Transportation Research Part C 77 (2017) 113–133

Contents lists available at ScienceDirect

Transportation Research Part C

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

Multi-scenario optimization approach for assessing the impacts of advanced traffic information under realistic stochastic capacity distributions

Mingxin Li [a], Nagui M. Rouphail [b], Monirehalsadat Mahmoudi [c], Jiangtao Liu [c], Xuesong Zhou [c,*]

[a] *Delaware Center for Transportation (DCT), Department of Civil and Environmental Engineering, University of Delaware, Newark, DE 19716, United States*
[b] *Institute for Transportation Research and Education (ITRE), Department of Civil, Construction and Environmental Engineering, North Carolina State University, Centennial Campus, Box 8601, Raleigh, NC 27695-8601, United States*
[c] *School of Sustainable Engineering and the Built Environment, Arizona State University, Tempe, AZ 85281, United States*

A R T I C L E I N F O

Article history:
Received 10 May 2016
Received in revised form 21 January 2017
Accepted 24 January 2017

Keywords:
Stochastic road capacity
Traffic assignment
Travel time variability
Value of dynamic traveler information
Risk-sensitive route choice behavior

A B S T R A C T

In this study, to incorporate realistic discrete stochastic capacity distribution over a large number of sampling days or scenarios (say 30–100 days), we propose a multi-scenario based optimization model with different types of traveler knowledge in an advanced traveler information provision environment. The proposed method categorizes commuters into two classes: (1) those with access to perfect traffic information every day, and (2) those with knowledge of the expected traffic conditions (and related reliability measure) across a large number of different sampling days. Using a gap function framework or describing the mixed user equilibrium under different information availability over a long-term steady state, a nonlinear programming model is formulated to describe the route choice behavior of the perfect information (PI) and expected travel time (ETT) user classes under stochastic day-dependent travel time. Driven by a computationally efficient algorithm suitable for large-scale networks, the model was implemented in a standard optimization solver and an open-source simulation package and further applied to medium-scale networks to examine the effectiveness of dynamic traveler information under realistic stochastic capacity conditions.

© 2017 Published by Elsevier Ltd.

1. Introduction

Major sources of congestion include recurring bottlenecks, incidents, work zones, inclement weather, poor signal timing, special events, and day-to-day fluctuations in normal traffic demand. Considerable research efforts have been devoted to understanding and quantifying the effectiveness of different traffic mitigation strategies in addressing various sources of congestion. For instance, recurring congestion due to bottlenecks can be mitigated through road capacity enhancement, while real-time traffic information dissemination can reduce negative impacts of disruptions of non-recurring congestion due to traffic incidents and special events.

In our research, we specifically focus on how to evaluate the impact of providing traffic information within a congested network with a realistic stochastic capacity distribution over multiple sampling days. As shown in a recent research effort by

* Corresponding author.
E-mail addresses: lmx@udel.edu (M. Li), rouphail@eos.ncsu.edu (N.M. Rouphail), mmahmoudi@asu.edu (M. Mahmoudi), jliu215@asu.edu (J. Liu), xzhou74@asu.edu (X. Zhou).

http://dx.doi.org/10.1016/j.trc.2017.01.019
0968-090X/© 2017 Published by Elsevier Ltd.

Jia et al. (2010) based on several bottleneck locations in the Bay Area, California, the sample histogram in Fig. 1 demonstrates the discrete probabilistic distribution of 100 lane capacity day samples, with a sample mean of 1837 veh/h/lane and a coefficient of variation of 0.064. As most of samples range from 1400 to 2100 veh/h/lane, which reveals the inherent randomness of stochastic road capacity (Brilon et al., 2005, 2007). Even under constant geometric, traffic, environmental, and/or operational conditions, road capacities vary with time over a certain range around a mean value. More precisely, highway capacity is the result of complex driver behavioral interaction. It also varies according to many external factors such as accidents, incidents, severe weather, or work zones. The inclusion of stochastic capacity at the critical points in a highway network produces a more realistic modeling of travel time variability and introduces the concept of sustainable flow rates.

In addition to *stochastic capacity*, four other sources also contribute to increase travel time variability and unreliability: (1) *Stochastic input demand*, (2) *Random departure time choice and route choice* which can lead to uncertain flow inputs for a certain set of links (Noland and Polak, 2002), (3) *The absence of precise and real-time traffic information* due to the sensor coverage or limited traveler knowledge/experience, which can further compound the issue of travel time uncertainty, and (4) *Traveler perception error*. In fact, there are only a small fraction of travelers who currently have full access or are willing to always retrieve pre-trip or en-route traveler information through web-based traveler information sites, car radio, dynamic message signs, or Internet-connected navigation devices (Khattak et al., 2008). When making route choices, the majority of travelers still rely on their personal knowledge and driving experiences that have been gained over a long time period of time, which can be described as the expected travel time (caused by stochastic demand and capacity). When there is a significant variation in capacity, the resulting network conditions could deviate considerably from the average traffic pattern. In this case, the expected value-based travel knowledge should be treated as a biased estimate to the current traffic state.

Based on the current active demand management program from US Federal Highway Administration (FHWA, 2016), we can find a wide range of emerging traffic mitigation applications (shown in Table 1) are closely related to dynamic traveler information provision. The effectiveness of those emerging strategies cannot be simply evaluated under a perfect equilibrium condition, as those demand-responsive and supply-responsive strategies are very sensitive to the underlying capacity and congestion conditions. To consider a long-term steady state under both recurring and nonrecurring traffic congestion, we need to realistically model those strategies under stochastic capacity/demand variations over a large number of sampling days.

Many studies in the literature (e.g. Yang, 1998; Yang and Meng, 2001; Yin and Yang, 2003) use a general stochastic user equilibrium (SUE) traffic assignment model to quantify the value of traveler information under deterministic and time-invariant road capacity, where all travelers are assumed to have unbiased travel time estimates but with different degrees of uncertainty with respect to their own information user group (e.g. equipped with an ATIS or not). The uncertainty levels are modeled through the perception error term in SUE. That is, commuters with advanced traveler information have smaller perception errors, compared to travelers without access to ATIS channels. It should be noted that the majority of the related references assume static deterministic road capacity. Bell and Cassir (2002) considered equilibrium traffic assignment as a non-cooperative, n-player game. Recently, in order to reformulate the traditional static traffic assignment problem under stochastic capacity conditions, different numerical approximation methods have been proposed to describe the travel time variability for a single-day traffic equilibrium solution. For example, Lo and Tung (2003) and Lo et al. (2006) adopted Mellin transforms to describe network performance caused by stochastic link capacities. Chen and Zhou (2010) proposed a α-reliable mean-excess traffic equilibrium (METE) model to represent equilibrium route choice assignment under stochastic demand and supply. Their model assumes that travelers are willing to minimize their conditional expectation of travel times, with specific risk-taking consideration in their route choice decisions. According to Mirchandani and Soroush (1987), travelers' risk-taking behavior under an uncertain environment can be categorized into risk-prone (Chen and Zhou, 2010), risk-neutral (Arnott et al., 1991, 1999; Gao, 2012; Tan and Yang, 2012; Ban et al., 2013; Lu et al., 2014; Rapoport et al., 2014) and risk-averse (Bell and Cassir, 2002; Chen et al., 2011; Chorus et al., 2006, 2010; Connors and Sumalee, 2009; Lam et al., 2008). The non-uniqueness of path flow solutions was well recognized in the past, and was circumvented by imposing additional constraints or assumptions that limit the set of feasible solutions to remain unique path flows (He et al., 2010; Guo, 2013;

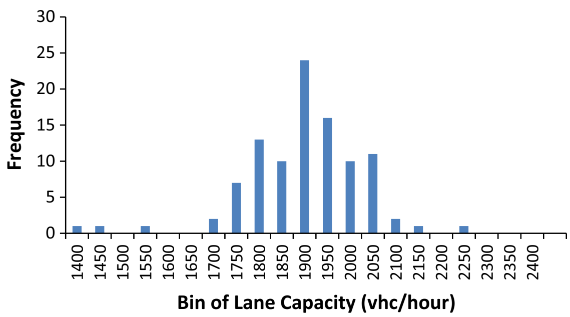

Fig. 1. Example histogram of 100 stochastic road capacity samples.

Download English Version:

https://daneshyari.com/en/article/4968623

Download Persian Version:

https://daneshyari.com/article/4968623

Daneshyari.com