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Dynamic micro-assignment modeling approach for integrated multimodal urban corridor management

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Abstract

Development and analysis of demand management strategies for integrated multimodal urban corridor management requires application of a new generation of demand modeling and network analysis tools. This paper describes the development of a dynamic trip micro-assignment and (meso) simulation system that incorporates individual tripmaker choices of travel mode, departure time and route in multimodal urban transportation networks (with different travel modes such as drive alone, shared ride, bus rapid transit and metro rail). These travel choice dimensions are integrated in a stochastic utility maximization framework that considers multiple user decision criteria such as travel time, travel cost, schedule delay, as well as travel time reliability. A variational inequality model is first proposed to describe the general stochastic dynamic traffic user equilibrium problem. For a typical case that assumes the logit-based alternative choice model, this paper develops an equivalent gap function-based optimization formulation and a heuristic iterative solution procedure. Based on a multi-dimensional network representation, an efficient time-dependent least cost path algorithm is embedded to generate an intermodal route choice set that recognizes time-dependent mode transfer costs and feasible mode transfer sequences. A two-stage estimation procedure that can systematically utilize historical static demand information, time-dependent link counts, as well as empirically calibrated stochastic departure time choice models is proposed to infer commuters' preferred arrival time distribution, which is important in modeling departure time choice dynamics. A case study based on a large-scale multimodal transportation network (adapted from the Baltimore–Washington corridor) is presented to illustrate the capabilities of the methodology and provide insight into the potential benefit of integrated multimodal corridor management.

Keywords: Integrated corridor management; Dynamic traffic assignment; Multimodal networks; Travel time reliability; Departure time dynamics; Intermodal shortest paths; Demand management; Intelligent transportation systems; Supply–demand integration

1. Introduction

Integrated corridor management (ICM) refers to the coordination of individual network operations between adjacent facilities to create an interconnected system capable of cross-network travel management,

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leveraging the investments that have been made in communication and sensing technologies along major corridors in many metropolitan areas. ICM is intended to bring the full potential of intelligent transport technologies to influence not only operational aspects but also the demand for travel in the corridor, to bring about improvement in travel time, delay, fuel consumption and emissions, and increase the reliability and predictability of travel. Success of ICM deployment depends on careful planning and an integrated system-level perspective, which calls for advanced transportation analysis tools to estimate and predict network conditions and to analyze network performance for both strategic and tactical purposes. This calls for accelerating the adoption and deployment of the kind of methodologies and models that have evolved over the past decade, such as dynamic micro-assignment models and individual level activity-based approaches.

Dynamic traffic assignment (DTA) modeling tools uniquely address the needs of metropolitan areas and state agencies for decision support methodologies for integrated corridor management. To describe the buildup and dissipation of system congestion, a variety of DTA approaches have been proposed and developed to model route choice of passenger cars with fixed departure time (Mahmassani, 2001; Ben-Akiva et al., 2001). To analyze demand-side measures such as feasible work hours, value pricing as well as transit-related intermodal strategies in congested metropolitan networks, there is a great need to extend exiting DTA systems to capture complex interactions among departure time choice, mode choice and path assignment, and to evaluate the direct and indirect impact of different demand management options in congested multimodal urban networks.

Considerable research over the past decade has been directed towards modeling several dimensions of choice available to trip makers. A number of studies have used the standard random utility maximization paradigm to describe commuter departure time choice decisions under fixed, exogenous and known values of system performance attributes. Several empirical studies by Small (1982) and Noland et al. (1998) have revealed that trip time, schedule delay and travel time reliability are key attributes in traveler departure time scheduling. Early theoretical studies by Hendrickson and Kocur (1981) and Mahmassani and Herman (1984) have sought to describe time-dependent equilibrium flow patterns in conjunction with associated network performance measures when the choices of route and departure time are considered jointly. In a recent study by Huang and Lam (2002) attempts have continued to combine the departure time choice dimension into an analytical DTA models.

Joint departure time and route choice DTA models require time-dependent OD demand matrices with preferred departure time (PDT) or preferred arrival time (PAT) as essential model input. Most previous research along this line, however, used hypothetical PAT demand input, because estimating the PAT pattern from travel surveys in general is a very costly and time-consuming process. The continuing deployment of ITS offers more reliable and less costly channels to measure the complex transportation system dynamics. However, few studies have been devoted to estimating or updating the PAT/PDT distribution across the user population with archived traffic sensor data. Based on a deterministic schedule delay function, Van der Zijpp and Lindveld (2001) modeled departure time choice as a path selection decision in a space–time expanded network, and then estimated the PDT pattern by utilizing traffic observations and the traffic assignment matrix that maps PDT demand to link counts.

Multimodal corridor management assessment also requires consideration of transit trips, including assigning transit trips and capturing the interaction between mode choice and traffic assignment. An excellent survey is provided by Hearn and Florian (1999) on model formulations and relaxation methods for solving combined mode traffic assignment with asymmetric travel cost functions. Florian et al. (1999) developed a system of variational inequalities (VI) to describe multi-class user equilibrium in a multimodal network and discussed several restrictive model assumptions that are needed for constructing equivalent optimization models. A block Gauss–Seidel decomposition method was employed to solve individual traffic assignment problems for different network modes. To capture the complex interaction in congested urban networks with a considerable number of transit and intermodal trips, Abdelghany and Mahmassani (2001) presented a dynamic trip assignment-simulation framework that considers different travel modes such as private cars, buses, metro and high occupancy vehicles (HOV). Chang (2005) extended a cell transmission-based system optimal integer linear programming model by Ziliaskopoulos (2000) to incorporate buses in time-dependent intermodal user equilibrium models, and the resulting variational inequality problem is solved by an inner approximation solution algorithm that minimizes an equilibrium gap function. By extending Smith (1993)'s gap function-based refor-