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Exploration of day-to-day route choice models by a virtual experiment

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Abstract

This paper examines existing day-to-day models based on a virtual day-to-day route choice experiment using the latest mobile internet techniques. With the realized day-to-day path flows and path travel times in the experiment, we calibrate several well-designed path-based day-to-day models who take the Wardrop's user equilibrium as (part of) their stationary states. The nonlinear effects of path flows and path time differences on the path swapping are then investigated. Participants' path preferences, time-varying sensitivity and learning behavior in the day-to-day process are also examined. The prediction power of various models with various settings (nonlinear effects, time-varying sensitivity, and learning) is compared. Assumption of rational behavior adjustment process in Yang and Zhang (2009) is further verified. Finally, evolutions of different Lyapunov functions used in the literature are plotted and no obvious diversity is observed.

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Keywords: Day-to-day flow dynamics; virtual route choice experiment; regression analysis; model calibration and comparison.

1. Introduction and literature review

There has been a substantial stream of development of day-to-day dynamic models to look into the variation of traffic flows from epoch to epoch (Cascetta, 1989; Watling and Cantarella, 2015). It is believed that travelers'

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historical traffic experience, as well as their prediction on future traffic conditions, would influence their trip decisions from day to day. Prediction of the traffic condition in the future epoch (e.g., traffic volume of the morning peak on working day) can help the transportation agencies arrange appropriate management and control strategies ahead of time. It is especially useful when the network structure changes (Guo and Liu, 2011; He and Liu, 2012). In general, two types of trip decision, i.e., route choice and departure time choice, are considered in the day-to-day study context. The focus of this paper is solely on route choice. Readers interested day-to-day departure time choices can refer to some pioneering works by Hu and Mahmassani (1997), Mahmassani (1990), Mahmassani and Chang (1986), Mahmassani et al., (1986), and recently by Xiao and Lo (2016), just to name a few.

Starting from the pioneer work by Smith (1984) and Horowitz (1984), the day-to-day route choice models are to study how the aggregate traffic flow changes based on current/historical flows and travel costs. The day-to-day model is a deterministic-process model if it is formulated as ordinary differential equations or difference equations, and their steady states can be different kinds of user equilibrium (UE), including deterministic UE (DUE, i.e. Wardrop's UE), stochastic UE (Cantarella and Cascetta, 1995; Smith and Watling, 2016), and boundedly rational UE (Di et al., 2015; Guo and Liu, 2011; Mahmassani and Chang, 1987; Ye and Yang, 2016). The stochastic-process models, on the other hand, formulate flow dynamics as stochastic processes, and the steady state is the equilibrium probability distribution (Cascetta, 1989; Cascetta and Cantarella; 1991; Davis and Nihan, 1993; Hazelton, 2002; Hazelton and Parry, 2016; Hazelton and Watling, 2004; Parry and Hazelton, 2013; Watling and Cantarella, 2015).

The interaction between day-to-day dynamic route flows and other components of the transportation system is widely studied in the analytical way, which includes the traffic information system (Bifulco et al., 2016; Cantarella, 2013; Cho and Hwang, 2005; Friesz et al., 1994), fixed or responsive signal control strategies (Cantarella et al., 2012; Huang et al., 2016; Liu and Smith, 2015; Smith et al., 2015; Smith and Mounce, 2011; Xiao and Lo, 2015), congestion pricing (Friesz et al., 2004; Farokhi and Johansson, 2015; Guo, 2013; Guo et al., 2016; Tan et al., 2015; Wang et al., 2015; Xu et al., 2016; Yang, 2007; Yang and Szeto, 2006; Yang et al., 2007; Ye et al., 2015), and tradable credit scheme (Ye and Yang, 2013). Day-to-day dynamics in other travel modes are also studied, such as in railway (Wu et al., 2013) and transit (Bar-Yosef et al., 2013; Cantarella et al., 2015; Li and Yang, 2016).

Besides theoretical development, the route choice based day-to-day dynamics is also studied through simulation and laboratory experiments. Most of these studies were concerned about how travelers' route choices are affected by various factors such as information, experience, risk, uncertainty, personality factors, as well as various transportation system components mentioned above (Avineri and Prashker, 2005, 2006; Ben-Elia et al., 2008, 2013; Hu and Mahmassani, 1997; Lotan, 1997; Lu et al., 2011; Mahmassani and Herman, 1990; Mahmassani and Stephan, 1988; Rapoport et al., 2014; Srinivasan and Mahmassani, 2003; Yang et al., 1993). The laboratory experiments were also used to test the static UE theories such as Braess Paradox and Downs-Thomson Paradox (Dechenaux et al., 2014; Morgan et al., 2009; Rapoport et al., 2009).

Our paper focuses on another interesting question that has not yet received sufficient attention in the research community: are the various route choice based day-to-day models proposed so far good enough to reflect the real-life situation, and if yes, what are their relative good performances? Regarding this question, some early and recent empirical studies are conducted by Avineri and Prashker (2005), He and Liu (2012), Mahmassani and Jou (2000), Meneguzzer and Olivieri (2013), Rapoport et al., (2014), just to name a few. In contrast, in this study we focus on a specific group of DUE-based day-to-day route choice models, which all have nice stability and convergence property but are not empirically studied yet. And to answer our question, we conducted a virtual route choice