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Experiment of boundedly rational route choice behavior and the model under satisficing rule

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ABSTRACT

In this paper, we study the boundedly rational route choice behavior under the Simon's satisficing rule. A laboratory experiment was carried out to verify the participants' boundedly rational route choice behavior. By introducing the concept of aspiration level which is specific to each person, we develop a novel model of the problem in a parallel-link network and investigate the properties of the boundedly rational user equilibrium (BRUE) state. Conditions for ensuring the existence and uniqueness of the BRUE solution are derived. A solution method is proposed to find the unique BRUE state. Extensions to general networks are conducted. Numerical examples are presented to demonstrate the theoretical analyses.

1. Introduction

Route choice problem refers to the decision-making of route (or path) use between origins and destinations in transportation networks. The question of interest is how travelers are distributed among all possible routes. To solve this, a rule by which travelers choose routes should be known in advance by the modeler. By assuming all road users behave in a completely rational way and seek to minimize their own disutility, Wardrop (1952) defined a state resulted from route choices of many individuals, so-called user equilibrium (UE). At the UE state, no user can further improve her or his utility by unilaterally changing routes. By relaxing some of the behavioral restrictions implied in a strictly deterministic disutility minimization rule, Daganzo and Sheffi (1977) developed a stochastic user equilibrium (SUE) model that considers the travelers' imperfect perceptions of travel times. In this model, the link travel time perception error is treated as a random variable which follows some known probability distribution. The Gumbel and normal distributions are two commonly used ones, which result in the well-known logit-based and probit-based route choice models, respectively (Dial, 1971; Daganzo and Sheffi, 1977). The SUE is achieved when users can no longer change their perceived utility. Existence and uniqueness of UE or SUE in general networks have been well investigated in literature, including the solution methods for obtaining these two states, see Sheffi (1985), Yang and Huang (2005) and Prato (2009) for more details. Recently, Kitthamkesorn and Chen (2013) proposed a path size Weibit stochastic user equilibrium model which adopts the Weibull distributed random error term to handle the route-specific perception variance. Another decision rule for route choice is based on the regret theory (Bekhor et al., 2012; Chorus, 2012a, 2012b).

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As a relaxation of the perfect rational and optimization assumption, Mahmassani and Chang (1987) introduced the concept of indifference band and analyzed the boundedly rational user equilibrium (BRUE) in the standard single-link bottleneck network. They studied the existence, uniqueness, and stability properties of the BRUE. The width of the band was calibrated by empirical observation (Mahmassani and Jayakrishnan, 1991; Hu and Mahmassani, 1997; Mahmassani and Liu, 1999).

Based on the concept of indifference band, Lou et al. (2010) defined a concept of the acceptable path and systematically examined the mathematical properties of BRUE in the static traffic assignment context. They proved that the set of BRUE flow distributions is generally non-convex and non-empty as pointed in Mahmassani and Chang (1987). One of the difficulties in carrying out the BR traffic assignment is that the BRUE state is generally not unique. Wendin et al. (2010) formulated the problem of finding a BRUE flow distribution as a mathematical program with complementarity constraints and searched for a strongly stationary solution using the manifold sub-optimization. Di et al. (2013) proposed a methodology of generating various path combinations and constructed the set of all BRUE solutions in traffic networks with fixed demand.

In the above studies about boundedly rational travel behavior, a key concept is the indifference band (Mahmassani and Chang, 1987) that commuters are assumed to behave as if they had an "indifference band" of tolerable schedule delay and the BRUE state of the system is reached when all users are satisfied with their current choices, and thus do not intend to switch again. Mahmassani and Chang (1987) also noted that while the boundedly rational perspective is not standard in transportation demand literature, it is quite widely accepted in a variety of disciplines as a plausible model of individual decision making, particularly when facing complex decision situations under limited information. For example, various satisficing models are well established in marketing research and consumer behavior, which is of particular relevance in light of analogy between commuting behavior and consumer repurchase decisions.

In this paper, we investigate the boundedly rational route choice behavior that reflects the realistic decision making in route choice problem, aiming at understanding this kind of behavior deeply. Many studies showed that in reality users do not always choose the shortest paths, and the classical Wardrop user equilibrium assignment model cannot give accurate prediction of traffic flow patterns (Nakayama et al., 2001; Avineri and Prashker, 2004; Morikawa et al., 2005). The theory of bounded rationality may provide better prediction to actual traffic flow pattern than the traditional behavior economic theory (Camerer and Fehr, 2006). The first to address the notion of bounded rationality was Simon (1955). Simon suggested a theory of bounded rationality based on satisficing and aspiration levels due to the informational and computational limits of human rationality. The basic idea of the Simon's approach is that people set up the aspiration levels on a goal variable and search for alternatives that can guarantee them. In the simplest case, the search process continues until a satisfactory alternative is found. Simon (1959) coined the term "satisficing" to describe this approach. Satisficing acts as a "stop rule". The concept of bounded rationality has been extensively studied in the economic and psychology literature. It has been shown that bounded rationality is important in many contexts (see de Palma et al. (1994), Conlisk (1996) and references cited therein). In the route choice context, real-world users often choose the first available route for ensuring certain aspiration level being reached. The explicit description of satisficing rule will be given in Section 3.

We first carry out a laboratory experiment to examine the participants' bounded rationality in making route choice decisions. Similar experiments on route choice behavior have already done by other scholars (Selten et al., 2007; Hartman, 2012). Selten et al. (2007) finished the laboratory experiments of a day-by-day route choice game with two parallel roads, and reported that aggregate road choices are accounted for quite well by the Nash equilibrium predictions and large fluctuations do not diminish with individuals' experiences. Hartman (2012) investigated how people respond to the use of a road toll, and found that the toll comes very close to achieving an efficient use of the traffic network. We will collect the users' perceived travel time costs on two routes and examine whether the users' decisions are rational.

We then make a theoretical investigation of boundedly rational route choice behavior under satisficing rule through introducing the concept of aspiration level. To our best knowledge, though there have been several studies examining the aspects of "attribute threshold" (Swait, 2001; Cantillo and de Dios Ortúzar, 2005; Cantillo et al., 2006) and "information processing strategy" (Chorus et al., 2006; Zhu and Timmermans, 2010) in boundedly rational behavior, there is not yet any research targeting the concept of aspiration level in route choice behavior when considering congestion effect. The concept of aspiration level is different from the concept of indifference band in the following two aspects. (i) Their decision mechanisms are different. In reality, a user may consider the difference between the route travel time and his/her aspiration level when choosing a route, not the indifference band that is the travel time difference between his/her current route and the best route. (ii) The indifference band is not the true sense of the bounded rationality proposed by Simon (1955) in behavioral perspective, while the aspiration level can reflect bounded rationality better. In this paper, we assume that the aspiration levels of all individuals at BRUE state are fixed. Actually, aspiration levels are not permanently fixed, but time-varying. Our future research will study the adjustment of aspiration levels. It should be noted that a similar concept, called acceptance level, is widely used in the transportation associated literature, in this paper, however, we prefer to use the term aspiration level for highlighting Simon's original work.

The rest of the paper is organized as follows. In the next section, we present the results of a laboratory experiment dealing with route choice behavior. In Section 3, we give some definitions and assumptions to be used throughout the whole paper. Section 4 analyses the properties of BRUE state under satisficing rule together with a numerical illustration. Conditions for ensuring the existence and uniqueness of the BRUE solution are derived and a solution method is proposed in this section. Extensions to general networks are discussed in Section 5. Section 6 concludes the paper.