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Integrating explicit parking search into a transport simulation

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Abstract

Explicit parking search is not widely integrated into transport simulation and transport models. In this paper, the integration of a parking search simulation into MATSim (Multi-Agent Transport Simulation) is demonstrated. This includes the integration into the agent's simulation logic using within-day re-planning methodology, a separation up of car trips into several segments for each stage of the trip, a parking search behavior and a data structure for parking infrastructure. The parking search model is applied in a case study for an area in Berlin, Germany. Compared to a standard simulation without parking search, results suggests that parking search traffic sums up to 20 per cent of the overall traffic in a residential area and has a significant impact on the overall travel times of agents traveling by car.

Keywords: parking; parking search; transport simulation; MATSim; parking behavior

1. Introduction

In recent years, agent-based parking search models have evolved and found usage in several cities. These models aim at simulating parking search behavior for streets or quarters of a city. This approach has proven suitable for modeling additional traffic effects of parking and/or behavioral questions with regard to parking search behavior. At the same time, agent-based transport simulations are a powerful tool to simulate agents' activities and travel patterns, as well as the behavior related to it, on a large scale. There have been several attempts to integrate parking search models into transport simulations, however, to the knowledge of the authors, there is currently no working simulation available offering both. In this paper, we introduce an approach to integrate parking search behavior into an agent based transport simulation.

1.1. State of the art

Parking, parking search and parking choice have been widely researched. On the behavioral side of parking search, papers by Axhausen[1] and Polak and Axhausen[2] provide a comprehensive overview of *park searching* behavior and ways to model it.

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Several tools to simulate it are available. One of them is PARKAGENT[3], a multi-agent, spatially explicit model developed as an ArcGIS extension. It allows the simulation of both streetside and garage parking lot locations in city quarters. Agent simulation takes place only during parking search, which is modeled in high detail. The biggest, and to the knowledge of the authors, only simulation scenario published about is set up for parts of Tel Aviv.

On the contrary, the project SUSTAPARK[4] includes a detailed traffic model of cities so that the influence of parking search into a city's overall traffic state can be simulated. The model is applied for Leuven, Belgium. The model used is based on cellular automata. Parts of the software are available under an open source license. A simulation of behavioral change seems only possible in terms of parking, but not in terms of other choice dimensions, such as departure times or mode choice.

A microscopic approach to model agents in parking lots is presented by Vo[5] using a NetLogo model. An extension of the model to larger areas might be possible.

Several papers proposed at ETH Zürich have addressed modeling and simulating parking choice in MATSim[6]. Their main modeling focus is on parking choice modeling (e.g., the choice between two differently priced garages).[7] This does not explicitly model e.g., agent-walking from or to parking lots, or the actual search for a space in a lot. Instead, a punishment is added to an agent's daily score in form of the length of the walking distance and the parking lot price. This open-source approach is very fast from the computational perspective and hence useful for simulating different pricing policies and the like, including mode choice and adaption of agents towards new modes, such as free-floating car sharing.[8] However, it leaves out congestion effects related to parking search and agents may spend the time they are using to find a place in a garage or walk to / from parking lots performing other activities. A parking search integration was also proposed,[9] but apparently never published. According to its author, it is not open to the public.[7]

2. Methodology

In line with the parking choice approach described[7], we also decided to use MATSim as a transport simulation to integrate parking search behavior. As an agent-based, flexible and pluggable open-source software, its co-evolutionary algorithms and customisable scoring functions provide a very versatile base to extend an existing model with parking search behavior.[10] Furthermore, it might be possible to integrate some of the existing *parking choice* scoring functionality described above with the approach, if required.

The typical concept of a MATSim scenario is the evolution of agents' scores over multiple iterations, originating from a synthetic population created from, e.g., census data. The score of an agent is summed up based on a daily plan of performed activities (usually positive) and travelling (usually negative).[11] After each iteration, a certain share of agents modify their plans ("*day-to-day replanning*"). Typical modifications include a change of departure time(s), a change of travel mode or a change of the traveled route. If the modification scores better than previous plans, it is kept, otherwise discarded again. This process is repeated over several iterations until some form of equilibrium is reached. Per default, activity locations and parking locations are equal, meaning that agents can start an activity directly after arriving by car.

There are also several implementations that allow agents to change their behavior within an iteration. This is referred to as *within-day replanning*[12,13] and has been used on various occasions, such as the simulation of taxicabs[14] or evacuation scenarios.[15] The integrated parking search model will be applied to an existing MATSim scenario[16] of the Berlin area.

2.1. Simulation extension and modification

For an integration of parking search algorithms, a combination of day-to-day and within-day replanning needs to be used. Whereas standard day-to-day replanning can be applied for departure time choice (and mode choice), route choice needs to be adjusted during simulation runtime. Depending on the location of an agent's vehicle, an agent's route may differ substantially between iterations and thus needs be calculated ad-hoc. An approach to deal with this ad-hoc calculation of routes for a large set of the fleet has been solved previously[17] by applying an exponential moving average (over travel times observed over a series of iterations) with a relatively low degree of weighting decrease. This warrants a relatively stable number of vehicles on most links from iteration to iteration.

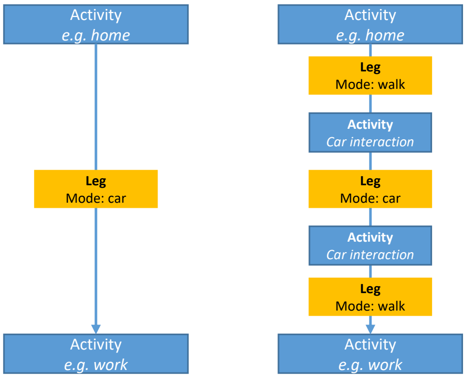

Fig. 1. An agent's car leg using MATSim's standard approach (left side) and with walk legs to and from parking in between (right)

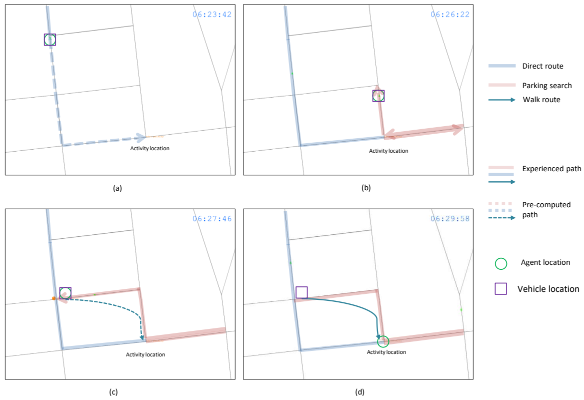

Fig. 2. Parking search process

2.2. Data and computational requirements

Apart from the typical simulation data required for MATSim simulation, the number of parking spots on each link in the study area is required. For links without this information, a direct on-street parking spot is assumed.
Due to the necessity to route each agent ad-hoc for each trip in each iteration, as described in the previous section, the computational requirements are higher than in standard MATSim simulation runs. If typically 10-20 per cent of the agents choose new routes between two iterations, the approach with parking search enabled will require 5-10 times more time for vehicle routing.

2.3. Agent logic

During a typical MATSim iteration, an agent starts traveling by car right after performing an activity. The route it travels along has been set at the beginning of the iteration (or originates from a previous iteration). Upon reaching its destination, the vehicle is removed from traffic and the agent's next activity starts. Thus, an agent may be either in traveling ("LEG") or activity performing state ("ACTIVITY"). For using parking search, the agent state space needs to be adjusted. Namely, each car leg needs to be split up in several sub-states: 1) Determining vehicle location and Walking there 2) Unparking the vehicle 3) Route calculation and travel to destination, including searching for parking 4) Parking the vehicle 5) Walk to destination. This means, a single car leg is split into three legs and two activities (fig. 1). A similar approach is also used for the simulation of schedule-based public transport in MATSim.[18]

2.4. Parking search behavior

A person's parking search behavior may depend on several factors, such as the location, the pricing of parking, personal experiences, the willingness to park illegally, and many more.[19] Therefore it is advisable to allow the search behavior to be agent-specific. To achieve this, the search behavior is kept behind an Interface with every agent having possibly a custom implementation. MATSim's finest granularity in terms of traffic flow is link-based, allowing parking search to be explicit on a link-to-link base.

In this paper, a simple random search logic is used to demonstrate the framework, as depicted in fig. 2. Initially, an agent drives to their destination along a path that has been pre-calculated upon departure (a). Upon reaching the destination, it traverses along randomly selected neighboring links to search for parking (b). Once a link has a free parking spot, the vehicle is parked (c) and the agent walks to its destination (d). This behavior may be appropriate in areas where there is a certain chance to find parking next to the activity location making it worthwhile to look for a spot here first. In areas with high parking pressure, the parking search process may start several hundred meters earlier.[3]

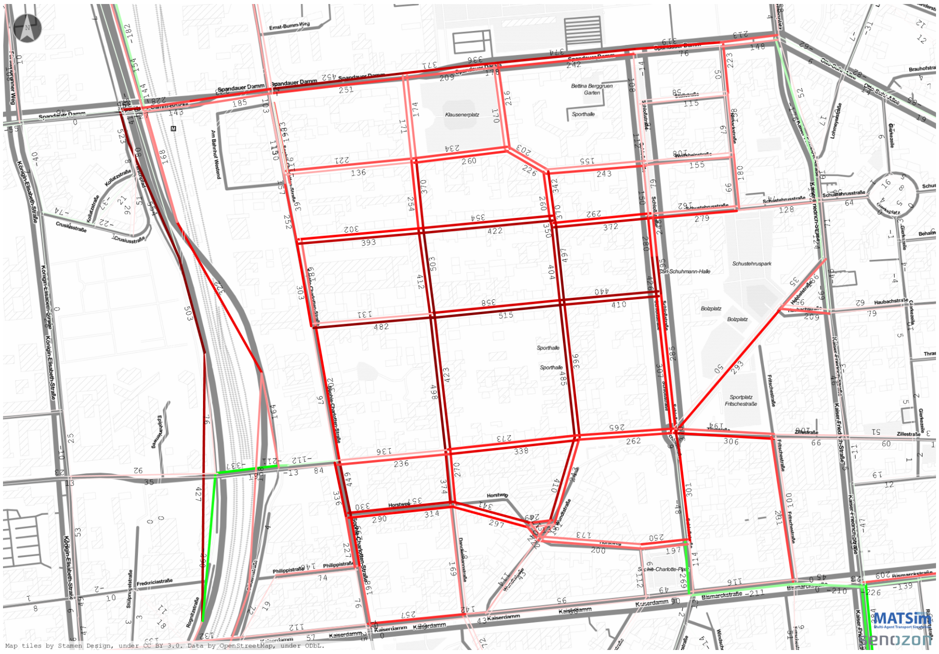

Fig. 3. Link volume differences with and without parking search enabled

2.5. *Scenario adaptation and parking integration*

The parking search framework developed is applied to an existing MATSim Berlin scenario.[16] Data about parking spaces and their occupancy during nighttime is available for two distinct areas in the Charlottenburg district. One of them is situated around the Klausenerplatz, an area where parking pressure is known to be high, the other one around Mierendorffplatz. For computational reasons, the synthetic population of the original scenario with 6 million agents was reduced to those agents, who perform at least one activity in one of the area or its immediate surroundings, leaving roughly 60 000 agents. Travel times on links outside the area were assumed to be the same as in the base case using dynamically changing network attributes. A total of 2 897 curbside parking spaces were counted in the Klausenerplatz-area and 1 512 spaces in the Mierendorffplatz-area.

In order to evaluate the influence of parking search on the simulation, the simulation was run both with and without parking search enabled. In both setups, 50 iterations were simulated. Agents had the choice of modifying their departure times within a 30-minutes interval. In the setup without parking choice (*"base case"*), routes could also be modified, whereas in the simulation with parking choice (*"policy case"*) enabled routing happens on the fly. For parking locations, iterations were seen as days. This means an agent picks up a car in the morning where it was parked last in the preceding iteration. Should an agent's trip chain contain several legs with different modes in a row, and the vehicle's location is too far away from where the agent is, the car is teleported to a free parking spot near the agent's location, where in reality, another person with access to the same car would have moved it.

3. Simulation results

The simulation of parking search has effects on the network side, where especially in residential areas with few thru-traffic huge differences in flow occur, as well as on each single agent moving by car. Only the larger area around Klausenerplatz will be assessed here, with the effects in the second area being roughly the same, though with an overall smaller impact, which may be explained with less parking pressure.

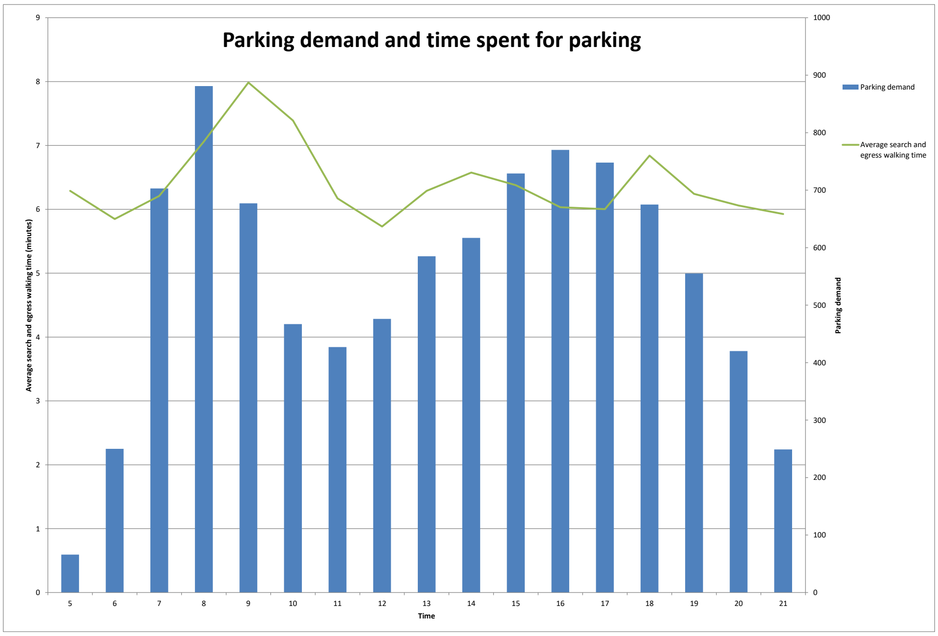

Fig. 4. Parking demand and average time spent for parking search and egress walking during the day

3.1. Network effects of parking search integration

The area around Klausenerplatz is mainly residential. The majority of links in the quarter are thus only used for vehicles arriving and departing from here, with almost no traffic passing through. In the base case without parking simulation, the daily traffic volume is therefore rather low, with 800 - 1 500 vehicles passing. When parking search is enabled, there is an increase of up to 500 vehicles on some links. Fig. 3 depicts the additional traffic volume of all the links in the area. Especially those links in the center of the area experience an increase of traffic flow. This may be explained with the limited area size observed. In aggregated numbers, vehicles traverse for an overall of 16 160 vehicle-km along the links with parking space data around Klausenerplatz in the base case. In the policy case, these accumulate to 20 564 vehicle-km.

3.2. Individual impact

The impact of parking search onto each individual reveals that the time spent for parking search and walking from the vehicle's location to the actual destination averages in the area at 6:27 minutes. Overall there are 9 581 parking maneuvers during the day. The demand peaks between 8 am and 9 am, which seems intuitive, considering several workspaces located in the area. Parking search time peaks during the time immediately after the morning peak, with almost 8 minutes spent on average between 9 am and 10 am. Nighttime parking search takes less time. This seems somewhat doubtful, but may be explained by constraints of the model, that may underestimate off-peak evening traffic.

For car trips starting or ending in the area, the average travel time increase is 8 minutes. This additional travel time is also reflected in the agent's score, which is 5 percent lower in the policy case.

4. Conclusion and next steps

Parking search traffic is a major component of overall traffic within residential areas which most transport simulations tend to underestimate. In this paper we were able to show that the additional effect for an area with high parking pressure in Berlin is around 20 percent of the overall vehicle mileage driven in the area. The average time spent for parking search and walking to the actual destination (or back to the car) accumulates to 8 minutes in the area.

The framework suggested for parking search integration into MATSim is a very versatile way for additional case studies. Future research should include the effect of different parking search strategies and their effects on travel times. Also, the fitness of different parking policies could be simulated in further steps. These could not only include pricing policies, but also parking privileges for certain user groups (such as carsharing vehicles) and their effect on mode choice. Also, scaling up the area where parking restrictions apply in the simulation might provide useful additional information. Lastly, an attempt should be made to generalize the effect of parking search and integrate this into the standard MATSim routing procedures.

Acknowledgements

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