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Building a validation measure for activity-based transportation models based on mobile phone data

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A B S T R A C T

Activity-based micro-simulation transportation models typically predict 24-h activity-travel sequences for each individual in a study area. These sequences serve as a key input for travel demand analysis and forecasting in the region. However, despite their importance, the lack of a reliable benchmark to evaluate the generated sequences has hampered further development and application of the models. With the wide deployment of mobile phone devices today, we explore the possibility of using the travel behavioral information derived from mobile phone data to build such a validation measure.

Our investigation consists of three steps. First, the daily trajectory of locations, where a user performed activities, is constructed from the mobile phone records. To account for the discrepancy between the stops revealed by the call data and the real location traces that the user has made, the daily trajectories are then transformed into actual travel sequences. Finally, all the derived sequences are classified into typical activity-travel patterns which, in combination with their relative frequencies, define an activity-travel profile. The established profile characterizes the current activity-travel behavior in the study area, and can thus be used as a benchmark for the assessment of the activity-based transportation models.

By comparing the activity-travel profiles derived from the call data with statistics that stem from traditional activity-travel surveys, the validation potential is demonstrated. In addition, a sensitivity analysis is carried out to assess how the results are affected by the different parameter settings defined in the profiling process.

1. Introduction

1.1. Activity-based transportation models

The main premise of activity-based micro-simulation transportation models is the treatment of travel behavior as a derived demand of activity participation. In this modeling paradigm, travel is analyzed through daily patterns of activity behavior related to and derived from the context of land-use and transportation network as well as personal characteristics such as social-economic background, lifestyles and needs of individuals (e.g. Bhat & Koppelman, 1999; Davidson et al., 2007; Fan & Khattak, 2012; Lemp, McWethy, & Kockelman, 2007; Wegener, 2013).

All the above information, complemented with a training set of household travel surveys which document the full daily activity-travel sequences of a small sample of individuals during one or a few days, is analyzed and translated into heuristic decision making strategy rules. These rules represent the scheduling process of activities and travel by the individuals (e.g. Arentze & Timmermans, 2004; Bellemans et al., 2010). Once established they can be used as the probabilistic basis for a micro-simulation process, in which complete daily activity-travel sequences for each individual in the whole region are synthesized, using Monte Carlo simulation methods. The synthesized individual activity-travel sequences are then aggregated into origin–destination (OD) matrix, with each matrix element representing the number of trips between each pair of locations of the region. This matrix, after being assigned to a road network through traffic assignment algorithms, can subsequently serve as essential input for travel analysis in the region, such as travel demand forecasting, emission estimates and the evaluation of emerging effects caused by different transportation policy

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scenarios. Fig. 1 illustrates the entire process of a micro-simulation model.

1.2. Problem statement

Despite comprehension and advancement of the activity-based transportation modeling system, the lack of reliable data in sufficient size does not enable one to have a decent benchmark and evaluation criterion for the model output (e.g. Cools, Moons, & Wets, 2010a; Cools, Moons, & Wets, 2010b). Typically, for this purpose, one examines the results of the model both internally and externally at different stages of the simulation process, as indicated in Fig. 1 (e.g. Bellemans et al., 2010; Rasouli & Timmermans, 2013; Yagi & Mohammadian, 2010). The internal validation involves the comparison of the estimated results with expanded travel survey data which is not used in the training phase of the model but usually collected in the same survey period. In this validation, certain aggregated measures, e.g. the average travel distance and travel duration, derived from both the predicted sequences and the observed ones, are examined (e.g. Cherchi & Cirillo, 2010; Roorda, Miller, & Habib, 2008). The sequence alignment method (SAM), which compares two sequences based on the composition and temporal ordering of the daily activities (Abbott & Forrest, 1986; Wilson, 1998), is also employed to assess the similarities between each of the observed sequences and its predicted counterpart (e.g. Sammour et al., 2012). However, the process involved in the development of the model, from initial data gathering to exploitation and validation of the first results, is lengthy and may take years, imposing a time lag between the data initially obtained and the data that is required for an objective and up-to-date validation measure. In addition to this time limitation, the high cost related to the surveys, makes it a challenge to collect samples in sufficient size, capable of providing a good representation of activity-travel behavior of a population. Moreover, travel surveys usually query information of only one or two days, in order to limit the negative effects associated with respondent burden. Consequently, this tends to obfuscate the less frequent activities, such as sports or telecommuting activities which are often carried out only once a week or once a month. These shortcomings have been well reported in the literature (e.g. Asakura & Hato, 2006; Cools, Moons, Bellemans, Janssens, & Wets, 2009).

In contrast to the internal validation, the external validation consists of an indirect evaluation of the model output at a later phase, i.e. traffic assignment stage (see Fig. 1). The estimated traffic volumes at a number of predefined road segments are compared against information from external sources, such as traffic counts collected by inductive loop detectors which are deployed on the road segments.

However, the external validation process encompasses an aggregation step to compose the OD matrix as well as an assignment step to allocate the travel demand matrix to the road network. Valuable information may be lost in these two steps. Consequently, positive outcomes of the compared results might be artifacts of the validation process itself, and thus provide no real guarantee of the accuracy of the model. Moreover, when mismatches are found, there exists no clear procedure to trace back the causes, thus limiting the discovery of remedies to improve model construction. Nevertheless, despite such limitations, at the present, the indirect external evaluation is essentially the only option for model quality assessment in practice, as no well-established methods are found for operating closer to the model itself (e.g. Janssens, Giannotti, Nanni, Pedreschi, & Rinzivillo, 2012). This is a problem that seriously hampers further model development and model application (e.g. Hartgen, 2013). Having useful and reliable benchmark and evaluation criteria for activity-based micro-simulation models has thus been a major concern.

1.3. Mobile phone data: a new data source for transportation modeling and validating

The wide deployment of mobile phone devices has created the opportunity to use the devices as a new data collection method to overcome the lack of reliable benchmark data (Jiang et al., 2013). Location data recorded from the mobile phone devices reflects up-to-date travel patterns on a significantly large sample of the population, making the data a natural candidate for the analysis of mobility phenomena (e.g. Do & Gatica-Pereza, 2013; Schneider, Belik, Couronné, Smoreda, & González, 2013). In addition, the data collection is a by-product of the mobile phone companies for billing and operational purposes that generates neither extra expenses nor respondent burden.

The importance and added value of mobile phone data in the study of travel behavior and transportation modeling have been manifested by a variety of research efforts, ranging from the investigation of key dimensions of human travel, such as travel distance and time expenditure at different locations (e.g. González, Hidalgo,

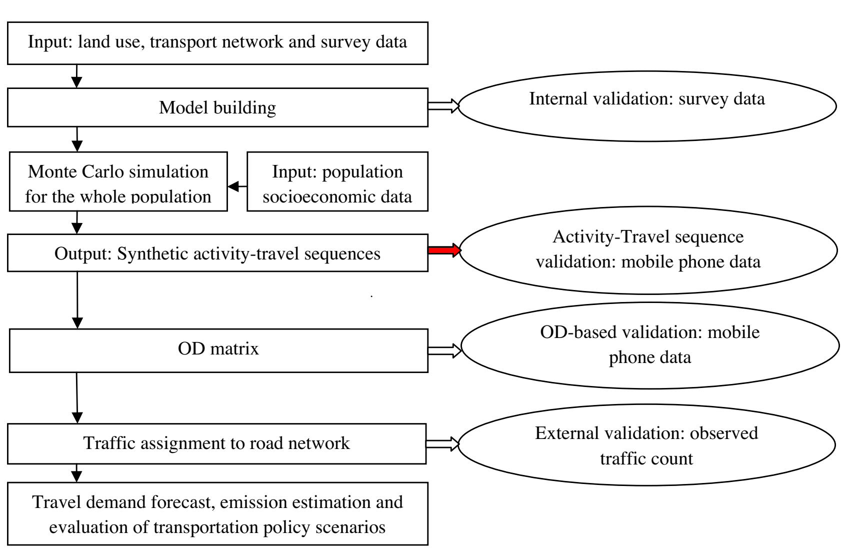

Fig. 1. The entire process of an activity-based transportation model.