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Agent-based modeling of traffic behavior in growing metropolitan areas

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Abstract

The urban settlement development of the past centuries was characterized by the process of suburbanization. Currently, the process of (re-) urbanization in metropolitan areas leads to population growth. This increase results in even more traffic participants in highly condensed areas and thus challenging the urban mobility system. Capacity and frequency of service of public transportation, a city's layout and road capacities constrain urban traffic. Transitions in travel behavior in Germany (e.g. less young adults consider cars as status symbols, and thus car ownership decreases) as well as the introduction of new types of mobility, such as sharing systems and electric mobility exacerbate the challenges for the future urban mobility. Both an expansion and modernization of the transportation system and an intelligent shift of traffic streams will help to overcome those challenges.
Traffic simulation software is naturally used to derive results about public transportation in metropolitan areas. With the help of agent-based modeling, however, human behavior in a certain research area can be modeled according to pre-defined rules and variables. Not every single inhabitant of the metropolitan area is represented by traffic simulation software, whereas in agent-based modeling all inhabitants will be featured in the model. Agent-based modeling is used for scenarios of the future traffic behavior and the ability to easily adapt to new constraints in the general framework of the model. The metropolitan area of Stuttgart is used as case study and MATSim is used as agent modeling software. Following the model setup, different scenarios are evaluated. The main research question focuses on the alteration of the urban mobility system when newly-built residential or industrial areas or rehabilitated areas are connected to the transport system. First results regarding the demographic development of Stuttgart are presented as well as the current status of the model itself.

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1. Introduction

Metropolitan areas are growing due to the constant population increase caused by the process or urbanization. This process is followed by an increasing demand for mobility in cities (Wegener 2013). Additionally, demographic change, commuter traffic and the tendency towards smaller households is altering urban mobility demands. An analysis of the urban mobility system from only one perspective falls short because of the interdisciplinary nature of mobility (Bläser and Hellali-Milani 2014). Thus, from a theoretical point of view, at least four different aspects need to be considered for a holistic study of the urban mobility system: demography, transportation system, urban structure and travel behavior.

Elementary attributes of the population from a demographic perspective are: age distribution, growth or contraction processes, the percentage of working population and the development of residential areas with respect to the price levels and location. Because of the continuous flow of people relocating to or leaving a metropolitan area, these attributes are fluctuating. However, newly-arrived inhabitants alter the existing mobility routines throughout the research area, especially in metropolitan areas (Scheiner 2009). Information about urban area and housing development are essential for a comprehensive analysis of the demographic structure variables describing the population (Gaube and Remesch 2013).

Either transportation itself or the constraints of the transportation network are boundaries of the urban mobility system. Transportation is limited in its capacities and its structure because it is utilized by several different user groups with every user group having their own needs (commuters, bicycle tourists, elderly people, etc.) (Schlaich 2011). The transport network influences the traffic itself in various ways: e.g. improved access to stops, promotion of multi- and intermodality, increase of the transportation frequency, increase of transportation lanes and reduction of access and egress times (Legara et al. 2014).

Hubs and crossings, for example, are formed by the built-up area. Thus, urban structures set the constraints for the development and control of mobility. Metropolitan areas, in particular, are continuously transitioned by, in most cases, a population increase. However, there is no generally valid mobility solution for the whole metropolitan area because of the heterogeneous inhabitant constitution. Density, compactness and mixed use development were identified to be the driving forces of urban structures (Batty 2012). Additionally, urban structure is connected to travel distances (Holz-Rau et al. 2014) as well as travel behavior (Næss 2011).

Human travel behavior is influenced strongly by psychology. Parameters such as price or availability of transportation do not sufficiently enough describe travel behavior. Comfort or ecological awareness, for example, are relevant to travel mode choice as well. In summary, it can be stated that travel behavior combines subjective and objective decisions. Thus the inclusion of travel behavior in a comprehensive analysis with demography, transportation and urban structures (which are only based on hard facts) requires careful decisions on the selection of measurement methods (Anable 2005).

This study focuses on the alteration of the urban mobility system due to population growth and thus a higher number of traffic participants. The consequences for the urban mobility system differ significantly depend on the traffic modes used (e.g. an additional commuter using his/her own car requires more space than a commuter using public transportation). Also, the location of workstations in the urban area or other activities shape the flow of traffic. The traffic modes utilized in this study are: car, bike, walk and public transportation (bus, tram and train). Initially, the presentation of the intended materials and methods occurs, followed by firsr results regarding the research question and the research area. Lastly, a discussion of the presented approach takes place considering possible alternative research attempts, potential add-ons for the MATSim model as well as possible first implications of the model for the city of Stuttgart.