Transportation Research Part B 103 (2017) 291–310

Contents lists available at ScienceDirect

Transportation Research Part B

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

Alternate weibit-based model for assessing green transport systems with combined mode and route travel choices

Songyot Kitthamkesorn[a,*], Anthony Chen[b]

[a] Excellence Center in Infrastructure Technology and Transportation Engineering, Department of Civil Engineering, Chiang Mai University, 50200, Thailand

[b] Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong

ARTICLE INFO

Article history:
Received 30 July 2016
Revised 14 April 2017
Accepted 24 April 2017
Available online 6 May 2017

Keywords:
Nested weibit
Path-size weibit
Mathematical program
Combined modal split and traffic assignment problem

ABSTRACT

Reduction of vehicle emissions is a major component of sustainable transportation development. The promotion of green transport modes is a worthwhile and sustainable approach to change transport mode shares and to contribute to healthier travel choices. In this paper, we provide an alternate weibit-based model for the combined modal split and traffic assignment (CMSTA) problem that explicitly considers both similarities and heterogeneous perception variances under congestion. Instead of using the widely-adopted Gumbel distribution, both mode and route choice decisions are derived from random utility theory using the Weibull distributed random errors. At the mode choice level, a nested weibit (NW) model is developed to relax the identical perception variance of the logit model. At the route choice level, the recently developed path-size weibit (PSW) is adopted to handle both route overlapping and route-specific perception variance. Further, an equivalent mathematical programming (MP) formulation is developed for this NW-PSW model as a CMSTA problem under congested networks. Some properties of the proposed models are also rigorously proved. Using this alternate weibit-based NW-PSW model, different go-green strategies are quantitatively evaluated to examine (a) the behavioral modeling of travelers' mode shift between the private motorized mode and go-green modes and (b) travelers' route choice with consideration of both non-identical perception variance and route overlapping. The results reveal that mode shares and route choices from the NW-PSW model can better reflect the changes in model parameters and in network characteristics than the traditional logit and extended logit models.

© 2017 Published by Elsevier Ltd.

1. Introduction

Transportation is a major cause of vehicular emissions. Transportation consumes million liters of fossil fuel daily, resulting in not only severe congestion but also air pollution, greenhouse gas (GHG), and consequently global warming. These adverse impacts have prompted the national government in many countries to promote "go-green" transport modes such as non-motorized modes (e.g., bicycle) and public transit (e.g., metro, tram, bus, etc.) to keep the environmental costs low and to help travelers make healthier travel choices, while accommodating the increasing travel demands.

To quantitatively evaluate the effectiveness of go-green transport policies, we need a sound behavioral model of travelers' mode shift between the private motorized mode and go-green modes as well as travelers' route choice with consideration

* Corresponding author.
E-mail address: songyot@eng.cmu.ac.th (S. Kitthamkesorn).

http://dx.doi.org/10.1016/j.trb.2017.04.011
0191-2615/© 2017 Published by Elsevier Ltd.

of both non-identical perception variance and route overlapping. A widely used approach is the combined travel demand model (e.g., Boyce, 2007; Briceño et al., 2008; Szeto et al., 2012; Kitthamkesorn et al., 2016), which provides a rigorous quantitative evaluation of different go-green promotion policies and a tractable computational tool in the network equilibrium framework. More specifically, the behavioral mode shift and route change can be effectively addressed by using the combined modal split and traffic assignment (CMSTA) model, which is a special case of the combined travel demand model that considers mode choice and route choice simultaneously. Based on different assumptions and applications, various CMSTA models have been developed in the transportation literature to model the mode choice and route choice made by travelers. A host of researchers (e.g., Florian, 1977; Florian and Nguyen, 1978; Abdulaal and LeBlanc, 1979; Oppenheim, 1995; Cantarella, 1997; Wu and Lam, 2003; García and Marín, 2005) has provided different modeling approaches to formulate the CMSTA problem. These formulations include mathematical programming (MP) (Florian and Nguyen, 1978; Abdulaal and LeBlanc, 1979; Oppenheim, 1995), variational inequality (VI) (Florian, 1977; Wu and Lam, 2003; García and Marín, 2005), and fixed point (FP) (Cantarella, 1997) for jointly determining the mode and route travel options. The early models (e.g., Florian, 1977; Florian and Nguyen, 1978; Abdulaal and LeBlanc, 1979) adopted a stochastic mode choice (i.e., random utility model) and combined it with a deterministic route choice (i.e., user equilibrium (UE) model). However, there seems to be an inconsistency between the two travel choices (i.e., using a deterministic UE to characterize route choice decisions while adopting a stochastic discrete choice model to describe mode choice decisions). To overcome this behavioral inconsistency, Cantarella (1997) and García and Marín (2005) provided the option to combine the stochastic mode choice model with either the UE model or the stochastic user equilibrium (SUE) model, while Oppenheim (1995) and Wu and Lam (2003) adopted the multinomial logit (MNL) model for modeling both mode choice and route choice decisions in the network equilibrium framework (i.e., integrating random utility model within the network equilibrium approach to model the congestion effect). The main difference among these models is the modeling approach. Oppenheim (1995) provided a MP formulation, Wu and Lam (2003) and García and Marín (2005) used a VI formulation, and Cantarella (1997) adopted a FP formulation.

Although the behavioral inconsistency problem has been resolved, the MNL model has two known drawbacks that stems from its independently and identically distributed (IID) assumptions with the Gumbel random error distribution: (1) its inability to handle similarities among alternatives and (2) its inability to handle non-identical perception variances among alternatives. At the mode choice level, the MNL model cannot handle the mode similarity (e.g., physical attributes and operating policies) (Ben-Akiva and Lerman, 1985) and the difference in mode perceived utility or disutility. At the route choice level, the MNL model cannot consider the route overlapping and route-specific perception variance (Sheffi, 1985). Recently, Kitthamkesorn et al. (2016) adopted the nested logit (NL) for mode choice and the cross nested logit (CNL) model for route choice model to handle the mode similarity and route overlapping, respectively. Both NL and CNL models used a two-level tree structure to handle the independence assumption (i.e., similarity among the available modes that share the same upper nest in the NL model and route overlapping in the CNL model). However, both NL and CNL models used the Gumbel distribution as the random perception error term, which requires the identical variance assumption in order to obtain an analytical probability expression. Hence, the CMSTA model developed by Kitthamkesorn et al. (2016) still cannot consider the non-identical perception variance in both mode choice and route choice levels. One possibility is to adopt the multinomial probit (MNP) model to overcome both shortcomings inherited by the IID Gumbel distribution (e.g., Meng and Liu, 2012). However, the MNP model does not have a closed-form probability expression, which poses computational difficulty since solving the MNP model requires intensive computation, e.g., Monte Carlo simulation (Sheffi and Powell, 1982), Clark's approximation method (Maher, 1992), or numerical method (Rosa and Maher, 2002).

In this paper, we develop an alternate weibit-based CMSTA model. Instead of the widely used Gumbel random error distribution, the proposed CMSTA model is based on the Weibull random error distribution. At the mode choice level, a nested weibit (NW) model is developed from the copula framework (Nelsen, 2006). Its nested structure handles the mode similarity while the Weibull distributed random error considers the mode-specific perception variance. At the route choice level, the recently developed path-size weibit (PSW) model is adopted to handle both route overlapping and route-specific perception variance. An equivalent mathematical programming (MP) formulation for the combined NW-PSW model is provided with some solution properties. It should be noted that MP formulation requires more assumptions (e.g., separability, differentiability, and symmetry of link cost functions, additivity of route cost structure, separable demand functions, etc.) compared to VI and FP. According to Cantarella et al. (2013, 2015, 2016), FP is the most flexible formulation among the three formulations as it can cope with a wider range of operational issues, including separable and non-separable (or asymmetric) link cost functions, additive and non-additive route cost structures, separable and non-separable demand functions, deterministic and stochastic choice models, single-user and multi-user classes, and uni-modal and multi-modal assignment problems. However, convergent solution algorithms available to FP formulation are very limited. Most algorithms rely on the method of successive averages (MSA) based on link flows or link costs (Cantarella et al., 2015,2016), which are known to suffer from slow convergence when highly accurate solutions are required. This is partly due to the non-availability of an objective function for performing a line search step, which is known to be an important component of solution algorithms to many mathematical formulations (Chen et al., 2013). On the contrary, the development of a MP formulation for the weibit-based CSMTA model provides the following benefits:

(1) The optimality conditions directly provide the equivalency between the MP formulation and the weibit-based mode choice and route choice probabilities. This is similar to the Beckmann transformation used as the objective function for the user equilibrium MP formulation (Beckmann et al., 1956) and its relationship to the Kuhn–Tucker conditions.

Download English Version:

https://daneshyari.com/en/article/5127002

Download Persian Version:

https://daneshyari.com/article/5127002

Daneshyari.com