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A cumulative prospect theory approach to commuters' day-to-day route-choice modeling with friends' travel information

Chong Zhang[a,b], Tian-Liang Liu[b,*], Hai-Jun Huang[b], Jian Chen[a]

[a] *Research Center for Contemporary Management, Key Research Institute of Humanities and Social Sciences at Universities, School of Economics and Management, Tsinghua University, Beijing 100084, China*
[b] *MoE Key Laboratory of Complex System Analysis and Management Decision, School of Economics and Management, Beihang University, Beijing 100191, China*

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ABSTRACT

This paper investigates the effects of social interaction information from friends on commuters' daily route choice decisions. Besides the actual route travel time shared among friends, both the amount and percentage of friends choosing each route are regarded as being influence factors. For estimating the factors' relative importance, this paper first develops a day-to-day route-choice learning model with friends' travel information based on the Cumulative Prospect Theory (CPT), and then designs and conducts a laboratory behavioral experiment to collect the statistical data associated with subjects' actual route choice decisions. Experimental results show that a larger rate of social interactions in an online travel community does not necessarily lead to a better route-choice outcome for individuals or the whole system. Furthermore, the overall impact of the amount and percentage of friends choosing each route on the generation of perceived travel time may be negative or positive, depending on the number of members in an online travel community. Using the developed model, the endogenous reference points of the subjects are estimated to first increase and then decrease over simulated days till being roughly leveling off, and the average travel prospect values of the subjects on all routes are estimated to first increase, then decrease and finally level off over simulated days. We also discuss the implication of integrating friends' travel information into modeling by comparing the forecast accuracies of the models with and without direct consideration of friends' travel information, and improve the developed model by incorporating the overlapping effects of routes.

1. Introduction

Innovations in information technology provide travelers with a myriad of traffic information sources, which have increasing impacts on their travel decision-makings. Generally, the information sources can be comprised into three main categories, i.e., travelers' own experiential information, conventional information and social interaction information. Travelers' own experiential information is extracted from memory and reinforced by learning from feedback of their own past experiences (Ben-Elia and Avineri, 2015). Conventional information is free or paid suggestion and guidance such as that spreading via radio and online maps, and social interaction information is gained from other travelers through social network. Social interaction is an important means of information exchange, and traffic information from social network affects travelers' perceptions of actions, behavior, attitudes, beliefs, and choices (Maness et al., 2015).

* Corresponding author.
E-mail address: liutianliang@buaa.edu.cn (T.-L. Liu).

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Most existing studies paid more attentions to travelers' own experiential information and conventional information in network equilibrium modeling (e.g., Yang and Meng, 2001; Yin and Yang, 2003; Huang and Li, 2007; Liu et al., 2009; Huang et al., 2011; Lindsey et al., 2014; Zhang and Yang, 2015; Bifulco et al., 2016; Nakayama, 2016), day-to-day dynamics or agent-based modeling (e.g., Yang and Huang, 2004; Huang et al., 2008; Wu and Huang, 2010; Xu, Lam and Zhou, 2014; Xiong et al., 2016), and behavioral experiments or surveys (e.g., Mahmassani and Liu, 1999; Zhong et al., 2012; Tseng et al., 2013; Razo and Gao, 2013; Ben-Elia et al., 2013; Rapoport et al., 2014). Different from them, this paper focuses on the effects of social interactions in an online travel community. Travelers who have joined in the same online travel community can share travel information and experiences with friends, i.e., other members of the community. This type of travel information can be readily and spontaneously generated. Moreover, it is usually targeted and more credible for travelers, and can be gathered and shared rapidly in easy and cheap ways through social network platforms (Liu et al., 2013), such as Waze (the world's largest community-based traffic and navigation application, www.waze.com) and Wechat (one of the largest messaging and social networking applications, www.wechat.com). The gathered and shared information by friends could help travelers not only complete non-recurrent trips, such as those associated with shopping (Han et al., 2011) and sightseeing (Iryo et al., 2012), but also make recurrent choices for daily commute (Xiao and Lo, 2016; Wei et al., 2016). It has become a hot topic in transportation research to reveal how social interactions affect travelers' perceptions about travel utility and choice sets, and in what ways using social interactions can enhance the efficiency of the transport system.

The most prevalent method of modeling the effects of social interactions is to incorporate others' choice outcomes as an additional influencing factor in the evaluation of one traveler's alternatives. By conducting information cascade experiments in the sustainable context, Gaker et al. (2010) revealed that once given the prior choices of others, subjects more likely take the most chosen option, confirming that social norms are among the most powerful influences of travel behavior. Sunitiyoso et al. (2011) verified by a laboratory experiment the co-existence of confirmation (reinforcing behavior if others have similar behavior) and conformity (following the choice which is most chosen). A preliminary experimental study by Liu et al. (2013) found that, a larger rate of social interactions, i.e., a larger ratio of the amount of friends one subject has to that of other subjects, does not necessarily lead to a better joint choice of travel mode and departure time for individuals in terms of equity or higher efficiency of the transport system. All of these works imply that besides the amount of friends (Iryo et al., 2012; Xiao and Lo, 2016; Wei et al., 2016), the percentage of friends choosing each alternative is also one of social influence factors affecting travelers' perceptions about travel utility.

In this paper, we propose a Cumulative Prospect Theory (CPT) approach to model commuters' day-to-day route choices with social interaction information from friends in the same online travel community. Specifically, we add direct variables with respect to social interactions, i.e., the amount and percentage of friends choosing each route, in commuters' perceived route travel time functions, besides the actual route travel time shared among friends and the past perceived route travel time. After that, following but a little different from the works of Xu et al. (2011a, 2011b), we build a utility measurement system based on the CPT, developed by Tversky and Kahneman (1992), in a day-to-day learning setting to capture commuters' psychological behavioral characteristics, such as their risk attitudes, rationality and travel preferences. In this learning setting, not only reference points, i.e., travel time budgeted to guarantee on-time arrival at destination, are endogenously and dynamically generated, but also commuters' perceived travel time distribution on each route is daily updated. With CPT-based utility values, commuters are assumed to choose routes for daily commute trips under the multinomial logit rule. Furthermore, we design and conduct a laboratory behavioral experiment to collect the data associated with commuters' actual choice decisions for parameter estimation and model validation. After being recruited to join the experiment, all subjects are requested to first complete a questionnaire survey in which their risk attitudes in the framework of the CPT can be obtained statistically, and then make route choices with social interaction information from friends in a pre-set online travel community for each simulated day.

The main findings of this paper are summarized as follows. Firstly, the average value and variance of all subjects' actual travel time are minimal under different rates of social interactions. In our experiment, they are 41.7% and 83.3%, respectively. This implies that more information from friends does not necessarily lead to a better route choice outcome for the whole system (in terms of efficiency) or individuals (in terms of equity), which verifies the experimental results initially obtained in Liu et al. (2013). We also find that regardless of what rate of social interactions is given, there are large gaps between the experimental numbers of the subjects choosing each route and the system-optimum theoretical ones. It indicates that the social interaction information from friends does not play a direct role in guiding the system to evolve toward the system optimum. Secondly, the amount and percentage of friends choosing each route may have opposite impact on the generation of the new value of perceived travel time on that route, and their overall impacts are first negative and then positive as the number of members in an online travel community increases. Thirdly, using the proposed CPT-based day-to-day learning model, the endogenous reference points of subjects are estimated to first increase and then decrease over simulated days till being roughly leveling off, which is close to the user-equilibrium value of route travel time; and the average travel prospect values of the subjects on all routes are estimated to first increase, then decrease and finally level off over simulated days. This implies the system converges to the state of stochastic user equilibrium in terms of the CPT-based utility measurement. Finally, according to the commuting simulation results, the developed learning model with direct variables with respect to social interactions has the more accurate forecast of the experimental route-choice outcomes than the model with no direct consideration of social interactions. This implies that the amount and percentage of friends choosing each route might truly affect the subjects' perceptions about the route travel time. And, the further improvement of the developed model by incorporating the overlapping effects of routes in the experimental traffic network has a better forecast accuracy.

The remainder of this paper is organized as follows. We introduce the CPT and several related concepts in Section 2, and develop the CPT-based day-to-day route choice model with friends' travel information in Section 3. The design and results of the laboratory behavioral experiment are presented in Section 4 and Section 5, respectively. In Section 6, we emphasize the implication of integrating friends' information into modeling through commuting simulations and improve the developed model by taking the overlapping parts among routes in consideration. Section 7 concludes the paper.