Route choice model estimation in a dynamic network based on GPS data

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Abstract

Three main issues are associated with the estimation of random utility route choice models based on revealed preference (RP) data collected in real networks. Firstly, choice set sampling is difficult (for reviews see Bovy 2009, Frejinger & Bierlaire 2010). Secondly, utilities may share unobserved attributes and in which case IIA does not hold (e.g. Cascetta et al. 1996, Ben-Akiva & Bierlaire 1999, Bekhor et al. 2001, Frejinger & Bierlaire 2007). Thirdly, the attributes of the alternatives (e.g. travel times at the time of the observation) are in general unknown. Dealing with these issues is more complex in dynamic than

static networks (Gao et al. 2008). Recently, Fosgerau et al. (2011) proposed a link choice based model that can be consistently estimated based on path observations but with the advantage of not requiring any definition of path choice sets. Thus, addressing the first issue mentioned above. They present estimation results based on GPS data for a static and deterministic network.

This paper presents the first route choice model for a dynamic network with deterministic link attributes estimated based on RP data collected in a congested network for which link travel times are known. We show how the model of Fosgerau et al. (2011) can be specified and estimated in this context. We therefore address two of the three main issues stated above in a dynamic network setting.

The data set consists of a combination of travel diaries and GPS traces collected for 9 weeks in the spring of 2011 in The Netherlands. Participants were selected among staff of the Delft University of Technology and all lived in The Hague and commuted by car to Delft. This setting ensured the existence of at least two attractive alternative paths and as a result a route choice could be made in response to traffic conditions, time of day, etc. Commuting distances are approximately 16 km, commute frequencies on average 3.5 times per week, 32 participants were selected, travel diaries were filled in after each trip and 80% of the travelers also had access to personalized traffic information provided via TomTom.

In this paper we focus on modeling the commute route choice on the main road network, $G = (A, V, \mathcal{T})$ where A is the set of links ($|A| = 520$), V the set of nodes ($|V| = 195$) and $\mathcal{T}$ the set of time intervals. Link travel times have been retrieved from the TomTom database and consists of the travel time on each link at one minute intervals during the whole study period. The link travel times reveal large travel time variances on highways and smaller travel time variances on the other types of main roads. The trips can be matched to this network without ambiguity thanks to the high accuracy of the GPS devices (3 meters); there are very few cases of lost signal. We discard the parts of the trips that take place outside the main road network close to the origins and destinations. This does not affect our model since we do not include origin-destination specific attributes but rather focus on characteristics of the roads. The resulting data set has 1200 path observations.

Fosgerau et al. (2011) formulate the route choice problem as a sequence of link choices using a dynamic discrete choice model (Rust 1987). At each node the traveler chooses the

utility-maximizing outgoing link. The utilities of each link are given by the instantaneous cost for each link, the expected utility at the end of links and i.i.d. extreme value I error terms. Link choice probabilities are then given by a multinomial logit model. Expected downstream utilities are identified from Bellman equations. This leads to a chosen path in a sequential and dynamic fashion. In general there are infinitely many potential paths connecting an origin to a destination as paths may contain loops and can be arbitrarily long. It turns out that the probability that a given path is chosen has the form of a multinomial logit model, except that the number of alternatives is infinite. The Bellman equations in this context correspond to a system of linear equations which can be efficiently solved.

The time interval for the link travel times is 10 seconds which is shorter than the minimum link travel time. The number of possible states are $|A||\mathcal{T}|$ (compared to $|A|$ in the static case) which is large but manageable for a network of our size. Note that $\mathcal{T}$ can be defined specific to each trip to reduce the size of the state space. When the network is time expanded in this way, the model can be estimated in the same way as for a static network (see Fosgerau et al. 2011). Hence, we use the same, existing, estimation code implemented in MATLAB.

This is ongoing work and we have now finished processing the data and the network and are in the start-up phase of the estimation. In the paper we will present estimation results for different definitions of the instantaneous utility functions with a particular focus on travelers' sensitivity to travel time variability. We will also investigate if this sensitivity is different when travelers have access to personalized traffic information via the TomTom device. We know from the travel diaries who had a TomTom and for which trips it was actually used.

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