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Simultaneous determination of the equilibrium market penetration and compliance rate of advanced traveler information systems

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Abstract

We consider a specific advanced traveler information systems (ATIS) whose objective is to reduce drivers' travel time uncertainty with recurrent network congestion through provision of traffic information. Since the provided information is still partial or imperfect, drivers equipped with an ATIS cannot always find the shortest travel time route and thus may not always comply with the advice provided by ATIS. Thus, there are three classes of drivers on a specific day: drivers without ATIS, drivers with ATIS but without compliance with ATIS advice, drivers with ATIS and in compliance with ATIS advice. All three classes of drivers make route choice in a stochastic manner, but with different degree of uncertainty of travel time on the network. In this paper we investigate the interactions among the three classes of drivers in an ATIS environment using a multiple behavior stochastic user equilibrium model. By assuming that the market penetration of ATIS is an increasing function of the actual private gain (time saving minus the cost associated with system use) derived from ATIS service, and the ATIS compliance rate of equipped drivers is given as the probability of the actual travel time of complied drivers being less than that of non-complied drivers, we determine the equilibrium market penetration and compliance rate of ATIS and the resulting equilibrium network flow pattern using an iterative solution procedure.

Keywords: Advanced traveler information systems; Network equilibrium; Market penetration; Compliance rate

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1. Introduction

Advanced traveler information systems (ATIS) have experienced a rapid growth in the past decade, as an alternative to alleviate traffic congestion and enhance the performance of road networks. There has been substantial interest in user behavior modeling under ATIS and benefit evaluation of ATIS in order to determine the feasibility, benefits and risks of such technologies. Various theoretical and practical results have been achieved through approaches of laboratory experiments (for example, Mahmassani and Jayakrishnan, 1991; Yang et al., 1993; Reddy et al., 1995), mathematical and computer simulation models (for example, Ben-Akiva et al., 1991; Kanafani and Al-Deek, 1991; Al-Deek and Kanafani, 1993; Hall, 1993; Yang, 1998) and even field deployments (for example, Tsuji et al., 1985).

The market penetration of ATIS, defined as the proportion of vehicles (drivers) equipped with ATIS, has been widely recognized as an important factor to determine the actual advantages of ATIS implementations (for example, Yang et al., 1993; Yang, 1999). Most previous studies have focused on the investigation of the advantages or benefits by assuming varied levels of market penetration exogenously. Furthermore, equipped drivers were assumed to be spread *homogeneously* among all origin–destination (O–D) pairs, regardless of their trip characteristics (for a review, see Yang, 1998; Yang et al., 1999). It is, however, questionable whether these exogenous given ranges of market penetrations will be attainable or sustainable in a true competitive ATIS market.

Recently, Yang (1998) developed a theoretical endogenous market penetration model for ATIS services in a road network. Market penetration was determined from the information benefit derived from ATIS using a mixed stochastic and deterministic network equilibrium model. More recently, Yang et al. (1999) addressed some important issues in the evaluation of ATIS benefit when market penetration is an endogenous variable. Both private and system benefits by ATIS have been evaluated with reference to trip lengths, level of traffic congestion and degree of travel time variability as well as annual system usage cost and driver's value of time. They found that different trip lengths are associated with different travel time savings and hence different market penetrations, ignoring this important factor may lead to misleading results of ATIS performance. In particular, the previous assumption of uniform market penetration may underestimate the expected system benefit achieved from ATIS in terms of total travel time reduction. Besides the determination of final saturation level of market penetration of ATIS services, Yang and Meng (2001) have further modeled the time line of the growth of market penetration to reach such a saturation level based on a modified logistic type growth model. The parametric sensitivity analyses of the growth pattern might be useful for the optimal control of temporal evolution of ATIS products or services (Yang and Huang, 2002).

It is obvious that the real benefits of ATIS implementations critically depend on how drivers will respond to these systems. All of the aforementioned studies assumed perfect compliance of equipped drivers with ATIS routing advices. However, although ATIS are intended to provide more accurate real-time information to drivers reducing the degree of travel time uncertainty, it is doubtful whether drivers would ever rely on these computerized guidance systems. Even there is no deliberate attempt being made to sacrifice individual benefits in the interests of a system-optimum, drivers' compliance with ATIS is still influenced by information attributes such as quality, nature and feedback, traffic conditions, driver characteristic, and prior experience. In