Agent-based Transportation Demand Management
Demand Effects of Reserved Parking Space and Priority Lanes in Comparison and Combination

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Abstract: Fostering the usage of alternative mobility modes, e.g., carsharing or carpooling becomes more and more urgent in modern urban planning. Politicians and city planners have already recognized that putting targeted incentives can influence people's mobility behavior in an effective way. Agent-based simulations of transportation demand can be a valuable tool to support these planning processes. This work is based on a state-of-the-art transportation demand simulation and shows modeling and simulation modifications related with agents under the influence of incentives. These agents have been assessed in qualitative and quantitative studies prior to the simulation. Results show that agent-based simulation of transportation demand is suitable to evaluate impacts of transportation demand management measures. More specifically, all investigated measures show certain impacts on mobility mode choice, at which an incentive combination is most effective.

1 INTRODUCTION

Traffic congestion, air pollution, and rising economic costs are major problems that go hand in hand with inefficiencies in the public transport sector. People can already decide between various mobility options that hold the potentials of efficient capacity utilization. Unfortunately, their decisions are not always the best regarding the overall (urban) mobility system, the ecosystem, or public welfare. A possible solution for this problem is transportation demand management (TDM), which is defined as the art of modifying travel behavior, usually to avoid more costly expansions of the transportation system (Ferguson, 1990). Research has investigated a large variety of TDM measures and their effects for a long time, because of their crucial importance for city planning. Agent-based demand simulation can support these planning processes by predicting the impact of different measures. This work primarily investigates the hypothesis that agent-based simulation (ABS) is a suitable tool to simulate the effects of TDM measures. To do so, we collect required data and modify an existing transportation demand simulation to include TDM measures.

In this work, we followed a three step procedure. Because mobility needs and demands, choice of mobility mode and the willingness to change the preferred mode of transport are socio-psychological issues, a qualitative study (Rennekamp and Nall, 2006) was conducted in a first step. In an exploratory attempt the current mobility usage, on the one hand, and possible incentives to a more environmentally friendly behavioral change, on the other hand, were discussed within a group of students and research assistants. In the second step, these qualitative results were validated in an online questionnaire study to gain quantitative data for the agent-based simulation, led by computer scientists, as the third and main step discussed in this paper.

The work is structured as follows. Section 2 gives an overview of demand side management measures stated in the literature. In addition, the field of agent based transportation demand simulation is described. Section 3 explains the related data basis, before Section 4 dives more deeply into the used simulation approach and presents the results. Finally, Section 5 reflects the approach and discusses contributions from interdisciplinary perspectives.

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Table 1: Survey on TDM measures based on (Rodriguez and Murtha, 2009), (Seik, 2000), (Smith, 2008), (Hensher and Pucket, 2007), (Schlag and Schade, 2004) and (Sonnenberger and Ruddat, 2013).

Category	Measure
Information	(real-time) travel information provision, public information campaigns, context-sensitive design, TDM marketing, multi-service smartcard pilot application, information via registration offices, online information database, station signs, sharing stations on city maps, public authorities using carsharing, celebrity advertising
Infrastructure	high-occupancy vehicle (HOV) lanes, parking policy, improved mode paths, park and ride, pedestrianized zones, avoiding major new road infrastructure, bicycle parking, clustered land use, shared parking, priority parking, carsharing integrated in housing complexes, flexibility for stationary carsharing, combined car- and bikesharing stations, sharing on peripheral public transport stations, parallel station and free floating carsharing
Economical	product bundling, congestion pricing strategies, (electronic) road pricing, fuel tax, parking charges, tradable permits, car tax, distance-based pricing, comprehensive market reforms, least-cost planning, congestion and variable user charging, travel card for parking and bus services, park and ride with integrated ticketing, tariff integration by monthly pass for all public transport modes, regional mobility card
Regulatory	parking controls, closure of city centers for individual car traffic, decreasing speed limits, traffic management, school transit management, special event management, tourist transport management, mode integration, vehicle use restrictions, smart growth planning, access managment, reducing parking space, new mobility concepts, rural carsharing networks, programs to encourage ridesharing
Institutional	guaranteed ride home, shuttle services, campus transport, additional capacity, mode improvements, alternative working patterns, opening organizational car pool

2 RELATED WORK

This section is divided into two parts. The first gives an overview of transportation demand management measures stated in literature. The second subsection describes the field of agent-based transportation demand simulation.

2.1 Transportation Demand Management Measures

In the literature, similar terms, e.g., Travel Demand Management (Rodriguez and Murtha, 2009), Transport Demand Management (Ison and Rye, 2008), or Transportation Demand Management (Ferguson, 1990), describe the issue of influencing people's mobility behavior in an efficient way. Table 1 summarizes prominent TDM measures stated in current literature. Basically, measures can be divided into incentives, on the one hand, and constraints, e.g., variable costs and pricing measures, on the other hand. Some measures like parking provision or high-occupancy vehicle (HOV) lanes are stated by most references and have been investigated for years (Jacobs et al., 1982). More recent measures, e.g., product bundling, complement the survey and give a comprehensive impression of possible measure options.

Since the 1970s, the topics carpooling and usage incentives have been investigated by researchers worldwide (Teal, 1987), (Ben-Akiva and Atherton, 1977). But 40 years later, car pooling still plays a minor role in the urban mobility mixture. In this paper, we especially focus on the effects of incentives on the modal split of younger adults in western societies.

2.2 Agent-based Transportation Demand Simulation

The described work is based on agent-based simulation (ABS). ABS is a microscopic approach for describing complex and dynamic systems (Macal and North, 2013; Magg, 2012). Because of the broad field of application, ABS is popular for investigations of manifold research problems (Macal and North, 2009). Hence, it is an interdisciplinary approach which often touches various research fields (Axelrod, 2006). If ABS is used for modeling complex economic systems, e.g., consumer or business model analysis (Zutshi et al., 2013), it is also called agent-based computational economics (ACE) (Tesfatsion, 2006). Especially because of its basis on individual decision making, ABS is also used in the area of transportation demand simulation (Magg, 2012).

There are different microscopic demand simulation approaches, e.g., mobiTopp, TAPAS and ORIENT (Magg, 2012). We build up our investigations on the valuable developments in this area and use the tool MATSim[1] for demand simulation. It enables agent-based urban transportation simulation for extraordinary large areas and has been developed and improved over several years (Horni et al., 2011). Due to its modular component structure, MATSim offers suitable room for adjustments and extensions (Magg, 2012).

3 DATA BASIS

As a reference for the simulation, insights into users views on possible incentives were gathered using a focus group study and an online survey.

3.1 Qualitative Data

A focus group study is an explorative method to gather broad and detailed data on a certain topic from a limited number of participants. It is used in early stages of research to identify aspects of the research question that are relevant to users. It does not provide statistically relevant data due to its qualitative nature but serves as a pre-study for the quantitative follow-up study.

Figure 1: Focus Group on Mobility Demands.

Methodology

For the focus group study, 8 participants in their mid-twenties to mid-thirties were invited to take part in a discussion. 6 of them were male, 2 female, and all of them were either students or had already completed their university degree courses. The participants had mixed mobility profiles that ranged from passionate motorbike riders and car-owners to participants using only their bike and car-sharing. One participant reported not to hold a drivers licence. Participants did not receive any gratification for their participation. Half of the participants took part in the discussion as a university course requirement.

First, the group was introduced to the topic of urban mobility by being asked to name all types of mobility modes they knew. In a next step, advantages and disadvantages of different means of transport were discussed. Participants were then asked which incentives would be needed for them to change their current preferred mode of transport and how the change to more environmentally friendly modes could be promoted. The discussion was led by two experienced moderators and lasted approximately 2 hours. Audio-recording and note-taking by two assistants and the moderators were used for data collection.

Results

The productive group discussion showed manifold results and creative outputs. At this point, most relevant findings are described.

Participants predominantly showed most interest in provided parking space and ticket service bundling as incentives. In particular, an encompassing ticket, covering the usage of public transport modes, commercial and private carsharing was discussed in detail. Participants discussed the idea of using a ticket with unlimited subscription to public transport modes and addionionally including a flexible component for alternative mobility modes, e.g., carsharing or bike-sharing. There was a broad interest in this concept which indicates that this product bundling has the potential to lower barriers towards alternative mobility modes.

Moreover, diverse ticket alternatives were discussed. For this purpose, every participant was asked to specify a certain mobility budget. They had problems concerning this issue which leads to the conclusion that modeling of agent's budget is going to be problematic. Therefore, we excluded related pricing measures from this investigation.

Moreover, other incentives, e.g., priority lanes, were discussed. Remarkable was the fact that every group participant had individual requirements concerning different incentives. This fact will be considered during agent modeling Section 4.

3.2 Quantitative Data

The qualitative input by the focus group built the foundation for a constitutive online survey.

[1]http://www.matsim.org

Methodology

This survey served as a quantitative data input for the agent modeling and for the simulation validation. Corresponding to these aims, the survey was conducted to deliver insights about participants estimations of selected incentives as well as related mode choice. Fifty applicable datasets were used for simulation. Corresponding to the focus group, most participants were students in the mid thirties. 36 percent of them were female and 64 percent were male.

After introducing the basics needed for fundamental understanding, e.g., mobility mode definitions, subjects had to specify which modes they are currently using. Thereupon, a distribution of not used modes was modeled into the agent database. Next, the incentives ”reserved parking” and ”priority lanes” had to be evaluated concerning personal importance. Finally, subjects had to state their mode choice without and within a specific incentive scenario.

Results

The quantitative data was used for two purposes: on the one hand, the requirements for specific incentives was evaluated. Thereby, average results showed that parking space was more important to the participants than priority lanes. Hence, the distribution of individual requirements was modelled into the agent database. On the other hand, we used the survey data to validate the model and simulation outputs. The respective survey results concerning the mode choices are depicted in Figure 3.

4 AGENT-BASED TRANSPORTATION DEMAND SIMULATION

After the collection of empirical data, the simulation on incentives and their effects on choice of transport mode was performed.

4.1 Simulation Methodology

The executed simulation approach is based on the open source tool MATSim. This toolbox for agent-based transportation demand simulation was developed and improved during the last decade by several entities and therefore established as a suitable instrument for research. To examine the TDM effects, we modified the simulation approach in different areas.

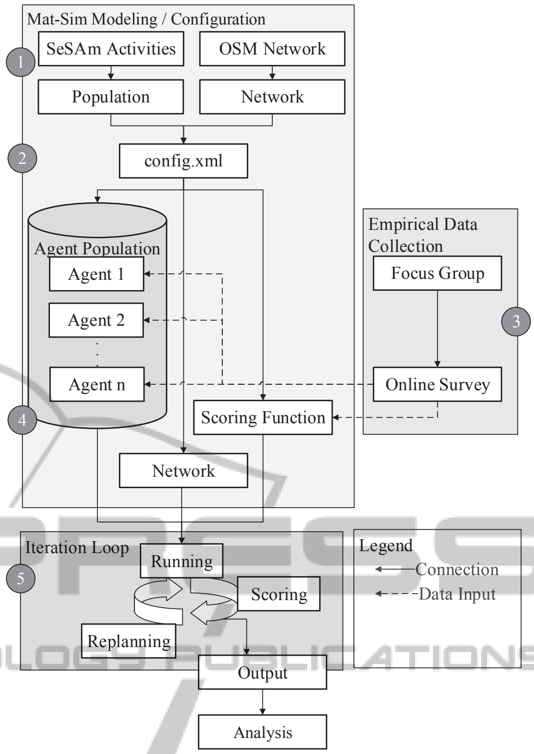

Figure 2: Simulation Architecture based on MATSim.

Figure 2 depicts the overall simulation process. At the beginning, essential input data needs to be transformed into a data format (1) which can be used by MATSim. In the past years, researchers identified activity chains of agents as an important part of public transportation simulation. The required data is often gathered by surveys. In this work, we used another agent-based simulation of individual daily routines (Freudenstein, 2003), which is based on the tool SeSAm[2], as a data input. Additionally, the network data of the observed German city region of Aachen was converted.

After adjusting the population and network data of the German region of Aachen, elemental procedures and agent strategies were configured (2). Then, every agent which was part of the overall population database was modeled, depending on the quantitative survey results. The specific sensitivity of every person towards different incentives was evaluated (3), and, as a consequence, modeled in the agent database (4). This was realized by adding specific agent attributes.

During the simulation, normally agents estimate their proceeding via a scoring function. The default scoring function by MATSim does not estimate the transport mode explicitly, and the new designed agent

[2]http://130.243.124.21/sesam/index.php/

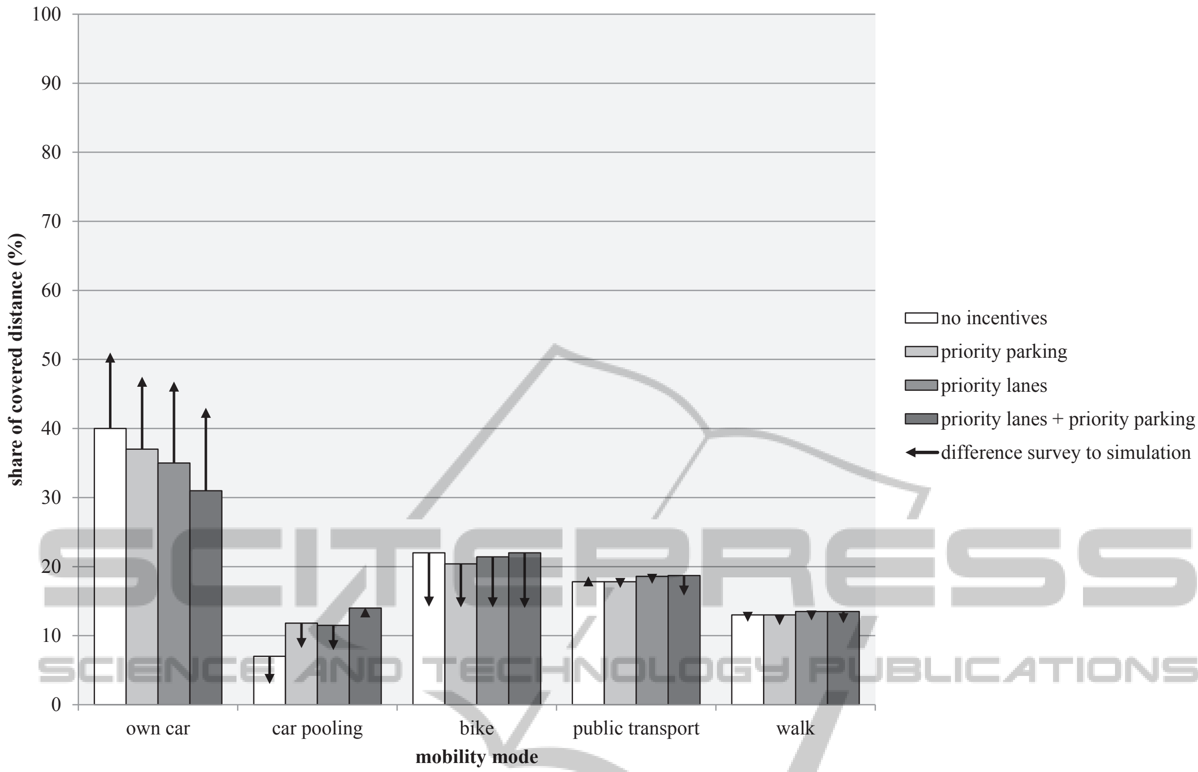

Figure 3: Simulation results: Effects of different incentives on mode choice

attributes are not incorporated into this process either. Hence, the scoring function was extended to incorporate incentive estimation, which is modeled as an individual agent attribute, into the overall agent scoring. Our modifications were based on the LegScoring. In case of incentives, agents estimated the plan depending on their requirements towards the certain incentive.

Running the simulation consisted of loading relevant network and population data. Afterwards, agent plans were routed in the network. Thereby, depending on events, e.g. traffic congestion, agent plans mutually influenced each other. Then, agent plans were estimated via the extended scoring function. After scoring, agent plans were modified, depending on given strategies during the configuration phase (2). This process (5) describes one iteration, in which lower scored plans are dropped in favor of better estimated plans. This iteration loop serves as a growing decision basis for agents to optimize their behavior. The simulation was performed in up to fifty iterations.

Finally, the results were compared with the survey data to validate the model parameters.

4.2 Simulation Results

After the validation process, simulation results (Figure 3 depicted the demand effects corresponding to the quantitative survey data. All investigated incentives showed relevant effects: the agents choice of carpooling increased, while the use of ”own car” decreased. These were also the only two means of transport for which the shares changed dramatically when the incentives were introduced, the usage of bike, public transport and walking hardly changed at all. Therefore, the latter will not be discussed here in detail. The simulation further showed that when only one incentive was used, priority parking had the least effect compared to the scenario with no incentives. Concerning the combination of incentives, it can be seen that the more incentives are introduced at the same time, the greater the share of car pooling becomes (at the expense of individual car usage).

5 DISCUSSION

Our stated approach investigated people’s predisposition towards selected incentives, which allowed to simulate a measure comparison and combination. Results indicated that the incentives chosen for this simulation only had an effect for car users in the way that they would be more willing to participate in carpooling. The fact that bike usage and walking did not change substantially when incentives were introduced could be due to the nature of these two modes: they can be used flexibly, do not cost anything and no ticket is needed for them, so the motivation to use them might be different from e.g. car and public transport.

Principally, this work substantiates the hypothesis that agent-based demand simulation is a suitable instrument to examine the effects of TDM measures and incentives in urban transportation in comparison and combination. Compared to established TDM evaluations, agent-based demand simulation investigates the interactions of large numbers of entities in complex transportation networks. Furthermore, daily routines and situational effects like traffic congestion can be incorporated into investigations. This adds an additional value for planning processes.

Nevertheless, there are some drawbacks. First, the explanatory power of ABS approaches is substantially dependent on the underlying data quality. To validate an ABS in this scientific field, a widespread investigation under realistic conditions (Jacobs et al., 1982) is more suitable than an online survey.

In addition, demand simulation becomes more complex in the area of monetary incentives or regulations. Even though it is basically possible to equip agents with budgets concerning agent modeling, our focus groups showed that participants have problems to specify a certain mobility budget. Moreover, focus groups indicated the individual requirements concerning specific measures.

In fact, findings like these underline the valuable contribution of focus group studies already in the beginning of modeling and simulation processes of human behavior and interactions.

5.1 Limitations and Future Work

Concerning the qualitative and quantitative surveys on mobility choices, the data has limited significance for very young or aged population groups, because the study concentrated on young students. Besides this, the results were not analyzed for specific user groups, but only on an aggregated basis for the sample as a whole. Future research should take into account that user groups might differ in regard to the most accepted and most efficient incentive, which could then also help to strategically tailor incentives to certain groups of people.

This simulation worked with a simplified modeling of car pooling. There are some research efforts to improve joint trip modeling further (Dubernet and Axhausen, 2012), which would also be valuable to implement.

Furthermore, scientific contributions show that ABS, and especially MATSim, is suitable for economic investigations, e.g. pricing measures (Kickhöfer, 2009). Concerning this background, it would be interesting to evaluate the demand effects of mobility service bundling.

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