Estimating the Effects of Any Future Mode on the Accessibility of an Urban Area Using a Multimodal Supernetwork

On-going research – abstract + introduction

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ABSTRACT

Future modes are expected to change modal split but it is difficult to estimate how these will change the composition of (multi)modal trips and the accessibility of urban areas, since revealed preference data is not available for future modes. A modular multimodal supernetwork has been developed to estimate how any future mode can change modal split and accessibility of urban areas. This is to simulate multimodal trips with all switching possibilities (read: mobility hubs) modelled in a supernetwork with the possibility to add new modes based on their characteristics (without using mode-specific constants). To the authors' knowledge, this is the first time such a model is used to estimate the modal share of a future mode and its effect on the accessibility of an urban area.

INTRODUCTION

Several mobility systems, ranging from shared electric bicycles to autonomous vehicles, have been developed and some of these have been introduced on the roads. These new mobility systems could change the way our societies function in terms of sustainability, equity, accessibility, and safety [1]–[3]. A widely-used definition of new mobility systems does not exist in literature. Mobility systems are integrated into society and can comprise of many different elements covering several aspects of society [4]. It can be challenging to define what a new mobility system is exactly, since it is not intuitive to define when a mobility system is new (read: different 'enough') from already existing mobility systems. In our previous research [5], [6], and this paper we define a new mobility system as follows: *new mobility systems add value, such that mode choice changes significantly, compared to already existing implemented mobility systems in the research area.*

The dominant effects of new mobility systems on our urban areas are visualized in the conceptual model in Figure 1, which is based on the LUT feedback cycle from Wegener [7]. The introduction of new mobility systems in the center of the conceptual model represents the main source of the change on accessibility. First, the introduction of new mobility systems affects the choice set for users with respect to mode and to route (a new mobility system has other route options, e.g., AV-dedicated lanes). This, in place, affects accessibility, since different mode and route choices lead to different travel patterns. Following the conceptual model, accessibility changes land use, and land use changes the demand for new mobility systems (e.g., increased accessibility increases the demand for land, leading to a need for a more spatially efficient mobility system) and the activities. Finally, activities affect the need for trips, and thus mode and route choice. Note that the scope of this paper is limited to the blue and red arrow in Figure 1.

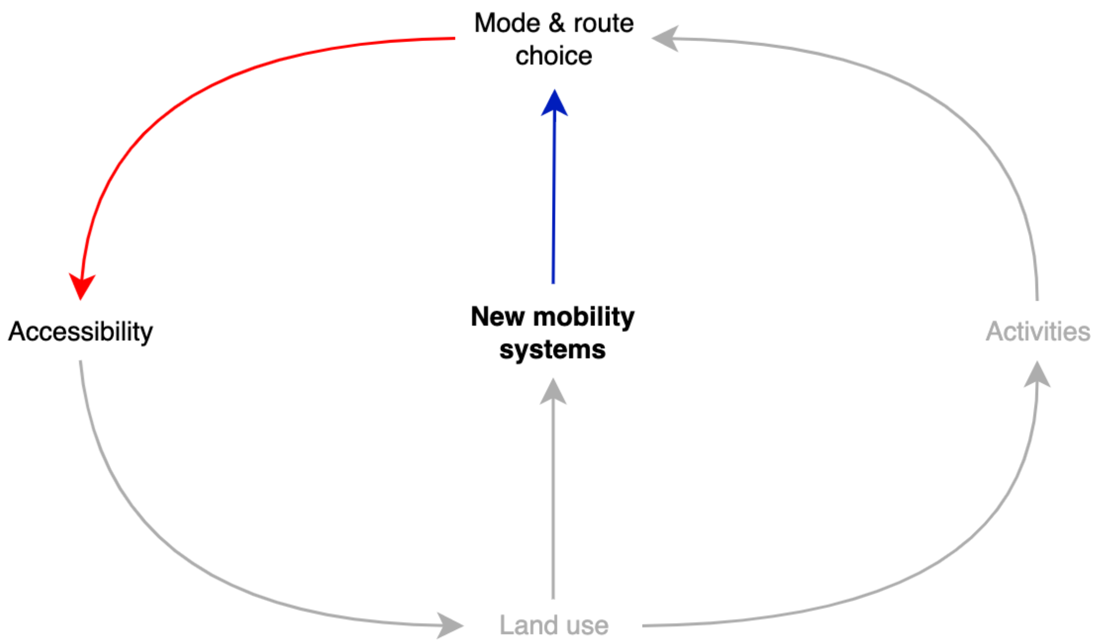

Figure 1: Dominant relationships of the effects of new mobility systems on mode choice and accessibility. Adaptation from Wegener [7].

Researching how new mobility systems affect accessibility is difficult since revealed data of the potential users using these new mobility systems are not available yet. In previous research, estimating the modal split using revealed preference data, this was solved by using the abstract mode modelling approach to estimate the modal share of a shared autonomous vehicle and an electric step [5]. The abstract mode modelling approach was introduced by Quandt & Baumal and describes a method to formulate a discrete choice model by describing the utility of each mode with the same mode attributes for each mode and by leaving out mode-specific constants and parameters [8]. This abstract mode modelling approach can be used to estimate the modal share of any future mode by defining the values of the mode characteristics, filling in the utility function of the future mode and adding this option to the choice set in a discrete choice model [5].

If one wants to analyze not only the effect on mode choice, but also on accessibility, the 4-step traffic assignment model can be used [9]. This model describes four steps in which the input data is used to generate trips, distribute trips, calculate the mode choice, and finally assign the traffic. The introduction of a new mobility system affects both mode and route choice simultaneously, since some routes are mode specific or only for a certain subset of modes (see Figure 2). A traffic assignment model that takes into account both mode and route choice simultaneously to assess how new mobility systems affect accessibility can be developed. Following the same logic as with the previously mentioned discrete choice model [5], one can add the new mobility system, including new route options, in a traffic assignment model to research both mode choice and accessibility at the same time by describing each mode with the same mode attributes and without any mode-specific constants. In this way, revealed preference data can be used to value each mode characteristic and estimate both mode and route choice.

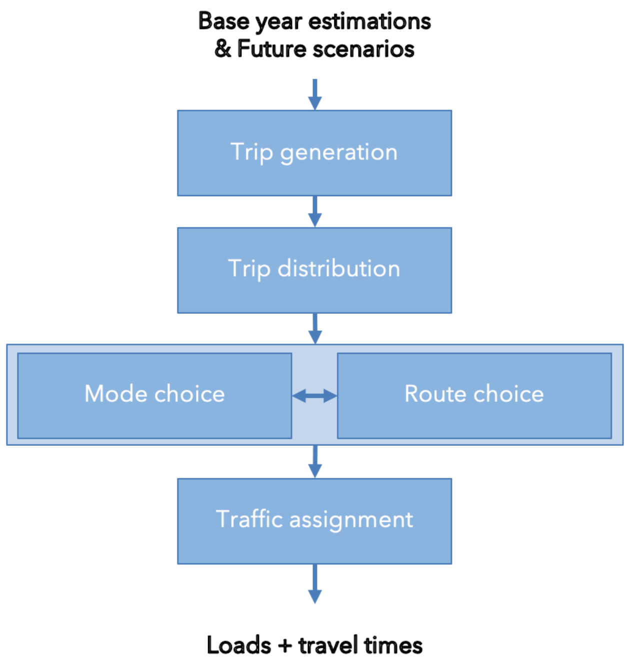

Figure 2: 4-step model with mode and route choice simultaneously estimated. Adaptation from 4-step model of McNally [9].

A multitude of studies discuss the types of traffic assignment models and distinguish between static, quasi-dynamic, and dynamic modeling approaches, where a static model assumes that traffic conditions are always the same and does not depend on time, a dynamic model assumes that traffic conditions change over time, thus including effects, such as congestion, spillback, and rerouting, and a quasi-dynamic model assumes that traffic conditions are always the same, but spillback is still modelled. [10]–[12]. (Quasi-)dynamic models can capture emergent effects that cannot be captured in static models. These models, however, are computationally move heavy than static models, so depending on the goal of the model, (fully) dynamic models are not always the best choice.

Generally, three levels of detail are distinguished when discussing traffic assignment models; microscopic models that describe the behavior of individual agents, macroscopic models that describe the behavior of agents as a continuous flow, and mesoscopic models that fill the gap in between micro- and macroscopic models [10]. Mesoscopic models describe agents using aggregated terms, e.g., in probabilistic terms, but behavioral rules are on an individual level. Emergent effects can be theoretically be observed in micro- and mesoscopic models, where the computational complexity ranges from high to low for micro-, meso-, and macroscopic models respectively [10], [12]. When analyzing accessibility in urban areas with respect to mode and route choice, dynamic micro- and mesoscopic models have the preference, since these can observe congestion, spillback, rerouting, and other emergent effects.

A way to come closer to estimating the true modal share of new mobility systems is to include multimodal trips which can capture first and last-mile mobility systems (e.g., shared bicycles available at train stations are only valuable as last-mile mobility system) [13]. This can be done by developing a multimodal supernetwork, as opposed to a unimodal model, which can model multimodal trips without the need to predefine the combinations of mobility systems manually beforehand [13], [14]. These models only need to know where people are allowed to switch modes (e.g., where the mobility hubs are located).

We expect that applying the unlabelled mode modelling approach to a dynamic microscopic multimodal supernetwork can yield great insight to expose how travellers make mode and route choices and how it these choices influence the accessibility of an urban area. A requirement to this approach is that the revealed preference data contains a complete and coherent set of mode attributes that can describe current and future modes adequately. Furthermore, it must be assumed that the travellers' valuation of the mode attributes does not change with the introduction of a new mobility system.

This paper explores how the abstract mode modelling approach can be applied to a dynamic microscopic traffic assignment model with a multimodal supernetwork to estimate the modal split of any future mode and the change in accessibility when a future mode is introduced. This method is demonstrated by estimating the future modal split and change in accessibility of a shared autonomous vehicle and a shared electric step. To the authors' knowledge, this is the first time a supernetwork is used to estimate the modal share of a future mode and the change in accessibility using revealed preference data. Knowledge gaps and possible future research directions to research the effects of new mobility systems on the accessibility of urban areas are identified as well.

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