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Discrete Optimization

A multiclass, multicriteria logit-based traffic equilibrium assignment model under ATIS

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Abstract

This paper presents a multiclass, multicriteria (cost versus time) logit-based traffic equilibrium assignment model in road networks served by advanced traveler information systems (ATIS). All users are differentiated by their own value of time (VOT) that follows some probability distribution. Users of each class, having their own VOT, are further divided into two groups, equipped and unequipped with ATIS respectively. The travel disutility received by each user is defined as a linear bi-criteria combination of travel time and monetary travel cost. It is assumed that all users make their route choices in a logit-based stochastic manner, but the equipped users have lower perception variation on the travel disutility than the unequipped due to the ATIS service. The model is formulated as a fixed-point problem and solved by the method of successive averages in conjunction with logit assignment. Numerical results show that the traditional single-class and/or single-criterion models may overestimate or underestimate the benefit from ATIS services.

Keywords: Transportation; Utility theory; Value of time; Multiclass multicriteria equilibrium; Advanced traveler information systems

1. Introduction

In recent years, there has been considerable interest in developing and evaluating advanced traveler information systems (ATIS) from both transportation practical and academic circles. Through provision of traffic information, ATIS can help commuters compensate for their limited knowledge and thus make more reasonable travel choice decisions. So far, a number of studies have been conducted for modeling the effects of ATIS on commuting behaviors and assessing the relevant benefits and risks. These studies can in general be classified into such three categories as field and laboratory experiments (Tsuji et al.,

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1985; Mahmassani and Jayakrishnan, 1991; Adler and Blue, 1998), computer simulation (Ben-Akiva et al., 1991; Al-Deek and Kanafani, 1993; Hall, 1993; Yang et al., 1993; Adler et al., 1999) and analytical modeling (Kanafani and Al-Deek, 1991; Yang, 1998; Lo et al., 1999; Yang and Meng, 2001; Lo and Szeto, 2002; Yin and Yang, 2003; Li et al., 2003).

Obviously, travelers equipped and unequipped with ATIS will behave differently in their route choices due to the fact that they obtain different quality of traffic information and then have different perception variances on travel disutility. In analytical modeling approaches, three criteria, namely user equilibrium (UE), system optimum (SO) and stochastic user equilibrium (SUE), are frequently used to model the commuters' route choice behaviors. Kanafani and Al-Deek (1991) estimated the ATIS benefit in a network with recurrent congestion by comparing the total network travel times generated under UE and SO respectively. In the studies by Harker (1988) and Bennett (1993), the equipped and unequipped drivers are modeled to follow the SO and UE criteria, respectively. Ben-Akiva et al. (1991), Yang (1998), and Yang and Meng (2001) developed mixed UE and SUE equilibrium formulae to model the different route choice behaviors of equipped and unequipped drivers. Recently, Lo and Szeto (2002), Yin and Yang (2003) and Li et al. (2003) adopted the logit-based SUE principle to describe the route choice behaviors of both classes of drivers. Their approaches are more close to the reality since either equipped or unequipped drivers cannot accurately compute the route travel disutility, considering the existence of various random factors in real world.

However, the aforementioned studies postulated all users have an identical and single value of time (VOT), i.e., all commuters are aggregated into one single user class. As we know, travelers are heterogeneous in many aspects due to their different socio-economic characteristics. They have different VOTs and often exhibit different decision-making behaviors in travel choices. In general, professional and self-employed workers have higher VOTs than assembly-line workers and clerks. Therefore, it is necessary to relax the single VOT assumption and then develop multiclass models that can consider the heterogeneity of commuters. In literature, these models are formulated either on a discrete set of VOTs for several user classes or by a continuously distributed VOT across the whole population (Leurent, 1993, 1996, 1998; Marcotte and Zhu, 2000; Nagurney, 2000; Yang and Huang, 2004).

On the other hand, users have their own personal understanding and preference on traffic condition. So, it is necessary to consider the travelers' trade-offs between travel time and out-of-pocket money when making route choices. The preference can be generally represented by the multicriteria modeling approaches. Adler et al. (1999) utilized simulation method to assess the impacts of the bi-objective route guidance systems on user and system performance. In their study, the travel disutility (or trip quality cost) is formulated as the linear weighted additive sum of travel time and cost. Nagurney and Dong (2002) proposed a multicriteria model in which commuters are allowed to perceive their travel disutility or generalized cost as the linear weighting of travel time and travel cost, with each of which being flow-dependent. Recently, Yang and Huang (2004) examined the multiclass, multicriteria traffic network equilibrium and system optimum problem.

In this paper, we propose a multiclass, multicriteria logit-based traffic equilibrium model for investigating the responses of different classes of users to ATIS. The user classes are differentiated by their own VOT that follows some probability distribution. Users of each class are further divided into two groups equipped with and without ATIS respectively. It is assumed that all users select the routes with minimum perceived travel disutility, which is a linear bi-criteria combination of travel time and monetary travel cost. The equipped users, served by ATIS, are better aware of the extent of disutility uncertainties than the unequipped, so they can find the routes with lower disutilities. The proposed model is formulated as a fixed-point problem, and solved by the method of successive averages in conjunction with logit assignment. Numerical results show that the proposed model can provide some new insights for assessing the impacts of ATIS on travel behaviors.

The paper is organized as follows. In Section 2, we describe some basic assumptions for the proposed modeling approach. In Section 3, we present a fixed-point formulation to state the multiclass, multicriteria equilibrium conditions under ATIS. Section 4 provides a solution algorithm for solving the proposed