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Day-to-day departure time modeling under social network influence

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ABSTRACT

With the prevalence of social media and location-aware mobile devices, travelers may make travel decisions not only by referring to their own experiences and conventional travel information, but also information shared on their social media. This study investigates the influence of this novel information on commuters' day-to-day departure time choices. We introduce a general framework for departure time choice with information sharing via social networks, which can be applied to any social network structure and is flexible for future extensions. The key in the framework, the learning process from friends' information in decision-making, is modeled based on the Bayesian learning theory. The properties of this learning model and the dynamics of the day-to-day departure time choice are analyzed. We further propose an agent-based approach to simulate travelers' choices. The parameters in the learning model are estimated based on an experimental data set. The agent-based approach is applied to validate the model and examine the effect of different social network structures, in terms of both travel choices and transportation system performance.

1. Introduction

The recent widespread use of social media among travelers provides a new platform for exchanging travel experiences and sharing traffic information. The shared information can be travel experience, travel mode choice, opinion about the choice sets, and so on. The development of this new method of spreading traffic information also benefits from the prevalence of location-aware mobile devices (e.g. mobile phone and car GPS). By sharing information via social networks, travelers can get more information about the dynamic and uncertain traffic environment and then optimize travel choices. Compared with conventional traffic information, such as that spreading via radio and online maps, the traffic information from social networks has some unique properties. Firstly, it is user-specific. Different travelers have different social connections, as people are inclined to connect with those who sharing common interests with them, such as the same travel plans or same mode choices. Since the information is generated by travelers, even for the same traffic environment, people with different social connections would receive different information, both in quantity and in content. Secondly, such information is more sensitive to unexpected traffic events, such as incidents or sudden demand surges, since travelers are acting as sensors, who are better in responding to dynamic changes in the traffic environment. Thirdly, the more individual travelers join in the platform and share information, the more accurate information about the traffic environment becomes available, forming a crowdsourcing system. The influence of such information sharing on travel behavior has been drawing increasing attention

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recently. Existing studies showed that the shared information by friends could help travelers update their perceptions about travel utility and choice sets, explore new areas or alternatives (Han et al., 2011), make efficient choices (Iryo et al., 2012), and affect both their short-term travel choices and long-term life style changes (Ettema et al., 2011; Páez and Scott, 2007).

Most existing studies in this line of research considered non-work trips, such as the shopping (Han et al., 2011) and sight-seeing (Iryo et al., 2012), as it seems natural for people to consult and exchange opinions with friends for unfamiliar or infrequent choices. We noticed that recently travelers take advantage of social network information for commute choices as well, which has not received much attention in existing related studies. For one thing, the traffic environment is dynamic and ever changing. Traffic condition changes, especially on available alternatives and unexpected big events (e.g. bridge collapse), will incentivize travelers to keep referring to real-time traffic information and making travel choice changes as necessary. The social network can be an important information resource due to its user-specific and up-to-date properties. For another, traffic information sharing via social networks for commute trips can be accomplished efficiently and automatically based on the embedded location information. For example, after a traveler sets her origin and destination (OD), the system can immediately show the related traffic information shared by her friends (e.g. friends' experienced travel times with the same OD), without the need to contact her friends for the information. Another thing making the communications efficient is the established social connections. Besides sharing information with actual friends, travelers can also be connected if they share the same locations or travel plans. For instance, if a traveler sets her experienced travel time of a certain OD as public, then all other travelers with the same OD can follow her on social network and receive her information. This method can largely increase the amount of information for travelers, which has been used in some industry applications, such as *Waze* (a crowdsourcing routing mobile application, https://www.waze.com/). As a result, we believe that social network has a great potential in spreading traffic information, and its influence on people's day-to-day dynamic commute choices is an important topic to be studied. One objective of this study is to formulate a generic framework so that various levels and forms of social connections can be modeled. For simplicity of analysis, departure time choice, one important component in commute choices, will be the focus of this study.

To model how travelers use social network information in decision-making, most existing studies first assume travelers are rational and utilitarian, and then change or add variables with respect to social influences in their utility functions, such as the amount of friends (Iryo et al., 2012) or the weighted average utility of friends (Han et al., 2011) of choosing each alternative. This basic idea will be followed in this study to model the social influences on departure time choice. Modeling the choice behavior of individual travelers is an important branch of studies on departure time choice; widely used models include discrete choice model (Small, 1982) and nested logit model (Small, 1987). The key factor in departure time choice is the estimated travel time of certain departure time. Therefore, we first model how travelers use friends' information to estimate the travel time of corresponding departure time, and then incorporate it into the departure time choice model (the multinomial logit model is used in this study). On the other hand, the transportation system is ever changing, and we are interested in the dynamics and evolution of travelers' day-to-day departure time choices with social network information. Stochastic process models have been developed to model the dynamics of transportation systems, such as the day-to-day traffic assignment (Cascetta, 1989; He et al., 2010; Parry and Hazelton, 2013; Smith et al., 2013; Watling, 1996; Watling and Cantarella, 2012). Most studies in this line of research assume that travelers have the same information on all alternatives. However, when the information from travelers' social networks is taken into consideration, it is very possible for travelers to have different levels of information about the transportation network performance. This induces heterogeneity in travelers' travel time estimation and probability of choosing departure times.

In this study, the dynamic learning behavior with social network information is modeled based on Bayesian updating, which is chosen due to its ability to readily handle the uncertainties associated with travel (Chen and Mahmassani, 2004; Parvaneh et al., 2012). It is also a natural way to describe learning behavior with sequential information updates (Jha et al., 1998), and is flexible for different contents and amounts of information. For day-to-day departure time choice, a traveler's initial estimation of travel time for each departure time forms the prior belief. Subsequently, the traveler's own travel experience and friends' information provide the observations (or called evidences) to update the prior belief. The posterior belief will be used for the next day's departure time choice. The significance of sharing information among travelers here is to help them obtain more observations about the uncertain traffic condition, update their prior beliefs, and make better choices. This process will be repeated from day to day, and all the self-experiences and friends' information will have accumulative effects on commuters' choices. In this study, we model this learning behavior in departure time choice, and analyze its properties and dynamics. We further propose a general framework for the problem, which is able to cater to all sorts of social network configurations and various potential extensions. Due to the complexity of theoretical analysis of this problem, we also develop an agent-based approach as an alternative to examine the influence of social networks on general cases.

Another important question in travel behavior modeling is parameter estimation and model assessment. To do this, we need to collect data from real travelers. However, it is hard to trace the social interactions and connections of travelers for an extended period of time and for a large area. Conducting surveys (Carrasco et al., 2008; Kowald and Axhausen, 2012; van den Berg et al., 2009) puts a high burden on data collection (Kowald and Axhausen, 2012). Purely agent-based simulation is efficient and frequently used (Hackney and Axhausen, 2006; Han et al., 2011; Ronald et al., 2012; van den Berg et al., 2013), but without validation from real data, it is difficult to assess whether the simulation results can reflect human behavior faithfully. Laboratory experiment is an eclectic approach for travel behavior data collection, such as the work of Mahmassani and Chang (1986). So we design and conduct an online experiment to collect people's actual responses to