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Review

Boundedly rational route choice behavior: A review of models and methodologies

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ABSTRACT

Perfect rationality (PR) has been widely used in modeling travel behavior. As opposed to PR, bounded rationality (BR) has recently regained researchers' attention since it was first introduced into transportation science in the 1980s due to its power in more realistic travel behavior modeling and prediction. This paper provides a comprehensive survey on the models of BR route choice behavior, aiming to identify current research gaps and provide directions for future research. Despite a small but growing body of studies on employing bounded rationality principle, BR route choice behavior remains understudied due to the following reasons: (a) The existence of BR thresholds leads to mathematically intractable properties of equilibria; (b) BR parameters are usually latent and difficult to identify and estimate; and (c) BR is associated with human being's cognitive process and is challenging to model. Accordingly, we will review how existing literature addresses the aforementioned challenges in substantive and procedural bounded rationality models. Substantive bounded rationality models focus on choice outcomes while procedural bounded rationality models focus on the empirical studies of choice processes. Bounded rationality models in each category can be further divided based on whether time dimension is included. Accordingly, static and dynamic traffic assignment are introduced in substantive bounded rationality while two-stage cognitive models and day-to-day learning models in procedural bounded rationality are discussed. The methodologies employed in substantive bounded rationality include game theory and interactive congestion game, while those in procedural bounded rationality mainly adopt random utility and non- or semi-compensatory models. A comparison of all existing methodologies are given and bounded rationality models' scope and boundaries in terms of predictability, transferability, tractability, and scalability are discussed. Finally existing research gaps are presented and several promising future research directions are given.

1. Introduction

Perfect rationality is widely used in modeling travelers' decision-making behavior. For instance, in mode choice, travelers are assumed to be expected disutility minimizers (Ben-Akiva and Lerman, 1985); and in route choice, only the paths with the least disutility or the least generalized cost are chosen (Sheffi, 1984). As opposed to 'rationality as optimization',

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Simon (1957) proposed that people are boundedly rational in their decision-making processes and they tend to seek a satisfactory choice solution instead. This is either because people lack accurate information, or they are incapable of obtaining an optimized decision due to complexity of the situations. Bounded rationality also requires less computational burdens and ensures existence of a satisficing solution. People search decisions dynamically and will not terminate till an alternative meeting a certain threshold level is found. This level will be adjusted if a satisficing alternative is difficult to find. "Such changes in aspiration level...tend to guarantee the existence of satisfactory solutions" (Simon, 1957). Due to its prevalence in human behavior, 'bounded rationality' has been studied extensively in economics and psychology.

Introduction of bounded rationality into transportation science originated from the need to explain experimental findings of travel behavior which cannot be captured by perfectly rational modeling. Mahmassani and Chang (1987) first employed bounded rationality (BR) in modeling pre-trip departure time selection for a single bottleneck. Since then, there is "small but growing" (Ridwan, 2004) literature on incorporating bounded rationality into various transportation models, such as hyperpath assignment (Fonzone and Bell, 2010), dynamic traffic assignment (Szeto and Lo, 2006), transportation planning (Gifford and Checherita, 2007; Khisty and Arslan, 2005), traffic policy making (Marsden et al., 2012) and traffic safety (Sivak, 2002). All these studies indicate that the BR assumption plays an important role in transportation modeling. However, "there is not yet much convergence among them" (Ridwan, 2004). In other words, there does not exist a standard BR framework for travel behavior study.

In this paper, we aim to conduct a comprehensive survey on boundedly rational travel behavior. There are two types of behavioral research (Simon, 1982): "studies that are aimed at discovering and testing invariant laws of human individual or social behavior" and "studies that estimate parameters we need for fitting theoretical models incorporating known/believed laws to particular situations where we wish to make predictions". The former is to reveal behavior and the latter is to model behavior. Accordingly, we will first review behavioral studies on disclosing and verifying bounded rationality. Then we will summarize research on boundedly rational route choice behavior models.

The rest of the paper is organized as follows: in Section 2, empirical and experimental evidence is listed to support bounded rationality in modeling people's choice behavior. An overview of boundedly rational route choice models will be first summarized in Section 3. In Sections 4.1.1–7, BR formulations are introduced in static traffic assignment, dynamic traffic assignment, two-stage cognitive process and learning models. An in-depth discussion of the boundaries of bounded rationality models along with selection criteria are discussed in Section 8. The present research gaps are summarized and several promising future research directions are pinpointed in Section 9.

2. Behavioral evidence on bounded rationality

In this section, we will review existing empirical evidence to show that perfect rationality is too ideal and boundedly rational behavioral framework is needed.

2.1. Why not perfect rationality

2.1.1. Heuristic and bias

Psychologists and experimental economists verify that people use heuristic rules when making decisions, leading to biases or systematic errors (Conlisk, 1996). For example, people react differently under the same situations when the problem is presented in different ways, called "framing effect" (Tversky et al., 1981).

'Debiasing' experiments are conducted to test whether biases caused by heuristic processes can be eliminated through repeated practice and adequate incentives or punishments. However, several research indicates that biases are "substantial and important behavioral regularities" (Conlisk, 1996) and will not disappear due to deliberation costs.

On the other hand, heuristics are also critical tools people employ when making decisions. People try to tradeoff "between cognitive effort and judgemental accuracy". Due to high costs of deliberation and information search, people tend to use heuristics to find the first alternative which they are satisfied with instead of calculating an optimal one.

2.1.2. Cognitive limit and deliberation cost

Hiraoka et al. (2002) showed that cognitive limits and deliberation costs play important roles in route choices. An experiment was designed where subjects spoke aloud while choosing routes and a protocol analysis was conducted to analyze subjects' cognitive processes from verbal data. Results indicate that drivers have the desire to choose routes with less travel time, involving less cognitive resources and making them feel comfortable while driving along. Among the above three route choice criteria, a choice consuming less cognitive process dominates the other two criteria and drivers choose routes dynamically when one route satisfying their criteria is found.

2.1.3. Violation of taking shortest paths

Transportation researchers from across the world have found evidence that people do not usually take the shortest paths and the utilized paths often have higher costs than shortest ones.

After evaluating habitual routes, only 59% respondents from Cambridge, Massachusetts (Bekhor et al., 2006), 30% from Boston (Ramming, 2001), 87% from Turin, Italy (Prato and Bekhor, 2006) chose paths with the shortest distance or the shortest travel time. According to GPS studies, 60% of subject commuters in the Twin Cities, Minnesota took paths longer