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Modeling Car Passenger Trips in mobiTopp

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Abstract

The transport mode car passenger accounts for a substantial share of the modal split. Travel demand models, however, often contain only a simplistic representation of this mode. Modeling car passenger trips realistically is complex, since the availability of this mode option depends on the presence of a car driver. Indeed an agent-based travel demand model is a solid foundation for a more realistic implementation of the car passenger mode.

The paper describes the former implementation of the car passenger mode in the agent-based travel demand model mobiTopp and the weaknesses of this approach. It discusses different situations where car passenger trips occur, namely joint activities and ridesharing, and outlines a simple but flexible concept for the implementation of ridesharing. It describes the changes to mobiTopp that where necessary to implement the ridesharing concept and the experiences made with this new car passenger model.

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Keywords: car passenger, travel demand model, mobiTopp, ridesharing

1. Introduction

Modeling car passenger trips plays an important role in travel demand modeling, since they account for a substantial share of the modal split. For example in Germany, car passenger trips amount to 12 percent of the modal split based on the number of trips and about 20 percent of the modal split based on the distances traveled. The share of car passenger in the modal split is greater than each of the modes cycling and public transport.[1] In addition, with the increasing market penetration of smartphone technology observed in recent years and the emergence of dynamic ridesharing apps, the mode car passenger has the potential to increase even more.

However, modeling the mode car passenger realistically in travel demand models is challenging. In contrast to other modes where the availability of a mode depends on the availability of an appropriate vehicle at most, the availability of the mode car passenger strongly depends on the behavior of other persons, namely the persons potentially offering a ride.

So it is not surprising, that in travel demand models the mode car passenger is often modeled very simplistically. SACSIM[2], for example, distinguishes the car based modes drive alone, and two shared ride modes. However, no distinction is made between car driver and car passenger and the shared ride modes are always available. There

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seems to be no coordination between persons using the shared ride mode. CEMDAP[3] models joint participation in discretionary activities and joint tours within the household context as well as service trips where an adult escorts a child to school or to a discretionary activity. In these cases, the driver is assigned the mode car driver with passenger and the passenger is assigned the mode passenger. However, it seems that for other tours the model allows to choose the mode driver with passenger or the mode passenger without a corresponding driver or passenger being present.[4] The CT-RAMP family of models[5] model joint activities and joint tours within the household context and ridesharing as escort trips for children to school and distinguishes drive-alone modes and shared-ride modes. However, it seems not to distinguish between shared-ride as a driver and shared-ride as a passenger. In ALBATROSS[6] car passenger is one of four modes, but there is no coordination with a car driver. MATSim started as car-only multi-agent travel behavior simulation, focusing on dynamic traffic assignment. Later the set of modes has been extended by the modes public transport, bike, and walk, but no car passenger mode.[7] However, a taxi mode has been implemented recently[8] and there are first attempts to include joint activities and joint trips into MATSim.[9,10] There is ongoing research on modeling ridesharing explicitly,[11,12] but integration into travel demand models is not yet far advanced.

2. The mobiTopp model

mobiTopp[13] is an agent-based travel demand model, representing every person of the planning area as an agent. An agent is an entity that makes decisions autonomously, individually, and situation-dependent and interacts with other agents.[14] In mobiTopp, each agent has an activity program for up to a week. In order to execute the activities of his activity program, the agent makes decisions for destination choice and mode choice, which are based on Discrete Choice models. Up to now interactions occurred only indirectly, when an agent uses a car of his household, which is not available for other household members until the agent returns home, thereby restricting the mode choice options of the other household members.

2.1. Structure

mobiTopp consists of two major stages: initialization and simulation. The initialization stage models the long-term aspects of the system like population synthesis, allocation of home zone and zone of workplace, and season ticket ownership of public transport. These long-term aspects define the framework conditions for the subsequent travel demand simulation.

The simulation stage models the travel behavior of the agents, consisting of destination choice and mode choice, chronologically and simultaneously over the course of the simulation period of up to one week. The behavior of an agent in mobiTopp can be described by a state diagram, see Figure 1. Guided by his activity program, an agent undergoes a cycle of executing an activity and making a trip until the activity program is finished. The main states are EXECUTE ACTIVITY and MAKE TRIP. An agent remains in the state EXECUTE ACTIVITY for the duration of the activity. When the activity is finished, the agent passes the state END ACTIVITY, where he makes a destination choice and a mode choice and possibly takes a car out of his household's car pool, then the state changes to MAKE TRIP. The agent remains in this state until the trip is finished and the state changes again to EXECUTE ACTIVITY, passing the transitional state END TRIP.

A route choice model is currently not implemented in mobiTopp. So there is currently no direct feedback loop, where destination choice and mode choice influence travel time and the adjusted travel time influences destination choice and mode choice, within mobiTopp. The feedback loop is realized externally instead: The resulting trip file of the simulation stage is aggregated to time and mode dependent OD-matrices, a traffic assignment is made for each period using an external program and the resulting travel time matrices are fed back into the next run of the simulation stage.

2.2. Mode Choice

mobiTopp distinguishes between five modes: walking, cycling, public transport, car driver, and car passenger. Recently the set of modes has been extended by carsharing,[15] but this mode is not considered here. The actual available choice set is situation-dependent, consisting of a non-empty subset of the full choice set. mobiTopp aims at modeling the available choice set realistically. This means, for example, that an agent who is not at home and has

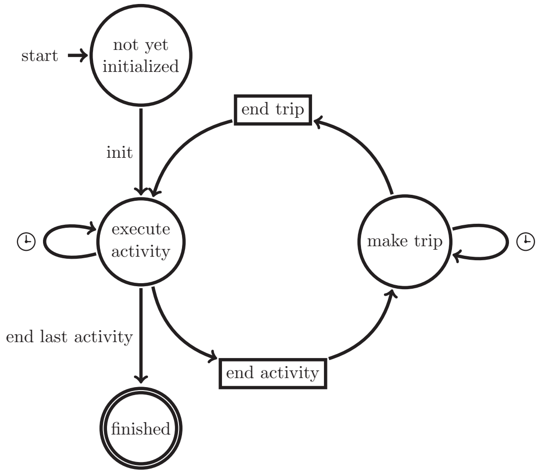

Fig. 1. State diagram of an agent in mobiTopp: The circles denote enduring states; the boxes denote transitional states; and the arrows show the transitions between states. The clocks at the arrows accentuate that the agent remains in these states until some specific time has elapsed, i. e. until the trip is finished, or the activity is finished. The agent starts in the state NOT YET INITIALIZED; after initialization, the state changes to EXECUTE ACTIVITY. The agent remains in this state for the duration of the activity. When the activity is finished, the agent passes the state END ACTIVITY and the state changes to MAKE TRIP. The agent remains in this state until the trip is finished and the state changes again to EXECUTE ACTIVITY, passing the transitional state END TRIP. As long as there are more activities left in the activity program, the cycle EXECUTE ACTIVITY–MAKE TRIP–EXECUTE ACTIVITY repeats. When the last activity is finished the state changes to FINISHED. During the transitional states, the agent acts. At END ACTIVITY the agent performs first a destination choice and then a mode choice. If the current activity takes place at home and the mode chosen is car driver, the agent takes one of the household's available cars. This car is then not longer available for other agents until the agent that has taken the car returns home again. During the transitional state END TRIP the car is returned to the household's car pool, if the trip was a trip back home made by mode car driver.

arrived at his current location by public transport should not have available the modes cycling and car driver for his next trip.

The actual choice set an agent has available depends on the current situation of the agent, i. e. the current location, the previous mode choice and the mode choices of the other agents of the same household. The most important factor is the agent's current location. If the agent is at home, in principle all modes are available independently of the mode used before. However, the mode car driver is not available if the agent does not hold a driving license or the household's cars are currently all in use. It is assumed that every agent owns a bicycle, so if the agent is at home the mode cycling is always available. If the agent is not at home, the available choice set depends essentially on the mode used before. If the previous mode has been car driver or cycling, only the mode used before is available for the next trip. This approach is based on the idea that a car or a bicycle that has been used at the start of a tour has eventually to return home. If the agent is not at home and the previous mode is one of the modes walking, public transport, or car passenger, the choice set for the next trip consists of these three modes. The modes car driver and cycling are not available, since these modes require a vehicle that is typically not available if the trip before is made by another mode.

The choice between the available modes is made by a Multinomial Logit model, which uses the variables distance, travel time, travel cost, season ticket ownership, sex, and further sociodemographic variables. For each available alternative, the probability of choosing this alternative is calculated. From the resulting discrete probability distribution, a random draw is made and the corresponding mode is selected.

Up to now the availability of the mode car passenger has not been modeled realistically in mobiTopp: in all cases where the agent is not restricted to a single mode by use of a car or bicycle in the preceding trip, the mode car passenger is available to the agent. Obviously, this is not realistic since for traveling as car passenger, someone providing the ride option is necessary. In consequence, the model results are in parts inconsistent: There exist trips between two zones made by mode car passenger, but there is no corresponding trip made by the mode car driver. In the case of multiple matching car driver trips for a trip made as car passenger, it is not clear in which car the agent is traveling as car passenger. So an agent-based simulation should do better.

3. Car passenger modeling

We define the mode car passenger as traveling with a private car, where the traveler is not the driver. There are in principle two different situations that lead to the mode car passenger. One of these situations is ridesharing, where one person makes a trip to the location of his next activity using a car as driver and offers a ride to a person that wants to travel to the same location or into the same direction [16] for another activity. The other situation is a joint activity where two persons have decided to jointly perform an activity and jointly travel to the location of this activity. If they use a car, the result is one trip with mode car driver and one trip with mode car passenger. A variation of the second situation is a service trip, where one person escorts another person to his destination (typically an adult escorting a child). If the mode used by the escorting person is car driver, the implied mode for the escorted person is car passenger. Both situations result in trips made as car passenger, but they are conceptually different.

Traveling as car passenger can occur within different contexts; the household context is the most common. The next larger context where traveling as car passenger occurs is the personal social network, comprising besides the own household for example friends, neighbors and colleagues. In an even broader context, car driver and car passenger do not know each other before. This context encompasses hitchhiking, carpooling, or dynamic ridesharing. [17]

3.1. Basic idea

The basic idea for modeling ridesharing is as follows: Drivers offer ridesharing trips; persons interested in ridesharing make ridesharing request; there is some matching between offers and requests. Obviously, this simple model is able to describe the scenarios mentioned above. In the family context and in the social network context the offers and request may happen ad-hoc, while in the anonymous context the support of some operator is necessary, either a human operator or an electronic like a web-service or smartphone app. In all these cases, however, the basic schema of offers, requests, and matching between offers and requests is the same.

Matching ridesharing offers with ridesharing requests will mostly not be possible without one of the participants adjusting his activity program. There are several dimensions in which this adjustment can occur. It can be either the driver or the passenger who adjusts his activity program. In the temporal dimension the resulting departure time, and thus the end of the preceding and start of the following activity, can be earlier or later. In the spatial dimension the location for the next activity, or in case of the car driver the route, can be changed.

3.2. Implementation

We opted for a basic implementation of the ridesharing model using the rules described in the following. Three ridesharing contexts exist: household, social network, and anonymous. The household context encompasses all persons of the same household. The social network context is defined very simplistically encompassing all persons living in the same zone (neighbors) or working within the same zone (colleagues). This is a bold definition, only meant to be of prototypically character, that could be later refined by sophisticated models. The anonymous context encompasses all persons of the planning area. Another possible context would be real-time ridesharing encompassing all persons having registered at a real-time ridesharing service, possibly modeled during the initialization stage using a binary logit model. An offer and a request are considered to match if the source zone and the destination zone are the same and the difference between the planned departure times is small, while this range can be configured. The car driver does not change his schedule, only the car passenger does. As there does not yet exits a working network model in mobiTopp, we decided to consider initially only end-to-end ridesharing trips, i. e. there is no picking-up or dropping-off during the trip.

There were some further implementation questions: when to make ridesharing offers and request and whether to store both or only one of them. Making ridesharing offers or requests is only possible after the mode choice has been made and before the trip has been started. In the former mobiTopp implementation, mode choice decisions were made just at the end of the activity and before the start of the next trip. In this case the offer respectively request would be only valid instantly, therefore we changed the point in time for the mode choice, which is now 30 minutes before the end of the activity (or at the start of the activity, whichever is later). The time for mode choice should not differ too much from the end of activity, since the availability of the mode car in the choice set used is based on the availability of a car in the household at the instant when the mode choice is made. It might be possible that a car is not available at the start of the activity but gets available near the end of the activity. We also decided to store only ridesharing

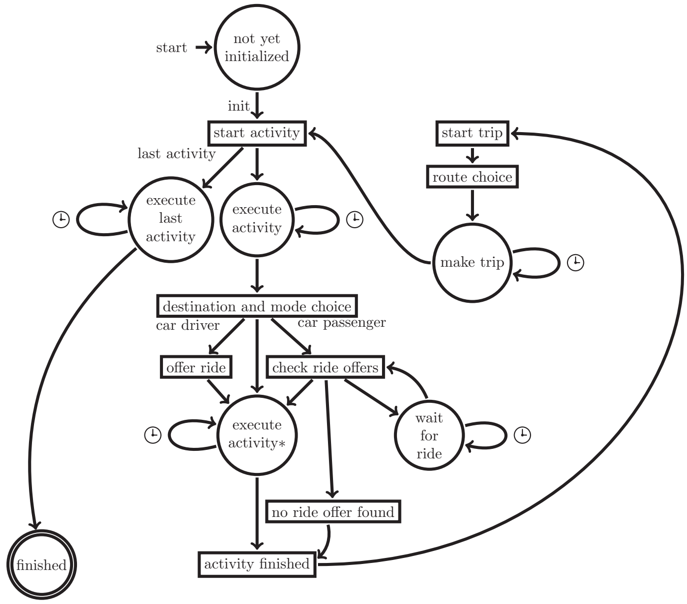

Fig. 2. State diagram of an agent in mobiTopp, implementing the new car passenger model: The states are given as circles; the transitional states are denoted as boxes. After initialization the agent's state changes to EXECUTE ACTIVITY; in case of the last activity the state changes to EXECUTE LAST ACTIVITY, no further mode choice is needed here. When certain time has elapsed, the agent makes a destination choice and a mode choice. If the mode chosen is car driver, the agents makes a ride offer and enters again, for the remaining of the activity, an EXECUTE ACTIVITY state. If the mode chosen is car passenger, the agent checks if a matching rider offer is available. If it is, the agent accepts the offer, adjust the duration of the current activity to match the ride offer, and enters for the remaining of the activity an EXECUTE ACTIVITY state. If no matching ride offer is available and the activity is not yet finished, the agent enters the state WAIT FOR RIDE and periodically checks if a matching ride offer is available. If there is no time left until the end of the activity, the agents passes the transitional states NO RIDE OFFERS FOUND, ACTIVITY FINISHED, START TRIP, and ROUTE CHOICE and ends in the state MAKE TRIP, where he remains for the duration of the trip. When the trip is finished, the agent passes the transitional state START ACTIVITY and enters again the state EXECUTE ACTIVITY.

offers, including the number of open seats. Immediately after the mode choice, a person who has chosen the mode car passenger makes a ridesharing request and checks if a matching offer is available. If an offer is available, he accepts it and the number of open seats for this offer is reduced by one. If the number of open seats equals zero, the offer is removed. If no matching offer is available, the person checks the offers again when the current activity is finished. Accepting a ridesharing offer just after the mode choice decision has typically the effect of reducing the duration of the current activity. Accepting an offer at the planned end of the activity has the effect of extending the duration of the activity until the start of the trip. The resulting state diagram for an agent using the new car passenger model is given in Figure 2. The main changes compared to Figure 1 are as follows: The destination choice and the mode choice occur before the end of the activity so the state EXECUTE ACTIVITY has been split into two. The handling of ridesharing offers and requests has been added.

4. Results and Discussion

mobiTopp, implementing the new car passenger model, has been applied to our model of the Greater Stuttgart Area with around 2.5 million agents.[13,15] After calibration, it was possible to reproduce the modal split quite well; even by the disaggregation dimensions purpose, employment, and day of the week. However, the necessary adjustments to the model parameters of the mode choice model were massive. In addition, the calibration process was very time consuming, always simulating the full population instead of a sample, since the availability of matching ride options is very sensitive to the number of traveling persons. Nevertheless, we have presented a working prototype of a car passenger implementation in mobiTopp, which is able to represent different facets of traveling as car passenger ranging from informal ridesharing in the household context to organized real-time ridesharing. The main idea can be extended easily to model the mode taxi passenger. For this, it would be necessary to store ridesharing request instead of ridesharing offers and to add some taxi driver agents, waiting for other agents' ridesharing requests, to the simulation.

The model has the limitation, that it currently supports only end-to-end ridesharing, where start and end zone of the trips of both persons have to match, i. e. no pick-up or drop-off during the trip is supported. Indeed for ridesharing to work, it would be only necessary, that the routes of the two parties have a substantial overlap, or that one route can be adjusted (with a minor detour) so that a substantial overlap results. The presented ridesharing model could be conceptually adapted to support such a fully general ridesharing, the only necessary change is the matching between ridesharing offers and requests, but for this problem solutions already exist in the literature.[18] Beyond that, the model currently only supports ridesharing, i. e. persons following their individual activity plans and only coordinating for the trip. Another source for trips made as car passenger are joint activities, where persons coordinate their activity plans and jointly execute an activity, typically some leisure or shopping activity, and travel jointly to the location of this activity. These joint activities are typically handled during the generation of activity programs;[19] this type of activity is still missing in mobiTopp and some care would be necessary to keep the corresponding activity schedules in sync.

The goal of the work described in this paper was modeling the car passenger mode more realistically in mobiTopp. This was successful in the sense that now for each trip made as car passenger a corresponding car driver exists. As a result, mobiTopp's output files contain for each car the id of the driver and the ids of the passengers. The model has been calibrated to match the modal split observed in a household travel survey. However, these results are only based on a ridesharing model; the modeling of joint activities, resulting in joint trips is still missing.

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