

# Chapter 18

## A Link–Node Nonlinear Complementarity Model for a Multiclass Simultaneous Transportation Dynamic User Equilibria

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### ABSTRACT

*Static transportation network equilibrium models have evolved from traditional sequential models to simultaneous (combined) models, and then to the multiclass simultaneous models to improve prediction of traffic flow. Most Dynamic Traffic Assignment (DTA) models, however, still deal only with the trip assignment step (traveler route choice) that is one of several steps in the transportation planning process. In this paper, the authors combine a dynamic link-node based discrete-time Nonlinear Complementarity Problem (NCP) DTA model with a static Multiclass Simultaneous Transportation Equilibrium Model (MSTEM) in a unified dynamic link-node based discrete-time NCP Dynamic Multiclass Simultaneous Transportation Equilibrium Model (DMSTEM) model. The new model improves the prediction process and eliminates inconsistencies that arise when the DTA or Dynamic Traffic Assignment with Departure Time (DTA-DT) is embedded in a more comprehensive transportation planning framework. An iterative solution algorithm for the proposed DMSTEM model is proposed by solving several relaxed NCPs in each iteration of the algorithm.*

### INTRODUCTION

Dynamic Traffic Assignment (DTA) models, which aim to predict future dynamic traffic states in a short-term fashion, have been extensively

studied for decades. DTA studies accelerated in the last fifteen years with the advent of intelligent transportation systems (ITS). Within DTA studies, the dynamic user equilibrium (DUE) problem, which tries to determine the distribution of

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time-dependent traffic flow of a traffic network assuming travelers follow rational route choices (such as to minimize travel time or other forms of cost), is one of the most challenging. Two distinct approaches have dominated the methodologies applied to DUE research: the simulation-based (microscopic/mesoscopic) approach and the analytical (macroscopic) approach. A review of these two approaches can be found in Ran and Boyce (1996); Peeta and Ziliaskopoulos (2001).

Among the analytical modeling techniques used for DUE, Variational Inequality (VI) and Non-linear Complementarity (NC) have been shown to be the most effective approaches (Friesz et al., 1993; Ran & Boyce, 1996; Lo et al., 1996; Lo & Szeto, 2002; Chen, 1999; Heydecker & Verlander, 1999; Peeta & Ziliaskopoulos, 2001; Akamatsu, 2001; Wie et al., 2002). Ban et al. (2008) recently applied NCP to model DUE with exact flow propagation based on a specially designed discretization scheme. Friesz and Mookherjee (2006) developed a differential variational inequality (DVI) technique to model DUE in continuous time. The DVI framework has been used more recently by Friesz et al. (2010) to model both the within-day and day-to-day traffic dynamics, and by Pang et al. (2009) to model multi-class single bottleneck dynamic departure time choice problems.

In the DUE literature, elasticity of the dynamic demand (input to DUE models) is usually modeled as departure-time choices for a given total fixed demand flow between each O-D pair during the whole time horizon (Friesz et al., 1993). Multiclass DUE models have also been studied with these analytical approaches (Ran & Boyce, 1996; Belimer et al., 2003) or simulation-based approaches (Ben-Akiva et al., 2001; Mahmassani et al., 2001). The early studies, however, focused on different vehicle classes and a few social-economic factors of drivers, such as value of times (VOT) preferences (Lu et al., 2008). With this goal, Ramadurai and Ukkusuri (2010) integrate activity-based models for demand analysis into

DUE. The model is solved using a super-network representation of activities and traffic networks.

By investigating further how socio-economic factors of drivers may affect trip generation, trip distribution, mode choice, and departure-times in a dynamic (i.e. time-dependent) fashion, and integrating the findings into DUE modeling, we expect to improve the practicality and accuracy of DUE models. With this objective, we combine the NCP-based DUE model in Ban et al. (2008) and the Multiclass Simultaneous Transportation Equilibrium Model (MSTEM) in Hasan and Dashti (2007) to develop a multiclass combined Trip Generation (TG)-Trip Distribution (TD)-Nested Modal Split (NMS)-Modal Split (MS)-Dynamic Trip Assignment (DTA)-Departure Time (DT) Model (NCPDUE-TG-TD-NMS-MS-DTA-DT). In the next paragraphs we provide the necessary background on static multiclass combined models as employed in the Multiclass Simultaneous Transportation Equilibrium Model (MSTEM) that we utilize in this paper.

Single-class static combined equilibrium models consider all travelers as one homogeneous group with respect to their travel-decision characteristics (particularly their money-value of time and sensitivity to travel times in choosing their origin, destination and mode of travel, etc. To be more realistic, travelers must often be divided into classes -- either by socio-economic attributes or purpose of travel. Travel-decision characteristics are thus the same within each class, but differ among classes.

The introduction of multiple classes increases the mathematical complexity of travel forecasting models. Travel costs in single class models are often separable and symmetric, allowing for convex optimization formulation. In multiclass models, travel costs of one class are affected by decisions of other classes; hence the cost structure is not separable, asymmetric, and not amenable to a convex optimization formulation (Patriksson, 2003). Boyce and Bar-Gera (2004) review the most

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