



Contents lists available at ScienceDirect

Transportation Research Part B

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

A heuristic method for a congested capacitated transit assignment model with strategies

Esteve Codina^{a,*}, Francisca Rosell^b^a Statistics and Operations Research Department., Universitat Politècnica de Catalunya., Campus Nord, Building C5, Office 216 C/ Jordi Girona, 1-3, Barcelona 08034, Spain^b Statistics and Operations Research Department., Universitat Politècnica de Catalunya., Campus Nord, Building C5, Office 217 C/ Jordi Girona, 1-3, Barcelona 08034, Spain

ARTICLE INFO

Article history:

Received 8 April 2017

Revised 25 July 2017

Accepted 26 July 2017

Available online xxx

Keywords:

Congested transit assignment

Variational inequalities

Strategy-based transit equilibrium

Heuristic methods

ABSTRACT

This paper addresses the problem of solving the congested transit assignment problem with strict capacities. The model under consideration is the extension made by Cominetti and Correa (2001), for which the only solution method capable of resolving large transit networks is the one proposed by Cepeda et al. (2006). This transit assignment model was recently formulated by the authors as both a variational inequality problem and a fixed point inclusion problem. As a consequence of these results, this paper proposes an algorithm for solving the congested transit assignment problem with strict line capacities. The proposed method consists of using an MSA-based heuristic for finding a solution for the fixed point inclusion formulation. Additionally, it offers the advantage of always obtaining capacity-feasible flows with equal computational performance in cases of moderate congestion and with greater computational performance in cases of highly congested networks. A set of computational tests on realistic small- and large-scale transit networks under various congestion levels are reported, and the characteristics of the proposed method are analyzed.

© 2017 The Authors. Published by Elsevier Ltd.

This is an open access article under the CC BY-NC-ND license.

<http://creativecommons.org/licenses/by-nc-nd/4.0/>

1. Introduction

Passenger transit assignment is a fundamental tool in evaluating and planning public transportation systems. Although the primary aim of such tools is to ascertain the passengers' route choice on transit networks, there is an increasing need to take into account the effects of congestion on the performance of the systems, specifically concerning the limitations on the maximum flows that the line segments may carry (Freijinger and Florian, 2013). Thus, this paper focuses on solving congested frequency-based transit assignment network models under the assumption that passengers make their decisions according to the concept of strategy from a static perspective. Initially, Chriqui and Robillard (1975) introduced the concept known as "set of attractive lines" at passenger stops. The extension to the case of multi-destination networks was done by Spiess (1984) and Spiess and Florian (1989), who introduced the notion of strategy as a choice of an attractive set of lines at each stop. The resulting model sought to minimize the expected value of the total travel time. Nguyen and Pallottino

* Corresponding author.

E-mail address: esteve.codina@upc.edu (E. Codina).<http://dx.doi.org/10.1016/j.trb.2017.07.008>

0191-2615/© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license.

<http://creativecommons.org/licenses/by-nc-nd/4.0/>

(1988) expressed the general concept of hyperpath for a transit network in terms of an acyclic directed graph that leads to a destination; they formulated a transit assignment model as a variational inequality model; and they proposed a solution algorithm based on an iterative MSA scheme. These initial models assumed that boarding may be possible when the first vehicle arrives at the stop; but they did so without taking into account limitations on the maximum number of passengers that can be transported, which consequently failed to consider that no passenger queueing may occur at stops. Gendreau (1984); Bouzayene-Ayari et al. (1995) initially studied the bus stop model. These bus stop models were integrated into transit assignment models by Bouzayene-Ayari et al. (1995) and Wu and Florian (1993). Bouzayene-Ayari et al. (2001) presented bus stop models in which waiting times at stops follow an additive law of the lines' effective frequencies. This model was analyzed under too restrictive assumptions which did not allow including delay formulas from queueing theory (bounded gradients for the delay formulas were required). Also, De Cea and Fernández (1993) used BPR-like functions to formulate a congested transit assignment model for taking into account congestion effects at transfer nodes, but without imposing strict capacity limits; thus, their proposed model may present solutions that go beyond the stated capacity limits of transit lines.

The works by Karauchi et al. (2003) present a different approach for considering congestion, since they include in their formulation passengers' risk aversion to failing at first boarding. These ideas are extended later in the quasi-dynamic transit assignment model of Schmöcker et al. (2008).

The inclusion of strict capacity bounds has also been considered in the traffic assignment models. The classical fixed-demand diagonal traffic assignment model is also formulated using increasing volume-delay functions but their solution flows may override physical bounds (i.e., capacities). This may be the case when using volume-delay functions directly from calibration. The use of volume-delay functions reproducing the effects of waiting times from queueing theory, which increase to infinity at queue's capacity, has had a series of contributions, starting with the one of Daganzo (1977a); 1977b) to more recent ones as in Nie et al. (2004). Basically all these contributions have relied on the well studied properties of the barrier and penalty methods as well as augmented lagrangian methods for mathematical programming problems. For the case of asymmetric problems (i.e., models based on variational inequalities), the inclusion of explicit capacity bounds is studied extensively in Larsson and Patriksson (1994), although they don't provide an algorithm for solving that model.

Nowadays, congestion effects and capacity limitations are taken into account virtually by any transit assignment model and not only by static deterministic frequency-based models but also by stochastic models such as that of Szeto et al. (2011) as well as by static schedule-based models and dynamic models, doing so by following either a macroscopic flow approach or a simulation approach (see, for instance, Verbas et al., 2016 and Cats et al., 2016, amongst others). Thus, Nguyen et al. (2001) developed a schedule-based model which takes into account the departure time and route choice jointly. The available capacity of the service is taken into account in order to enforce the FIFO rule of boarding passengers. In Hamdouch and Lawphongpanich (2008), the concept of strategies is included in a capacitated time table based model formulated as a variational inequality model; and, in Hamdouch et al. (2011), the problem of seat availability is considered in addition to the constraints imposed by line capacities. In Trozzi et al. (2013), a frequency-based capacitated dynamic model is developed by considering strategies and queueing at stops which observe the FIFO discipline.

Returning to static, deterministic frequency-based models that follow strategies, Cominetti and Correa (2001) analyzed the inclusion of congestion aspects and formulated the model conceptually as a fixed point problem. It must be noticed that, although the GSM model by Bouzayene-Ayari et al. (2001) was initially developed under restricting conditions that did not allow to include queueing model results, these difficulties were overcome in the paper by Cominetti and Correa (2001) (see Appendix A in that work). Cepeda et al. (2006) further studied the model initially set by Cominetti and Correa (2001) and approached it as a non-differentiable optimization problem that they solved heuristically by minimizing a gap function through an adaptation of the method of successive averages. Their model reflects the effects of congestion basically through the concept of effective frequencies experienced by passengers. The effective frequency of a line at a stop is a concept closely related to queueing, and it takes into account that a fraction of passengers may not board the first transportation unit that arrives; so, theoretically they must vanish when the stop is about to collapse. This model will be referred to in this paper as the C3F model. A remarkable feature of the C3F model is that, being based on the general stop model by Bouzayene-Ayari, allows to consider very complex models of passenger waiting times at stops which may originate from different headway distributions and can be used to incorporate queueing models for modelling passenger waiting times, which is specially useful in congested situations.

Babazadeh and Aashtiani (2005) proved that strategy-based transit assignment in congested networks is equivalent to a nonlinear complementarity problem formulated in the space of path flows. They also proposed a solution algorithm. Some other models for tackling the problem of congested transit networks can also be found in Castro and Leal (2003).

In Codina (2013), it is shown that the C3F model can also be reformulated as both a variational inequality problem and a fixed point inclusion. In that work, conditions for the existence of solutions are established when effective frequency functions either do not vanish at capacity or when they do vanish at capacity (i.e., passenger waiting times are finite or infinite at capacity, respectively). In this last case, the effective frequency functions implicitly define capacities which may be considered explicitly formulated as upper bounds. This is equivalent to saying that delay formulas from queueing theory may be integrated in order to model the waiting queues of passengers. It must be noted that the C3F model is the only static, frequency-based, strategy-based transit assignment model with that feature.

This paper is a consequence of and is substantiated by the results in Codina et al. (2013). It introduces a method for solving the C3F model in the special case when effective frequency functions become zero at capacity (infinite passenger waiting times) and also when they implicitly define sharp line capacities. Although a method was proposed in Cepeda et al.

Download English Version:

<https://daneshyari.com/en/article/7539369>

Download Persian Version:

<https://daneshyari.com/article/7539369>

[Daneshyari.com](https://daneshyari.com)