Transportation Research Part C 64 (2016) 133–147

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

An agent-based choice model for travel mode and departure time and its case study in Beijing

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ARTICLE INFO

Article history:
Received 14 May 2014
Received in revised form 28 January 2015
Accepted 4 June 2015
Available online 27 June 2015

Keywords:
Agent-based model
Mode choice
Departure time choice
Travel behavior

ABSTRACT

Aiming to alleviate traffic jams, many traffic management strategies/policies are adopted to nudge travelers to re-arrange their departure time or switch from driving to public transit or non-motorized mode. Analytical travel behavior model is needed to predict travelers' departure time choice and mode switch under such strategies. In this paper, we developed an agent-based model for travellers' choices of mode and departure time. Departing from the traditional utility maximization theory, this model focuses on the decision-making process based on imperfect information, bounded and distinctive rationalities. In the modeling framework, travelers accumulate experiences and update their spatial and temporal knowledge through a Bayesian learning process. Before making a trip, travelers decide whether to search for alternative departure time and/or travel mode according to their expected search gain and cost. When an additional search happens, travelers decide whether or not to switch to the new departure time and travel mode according to a series of decision conditions. Both the search and decision processes are represented by production (if–then) rules derived from a joint revealed/stated-preference survey data collected in Beijing. Then the agent-based model is applied to evaluate congestion charge policies with various demand scenarios in the 2nd ring road of Beijing. Results suggest that the model can display the peak spreading and mode switch process practically.

1. Introduction

As the rapid development of the economic, the number of private cars has expanding quickly in China, thus cause serious traffic congestions in many big cities (such as Beijing and Shanghai). Many traffic management policies and strategies (e.g. vehicle usage restriction, public transit priority) have been taken to solve this problem, but the result is not as good as expected. One of the most important reason is that the decision makers cannot know exactly how the travelers will switch their travel behavior after the policies and strategies are implemented, so the policies and strategies may not meet the actual requirement. Mode choice and departure time choice are important components of travelers' decision behavior during a trip. At macro level, mode and departure time have a direct bearing on the number and temporal pattern of vehicle trips on urban roadways; at micro level, mode and departure time have great influence on travel time and travel cost. It is necessary to build

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http://dx.doi.org/10.1016/j.trc.2015.06.006

effective behavior model to predict travelers' departure time shift and travel mode switch and evaluate the effect of traffic management policies and strategies.

There are many researches to study travel behavior. Traditional theory based on utility maximization assumes substantial rationality and complete information. The logit model derived from the traditional theory is widely used in transportation planning and management. Some researchers suggests that the assumptions of substantial rationality and complete information are not reasonable and do not conform to human behavior character. Then a new travel behavior theory which considers human beings' bounded rationality and incomplete information appears. Zhang (2006) developed a SILK theory which considers Search, Information, Learning, and Knowledge for travel decision-making analysis and he applied the new theory in route choice. Xiong (2011) extended the SILK theory into departure time choice. But there are no applications in mode choice and no research in departure time choice joint with mode choice, especially in developing countries. Both the details of the two theories will be showed as following literature review section.

This paper develops an agent-based joint travel mode and departure time choice model which considers human beings' bounded rationality and incomplete information, and focuses on the travelers' real decision-making process. Travelers are regarded as a group of agents which make decision in the traffic system according to a series of behavior rules. Each agent retrieves spatial, temporal and travel cost information and accumulates travel experience from every single trip. Then agent will update its knowledge through a Bayesian learning process. When a new trip occurs, each agent will make travel mode and departure time choice on the basis of search gain, search cost, search rules and decision rules.

A joint revealed/stated-preference survey was conducted in Beijing to calibrate and validate the search gain function, search cost function, search rules and decision rules. In practice, the agent-based model can be used to analysis the result of travel mode shift and departure time switch for different kinds of policies and strategies which may nudge travelers to change their travel mode and departure time, such as gasoline tax, road pricing, bus and metro fare, and vehicle usage restriction. For example, if we increase the road price during peak period, the proposed agent-based travel behavior mode could be adopted to forecast the peak spreading and mode switch process. This paper takes the road network within the Second Ring Road of Beijing to conduct case study and analyzes the influence on departure time shift and travel mode switch of the different congestion charge policies and the sudden increasing of trip number.

The remainder of the paper is organized as follows. The traditional theory based on utility maximization and agent-based modeling that considers bounded rationality and incomplete information are contrasted and reviewed in Section 2. Section 3 presents the survey design and data collection. Section 4 introduces the agent-based joint travel mode and departure time choice model in detail, then the model is calibrated and validated by using the survey dataset. Section 5 demonstrates the application of the model for policy and scenario analysis in Beijing Second Ring Road. Conclusions and discussions on future research are presented in Section 6.

2. Literature review

The theory of travel behavior is one of the most important theories in traffic management and control area. Travel behavior refers to the complicated decision making process what travelers make during a trip about travel mode choice, route choice, departure time choice, destination choice and so on (Wen and Koppelman, 2000; Arentze et al., 2001).

Traditional behavior theory assumes that human beings are perfect rationality and perfect information. Before making a decision, individuals can identify all the feasible alternatives. Each alternative consists of a set of attributes that can describe the certain alternative. And travelers derive a level of utility from that alternative based upon those attributes and the characteristics of the travelers, then they choose the alternative which can maximize their utility. This is called the utility maximization theory (Von Neumann and Morgenstern, 2007).

The most widely used travel behavior model based on the maximization theory is discrete choice model. This is operationalized in the modeling structure by making the choice process a function of both the alternative attributes and the characteristics of the traveler. The study of discrete choice model in modal share and modal split has a long history. Luce (2012) deduced the Logit model which is the typical representative of discrete choice model. On the basis of the research results on theory by McFadden (1973) and Ben-Akiva and Lerman (1985) get the discrete choice model into application in practical project. In order to estimate the probabilities, various forms of logit and probit models are invented.

While most of these models have the problem of independence of irrelevant alternatives (IIA) and are criticized for their inability to consider decision makers' computational capacity and information availability (Hausman and McFadden, 1984). A large number of researchers have made great efforts to eliminate the IIA property and develops a series of nested logit models and generalized nested logit models (Koppelman and Wen, 1998; Bekhor and Prashker, 2001; Wen and Koppelman, 2001). In addition, several researches have been taken to study the mode switching behavior based on the theory of utility maximization (Hunecke et al., 2001; Srinivasan and Mahmassani, 2003; Wang and Chen, 2012).

Departure time is another important component of travel behavior. Multinomial logit (MNL) approach was first adopted to model departure time choice by Abkowitz (1981) and Small (1982). Just the same as the application in mode choice, the multinomial logit departure time choice model also suffers from the problem of irrelevant alternatives (IAA). In order to avoid IAA, nested logit (NL) models are adopted to analyze correlated departure time intervals (Ben-Akiva and Bierlaire, 2003). Bhat (1998) adopted a nested logit model for departure time choice.

The rational travel behavior theory based on the assumptions of utility maximization and perfect information depicts how travelers should behave but not they actually do (Banister, 1978; Zhang, 2006). Some researchers argues that human