (or nearly linear) relationship was observed, suggesting the existence of an optimal level of supply for the operator. This finding will be further investigated in the future as, if confirmed, it would have obvious important implications for the planning of carsharing schemes.

In Balac et al., the influence of parking supply on demand and the quality of service of a one-way carsharing scheme were evaluated (*24*). Results show that different parking supplies have a different influence on the behavior of users, accessibility to carsharing stations, turnover, and quality of service. The results presented are important because until now much effort—by researchers and operators—has been put into the relocation process of the vehicles. Although more research is needed to confirm the authors' findings, they suggest that a more intelligent planning of the number of dedicated parking spaces—with optimization at the local level—could also help increase the productivity of the fleet. Relocation would still be necessary, but the findings invite the exploration of new

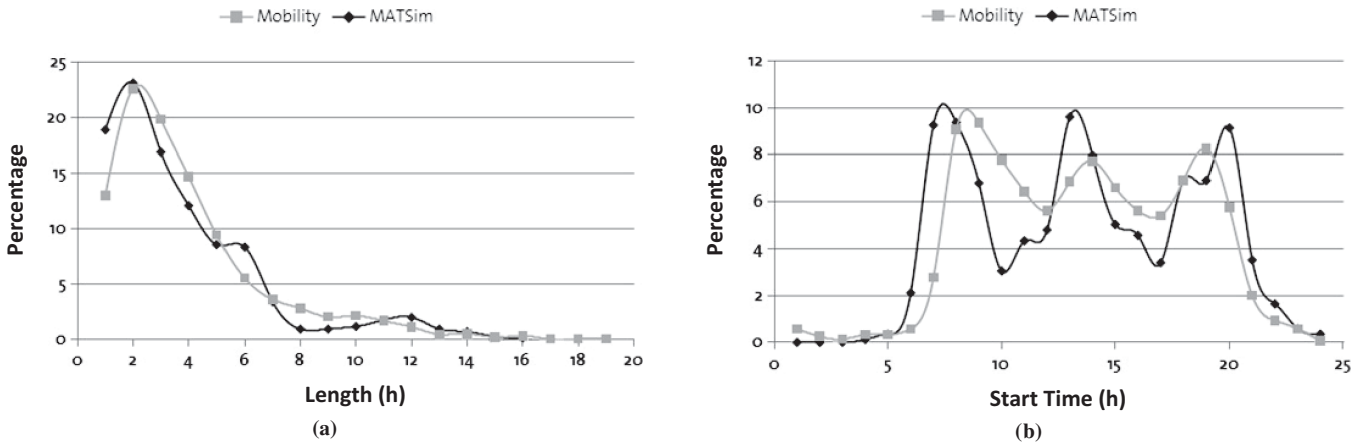

FIGURE 2 Comparisons between empirical data and simulation: (*a*) reservation length and (*b*) rental starting time [from Balac and Ciari (*23*)].

strategies that would combine parking space location and vehicle relocation to improve the operations of one-way systems.

CURRENT LIMITATIONS

The simulation still has several limitations. Some are being addressed in ongoing work, whereas others are part of the future research agenda.

The most obvious limitation is the behavioral model. The current model implicitly assumes that all elements of a carsharing trip are evaluated by travelers in exactly the same way as for any other mode. Mode choice is commanded by a multinomial logit–like structure, but parameters are all alike for all modes, meaning that individual preferences are not captured, not even on average. The assumption is, intuitively, quite rough, and in previous work, the authors demonstrated that this assumption does not hold in the Swiss context for round-trip-based carsharing. But the models estimated on that occasion cannot be directly implemented in MATSim for several reasons [more details can be found in Ciari and Axhausen (*25*)]. Generally speaking, a large descriptive literature deals with carsharing usage patterns (in regard to trip purpose, for example), but analytic approaches are still scarce and are one of the main research gaps in the field. In the case of free-floating and one-way carsharing, there is not much descriptive literature as these carsharing forms are still relatively new and not much empirical data have been made available to researchers. In addition to this general issue, MATSim is not distinguishing different activities at a level as fine as might be necessary to forecast carsharing usage. For example, the purchase of bulky items is known to have a strong correlation (among members) with carsharing usage, but MATSim—even though it is activity based—does not provide (yet) the necessary level of detail to distinguish such different types of shopping. Another limitation of the model is that a single day is simulated, whereas carsharing is known to have heavy fluctuations across a week. From an individual perspective, carsharing is a mode that typically is not used daily, and it would probably make more sense—and be easier—to predict carsharing usage of one member over a longer period of time.

The last item on this nonexhaustive list is the modeling of parking. In one-way and free-floating carsharing, the availability of parking at the end of the trip (close to the location where the planned activity will be carried out) is essential. For both carsharing forms in certain areas of a city, parking might be easier—or less expensive—than it would with a private car (or with a station-based carsharing vehicle). That aspect might make carsharing particularly attractive for some trips, but it is not captured at the moment.

CONCLUSIONS AND OUTLOOK

The simulation framework presented is one of the few instances of a comprehensive model of transport that explicitly includes carsharing as a modal option. From the standpoint of the representation of carsharing operations, the simulation is already very detailed. The simulation in its current form can already be used to obtain insight into how different operation strategies would work and to gain a feeling on how demand would be modified. In fact, some of the applications implemented so far went in that direction. In that respect, it is noteworthy that the simulation allows capturing the substitution effect of different modes on the basis of supply characteristics. The competition for the infrastructure among travel participants is explicitly modeled, ensuring that forecasts are always self-consistent. In addition, as noted in previous sections, the properties of agent-based modeling are particularly suitable to assess hypothetical scenarios on which limited previous knowledge is available. But the long-term effect of carsharing is not directly within the scope of the simulation. The simulation allows evaluating scenarios and therefore provides a snapshot and not a time-dependent-path view of things. However, MATSim is nevertheless ideally placed to assess future scenarios based on assumed behavioral changes. In that sense, it can be a perfect complement to other methods aimed at gaining insight into such modifications of mobility behavior. For a more accurate prediction of demand, more work is needed on the behavioral part. In fact, research going in this direction is being carried out as part of the scientific support to a free-floating carsharing pilot project in Basel, Switzerland (*15*). In the project, the collection of round-trip and free-floating carsharing empirical data is envisaged. This information will allow the estimation of more sophisticated mode choice models, which will be implemented in the simulation. MATSim is already capable of simulating parking search; however, the combination of that module with the carsharing module is still being tested. Substantial advances in this area are expected by the end of the year. Given the documented tendency of one-way systems (station based or free floating) to incur imbalances in the distribution of their fleets, much of the literature on such schemes focused on vehicle relocation. MATSim is a suitable framework to represent relocation and would therefore be an ideal tool to test relocation strategies, but as of now no relocation strategies have been implemented in the simulation. Work is on the way to fill that gap.

The examples presented are only a small taste of the virtually infinite number of applications possible with this tool. The goal of the authors of this paper is to build a predictive and policy-sensitive model that can be used by practitioners and policy makers to test any type of carsharing scenario. The work done with MATSim, summarized in this paper, is a solid basis on which to build to reach that goal.

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