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A frequency based transit assignment model that considers online information

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ABSTRACT

This paper develops a frequency based transit assignment model considering that online information of predicted arrival times is available to passengers. The methodology is developed for two information levels: (1) full, where the arrival times are available for all intermediate stops in the candidate paths, and (2) partial, where the arrival times are available at the boarding stop only. Passengers are assumed to consider the estimated arrival times together with the expected travel time when choosing their path. The assignment procedure includes the finding of attractive paths, setting of route choice decision rules for different cases of predicted arrival times, and the probability calculation for these different cases. The developed model is illustrated by an application for the Winnipeg network. In comparison to the well-known optimal strategies method, the suggested model produced significantly different assignment results and a notable reduction in the total travel time. The results illustrate the potential impact of online information on assignment results, and emphasize the need for its consideration in planning models.

1. Introduction

The transit assignment problem is defined as the mapping of passenger demand on a given transit network. Transit assignment is commonly applied to estimate passenger ridership and travel times for different line and frequency plans; therefore, it plays a key role in public transport planning.

Approaches to transit assignment are broadly divided into schedule and frequency based assignment. Schedule based models are commonly used for simulation of detailed time-dependent transit assignment. Frequency based models are commonly used for planning purposes, yielding the average distribution of passengers over time and enables the handle of large scale networks.

The core of the assignment model is the behavioral assumption regarding the route choice. A transit traveler path may comprise several legs such as walking to and from the stop, waiting for a line, riding a vehicle and transferring to other lines. Furthermore, the path may be not predetermined, but decided on the move in accordance with the predicted arrival times. The passenger presumed strategy dictates in which cases she will board a vehicle or wait for a later one. The behavioral assumption has a decisive impact on the problem formulation, expected waiting times and estimated distribution of passengers in the network.

Frequency based approach assumes the service operates with constant frequencies but with no trustworthy schedule. It is suitable to describe a bus network operating in congested roads with varied travel times or alternatively a very frequent service. There is no need to check the schedule if an attractive carrier arrives to the stop every few minutes; therefore, a passenger does not worry about the schedule, when the service is frequent. In cases the service is either very irregular or very frequent, it can be realistically described by a frequency based model.

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Frequency based assignment models generally assume that passenger boards the first arriving vehicle among a certain set of attractive lines (Spiess and Florian, 1989). This assumption is realistic when the passenger has no information on predicted arrival times. Nowadays, online information that informs the passenger for real-time estimated arrival times, becomes widely available. This information is likely to change passenger's strategy. For example, one may choose to skip an arriving vehicle, in case a faster one is expected to arrive soon or alternately board a slow line if the fast one is predicted to delay.

Information and communication technologies (ICT) have become more reliable and are widely used. Platforms such as electronic panels in bus stops and mobile apps inform the passenger of predicted arrival times. Such information may include the arrival times of vehicles to a boarding stop, and in some cases the expected waiting times at the transfer stops. Therefore, the passenger is likely to use the information for the selection of boarding line and/or a full path.

The objective of this paper is to develop a frequency based model that considers online information is available to passenger, and investigate its potential impact on assignment methodology and results. The model considers two types of available information, defined as follows:

- **Partial info** – passengers receive predicted arrival times of all lines at their boarding stop
- **Full info** – passengers receive predicted arrival times of all lines at their boarding stop and at their following transfer stops.

The 'partial info' resembles the case of electronic panels situated at stops and display arrival times. Passengers often use this information to select their path, according to the displayed times. The 'full info' resembles the case of information provided by mobile apps which are based on the arrival times to all relevant stops; such apps recommend the user on the best path considering the available online information. Passengers are assumed to choose their path at the boarding stop ('partial info') or at their origin ('full info').

Note that the 'partial info' definition here is different than the definition in Chen and Nie (2015). In their case, partial information refers to the case that arrival times are available for a subset of the lines serving a stop. The 'partial info' definition here is compatible with the online information describe in Gentile et al. (2005).

The remainder of this paper is organized as follows. The following section provides a short review on transit assignment models, focusing on the frequency based approach. The subsequent section describes the proposed methodology, assuming two types of information. Section 4 illustrates the model application for the Winnipeg transit network, and Section 5 compares the results of the two proposed models with the optimal strategies method. The last part of the paper presents a summary of the results and directions for further research.

2. Literature review

The transit assignment problem has been studied since the late 1960s, dealing with various aspects. Studies especially dealt with route choice strategies, probability distribution function (PDF) of vehicles arrival times, penalties given to different transit modes and congestion effects.

The modelling of passenger distribution in a transit network requires detailed graph representation. A link that is common to more than one transit line, requires multiple arcs in the graph to distinguish between passengers riding different lines. In a seminal work, Nguyen and Pallottino (1988) addressed this aspect by including 'hyperpaths' in the network graph. They defined explicit arcs for each segment in the transit network: transit lines, walking, transferring, and aligning links. This method is widely used in assignment models, and enables the consideration of complex routes. The first step in any assignment model is to modify the original network to a network with 'hyperpaths' that will enable a complete representation of all possible paths in the transit network.

The transit traveler's journey may comprise several components: walking to or from a stop, waiting, riding transit lines and transferring between them. Passengers assess these time components differently; it has been shown that waiting and walking time are valued 2–3 times longer than in-vehicle time (Wardman, 2004). These time perceptions can be expressed by different coefficients assigned to travel times; usually, some penalty is given to the waiting, walking and transferring times, compared to the riding time (Hamdouch et al., 2014). Values of walking, waiting and vehicle riding times were categorized according to the traveler sector and travel purpose (Wardman, 2004).

A significant factor in the modelling of transit assignment is the assumption of PDF that describes vehicles arrival times, and the derived waiting times. Early frequency based models assumed passengers arrive randomly to stops and that the service headways are constant and independent (Dial, 1967; Seddon and Day, 1974; Bowman and Turnquist, 1981). Given those assumptions waiting time has a uniform PDF constantly equal to the frequency for any time between zero to the headway value. The expected waiting time at a stop equals to one half of the headway. However, constant headways can be obtained only under perfect service regularity. In case the model assumes a complete irregularity of the service, the arrival of busses can be described as a Poisson process of rare events, and the waiting times are exponentially distributed. Therefore, many studies applied a function from the Gamma family of distributions (Bowman and Turnquist, 1981; Larson and Odoni, 1981; Marguier and Ceder, 1984). In this case the expected waiting time equals to the headway; it is twice longer than the deterministic headways case. This difference demonstrates the impact of PDF assumption on the expected waiting times. As the selection of paths in assignment models is based in part on the expected waiting times, the PDF assumption has a significant effect on assignment results.

Another central theme that received wide attention in transit assignment modeling is congestion effect. Transit congestion effect is considered when the travel time of a carrier depends on the passenger flow. In case the service is crowded, the waiting, boarding and dwell times tend to increase, and discomfort is caused to the passenger. If the capacity of the service is lower than the demand,