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Project Title:
Modeling multi-class truck traffic assignment method with different traffic restraint constraints

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Research Needs:
Traffic assignment is an essential and fundamental step in the transportation planning and management processes (Sheffi, 1985; Patriksson, 1994; Bell and Iida, 1997). Given constant travel demands between each origin-destination (O-D) pair (i.e., travelers), and travel cost functions for each link of the network (i.e., transportation network), the traffic assignment problem is to determine the traffic flow pattern as well as network performance measures (e.g., total system travel time, vehicle miles of travel, vehicle hours of travel, fuel consumption and emission, etc.). In practice, most traffic assignment models are single user class and make a number of modeling assumptions including: separability assumption on the link travel time function (i.e., no interactions), deterministic user equilibrium (DUE) or stochastic user equilibrium (SUE) without accounting for route overlapping, and no side constraints to describe the limited supply of certain scarce resources (e.g., link capacities) in a network which are shared by multiple vehicle types (e.g., passenger cars and multiple truck types) or to limit certain classes of vehicles (e.g., trucks) on underpasses due to height restriction, bridges due to weight restriction, and prohibited lanes due to lane restriction. However, as truck traffic continues to grow as a result of increasing freight shipments transported by trucks, there is an increasing interest to model multiple vehicle classes separately, especially in addressing the impacts of truck traffic on congestion, infrastructure deterioration, safety, and environmental concerns in

many urban cities. According to the Bureau of Transportation Statistics (BTS), freight shipments transported by trucks account for 71 percent by value in U.S. dollars and 76 percent by weight in tons of all commodity shipments (BTS, 2014). Hence, the purpose of this proposal is to develop advanced traffic assignment method and computation algorithm for addressing the asymmetric vehicle interactions, route overlapping, and traffic restraints in multi-class traffic assignment problems involving multiple types of trucks.

Research Objectives: The overall goal of this research is to develop advanced method and computation algorithm for the multi-class traffic assignment problem involving multiple types of trucks with different traffic restraint constraints. Specifically, the objectives include the followings:

1. Develop advanced multi-class traffic assignment method involving multiple types of trucks with various traffic restraint constraints.
2. Develop computation algorithm for solving the multi-class truck traffic assignment problem.
3. Collect data from different sources to develop a case study for evaluating the multi-class truck traffic assignment method and computation algorithm.

Research Methods:
The multi-class traffic assignment problem is an important extension of the classical traffic equilibrium problem (i.e., the Beckmann-type mathematical programming formulation) that aims to improve the realism of traffic assignment models by explicitly modeling multiple user classes in the same transportation network with individual cost functions contributing to its own and possibly other classes cost functions in an individual way (Dafermos, 1972). Applications of multi-class traffic assignment problem include modeling market segmentation of travelers' characteristics such as users with different valuations of travel times (Nagurney and Dong, 2002;), different risk-taking behaviors (Xu et al., 2014), different knowledge levels of network travel times (Yang, 1998), and modeling different vehicle types (e.g., trucks and passenger cars) sharing the same highway network (Daganzo, 1983; Toint and Wynter, 1996; Mahmassani and Mouskos, 1998; Wu et al., 2006; Noriega and Florian, 2007). Particularly, modeling the asymmetric interactions among different vehicle types has the potential to improve the realism of traffic assignment models (i.e., better capture the travel times required by different vehicle types to traverse a link). On the contrary, inadequate considerations of vehicle interactions in the traffic assignment models could result in inaccurate travel time estimates, which could affect flow allocations to routes and network equilibrium process. Interest in modeling multiple vehicle types separately in the traffic assignment problem is growing, especially in urban areas where truck flows are of increasing concern. There are also many practical applications such as evaluation of truck-related highway improvements and traffic operations (e.g., capacity addition in the form of additional lanes, lane access restrictions to certain vehicle classes, traffic controls for trucks, etc.), assessment of truck emission characteristics, pavement deteriorations by trucks, and evaluation of accident patterns by trucks. In addition, it is important to recognize that there are several different sizes of trucks, whose maneuver and operational characteristics as well as traffic restrictions are quite different, and this emphasizes the need to develop a multi-class traffic assignment model that considers the above modeling issues.

Motivated by the needs to enhance the realism of traffic assignment models for multiple user classes, this proposal develops advanced traffic assignment method and computation algorithm that consider asymmetric interactions among different vehicle types, path-size logit model for accounting random perceptions of network conditions with explicit consideration of route overlapping, and various traffic restrictions imposed either individually or together to multiple vehicle types in a transportation network.

Develop advanced traffic assignment method

As mentioned above, the modeling issues considered in developing an advanced traffic assignment method for multiple vehicle types involve:

(a) *Asymmetric interactions among different vehicle types in the link travel time functions*

A typical method used to combine multiple vehicle classes (or modes) to assess traffic flow rate on a highway is the concept of passenger car equivalent (PCE) or also known as passenger car unit (PCU) (Mahmassani and Mouskos, 1998; Noriega and Florian, 2007). A PCE assesses the impact that a mode of transport (e.g., truck) has on traffic variables (e.g., speed, density, and flow) compared to a single car. In the traffic assignment procedure, PCE factors will be used in the link travel time function to implement the stochastic multiclass traffic assignment by converting truck volumes to passenger car volumes to account for the fact that larger trucks take up not only more capacity on the roads but also more time to traverse the same stretch of roadway than passenger cars.

(b) *Path-size logit model for handling route overlapping in the multi-class SUE framework*

In the stochastic user equilibrium (SUE) problem, route overlapping is one of the major concerns in modeling route choice decisions (Prashker and Bekhor, 2004). In this proposal, the path-size (PS) factor will be adopted to handle the route overlapping problem due to its simplicity and relatively well performance compared to other closed-form models (Ben-Akiva and Bierlaire, 1999). The PS factor accounting for different path sizes is determined by the length of links within a path and the relative lengths of paths that share a link. It will be incorporated into a logit model to develop a path-size logit model for handling route overlapping in the multi-class SUE framework.

(c) *Various traffic restraints in a transportation network*

Traffic restraints described by various types of side constraints has been suggested as a promising approach to improve the realism of traffic assignment models (Larsson and Patriksson, 1999). In this proposal, various traffic restraints imposed either individually or together to multiple vehicle types in a transportation network will be considered. Trucks are often perceived to restrict the flows or safety on certain road segments. The most common reasons for truck flow restriction are improving highway operations and safety hazard including crashes, pavement and structural considerations, and work zone construction restrictions. In general, there are three types of restriction: lane restriction, height restriction, and weight restriction. For lane restriction on highways, truck flows are typically restricted to the right or outside lane (e.g., curb lane) to improve the efficiency of passenger car travel. For height restriction, trucks are restricted on tunnels or underpasses if the vehicles exceed certain height requirements. For weight restriction, heavy trucks exceeding certain weight limit are typically banned on bridges or elevated roadways. In addition, physical link capacity constraint that restricts the total flow of all vehicle classes to be less than or equal to the capacity will be incorporated into the traffic assignment model.

Develop advanced computation algorithm

To solve the multi-class traffic assignment problem with different modeling considerations mentioned above, a customized computation algorithm will be developed. It involves three main modules: direction finding, line search, and column generation. Direction finding module will be based on a iterative balancing scheme that has been proven to be effective in solving logit-type SUE problem with side constraints (Bell et al., 1997; Chen et al., 2009); line search module will make use of a new self-regulated averaging (SRA) scheme to avoid computing complex objective function and/or its derivatives (Liu et al., 2009), and column generation module will consider not only vehicle restrictions and physical capacity constraints, but also efficient storage of routes for multiple vehicle classes. These three modules of the computation algorithm will work together to handle the multi-class traffic assignment, asymmetric vehicle interactions through the link performance functions, the path-size logit model to account for route overlapping, and both aggregate and individual flow restriction constraints.

Expected Outcomes:

The results of the multi-class truck traffic assignment problem are critical input data for many analyses addressing the impacts of different truck traffic to congestion, infrastructure deterioration, safety, and environment. Specific analyses that make use of the multi-class truck traffic assignment results include pavement and bridge design and management, prediction of freight movements, capacity expansions of highway segments and freight corridors, accident analysis, and environmental analysis. We believe that the multi-class truck traffic assignment method and computation algorithm will be useful to the state DOT and metropolitan planning organizations (MPO) in addressing the impacts of different truck traffics to congestion, infrastructure deterioration, safety, and environment within their regions.

Relevance to Strategic Goals:

As mentioned above, the multi-class truck traffic assignment results will assist state DOT and MPO to better plan, design, and manage the impacts (e.g., congestion, infrastructure development, pavement deterioration, accident, air quality modeling, and safety issues) caused by truck traffic. These results aim to improve mobility of truck traffic along state and interstate highway systems, and hence have the potential to support regional and national economic developments. The results of this research project contribute to the following goals: (1) state of good repair, (2) safety, and (3) economic competitiveness.

Educational Benefits:

Freight transportation planning is an important component of the overall travel demand forecasting process. This research project will provide useful information and real-world data to develop teaching materials for freight transportation planning in the two courses taught by the PI at USU: CEE 5240/6240 Urban and Regional Transportation Planning and CEE 6290 Transportation Network Analysis. Our students will have the opportunity to learn about the freight transportation planning process conducted by the state DOT and to obtain hands-on experience with using the multi-class truck traffic assignment model and algorithm developed in this proposal.

Work Plan:
To meet the objectives set out above, we propose to undertake the following tasks in 18 months with a starting date of July 1, 2015, and an ending date of December 31, 2016. Specifically, these tasks are to:

1. Conduct a literature review on multi-class traffic assignment problem with emphasize on multiple vehicle types (2 months)
2. Collect data from multiple sources to develop input data for the case study (2 months)
3. Code the network with truck data in a geographical information system (2 months)
4. Develop advanced multi-class truck traffic assignment model (4 months)
5. Develop computation algorithm for solving the multi-class truck traffic assignment problem (4 months)
6. Conduct a case study using data collected in Tasks 2 and 3 (3 months)
7. Document findings and prepare final report (1 month).

Tasks will be carried out according to the following schedule:

Task No.	**Q 3 2015**			**Q 4 2015**			**Q 1 2016**			**Q 2 2016**			**Q 3 2016**			**Q 4 2016**		
1	■	■																
2			■	■														
3					■	■												
4							■	■	■	■								
5											■	■	■	■				
6															■	■	■	
7																		■

Project Cost:
Total Project Costs: $160,000
MPC Funds Requested: $80,000
Matching Funds: $80,000
Source of Matching Funds: LTAP

TRB Keywords:
Multi-Class Traffic Assignment; Multiple Vehicle Classes; Stochastic User Equilibrium; Traffic Restraints.

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