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Rethinking bus punctuality by integrating Automatic Vehicle Location data and passenger patterns

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ABSTRACT

This paper investigates punctuality at bus stops. Although it is typically evaluated from the point of view of bus operators, it must also account for users, as required in recent service quality norms. Therefore, evaluating punctuality at bus stops is highly important, but may also be a complex task, because data on both bus arrivals (or departures) and users must be taken into account and processed. Data on buses can be collected by Automatic Vehicle Location (AVL) systems, but several challenges must be addressed in order to use them effectively. Passengers data at bus stops cannot be derived from AVL, but they can be used to derive passenger patterns and need to be integrated into processed AVL data. This paper proposes a new punctuality measure defined as the fraction of passengers who will be served within an acceptably short interval after they arrive. A method is proposed to determine this measure: it provides (i) several rules to handle AVL collected data, (ii) a procedure integrating processed AVL data and potential passengers' patterns and (iii) a hierarchical process to perform the punctuality measure on each bus route direction of a transit network, as well as for every bus stop and time period. The paper illustrates the experimentation of this method on more than 4,000,000 data of a real bus operator and represents outcomes by easy-to-read control dashboards.

1. Introduction

Service quality is a key factor in public transport for both users and bus operators (EN 13816, 2002). A relevant element of service quality is the reliability. Generally speaking, it can be seen as the capability of bus operators to provide the service as promised in terms of multidimensional aspects, such as time, passenger loads, vehicle quality and so on (Ceder, 2007; Chen et al., 2009; Kimpel, 2001; Van Oort, 2011). In high frequency services, regularity (or adherence to headway) is a relevant time reliability element, because customers tend to reach bus stops following random patterns, without paying attention to bus arrival or departure times published in timetables, if any. In low frequency services, customers time their arrival at bus stops shortly before the scheduled time (Furth and Muller, 2006) and punctuality (or adherence to timetable) is a more appropriate time reliability facet. However, the scheduled headway threshold between high and low frequency services is not clearly defined (e.g. Marguier and Ceder, 1984; Nakanishi, 1997; Transportation Research Board, 2003a, 2003b).

While punctuality can be measured for both on-board users and users waiting at bus stops, this paper focuses on the latter case, because punctuality at bus stops makes for punctuality throughout the route. Nowadays, this type of punctuality is usually measured by bus operators using the percentage of on-time bus arrivals or departures at time points or stops,

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Acronym Definitions

AF	Arrival Function
AVL	Automatic Vehicle Location
BO	Bus Overtaking
CD	Control Dashboard
GPS	Global Positioning System
IOS	Incorrect Operation in the Service
OTP	On-Time Performance
SF	Staying Function
TF	Technical failure

according to predefined punctuality thresholds. However, this type of measure can be viewed as a binary variable, stating only if a service is punctual or not. Moreover, it depends on the specific thresholds at hand, which are typically bus-operator dependent. More important, this type of measure does not distinguish the amount of early and late bus arrivals or departures. Since several bus operators are aware of the previous drawback, they build frequency classes on early and late arrivals or departures, even if they keep on considering their own thresholds. These classes help bus operators detect criticalities, because they provide a general overview on the distribution of bus arrivals or departures. However, this approach neglects the different impact of each class on passengers. For example, if passengers know published times and buses arrive (or depart) before these times, passengers may feel to receive the service as "very unpunctual", because buses may have already left before their arrival, and they may wait at bus stops for a time longer than the scheduled headway. Moreover, if passengers know published times and buses arrive (or depart) after these times, the most penalized passengers are those who have arrived first. Generally speaking, it is important to know when passengers arrive at bus stops and how long they are supposed to stay there. In this paper, the amount of passengers accumulating at a bus stop over time for a given route is called passenger pattern.

The integration of passenger patterns into bus arrivals or departures data is investigated. This integration allows to obtain a new punctuality measure, which is defined as the fraction of passengers who will see a bus serving their stop within an acceptably short interval after their arrival. The proposed metric is of particular interest in case of low frequency services (e.g. scheduled headways larger than 20 min), where passengers typically know published times, and in medium frequency services (e.g. scheduled headway between 10/12 and 20 min), where some passengers know published times and some others do not. Therefore, this metric considers all passengers regardless of their knowledge of the published times and associates them to the first forthcoming bus by passenger patterns. Nevertheless, the shape of these patterns may disclose information on the knowledge of the published time (e.g. the larger the slope of a passenger pattern in the proximity of the published time, the larger its knowledge from users).

In order to perform high-quality punctuality evaluations, bus arrival or (departure) data must properly collected, effectively handled, accurately processed and represented in a user-friendly way. Nowadays, Automatic Vehicle Location (AVL) system can collect huge amounts of data on bus arrival or departure and opens the door for detailed analyses, but their use requires handling anomalies such as missing data points and possible bus overtakings. Moreover, while typical practices of bus operators are thought to operate in poor-data environments, new methods must be developed to exploit the rich-data environments provided by AVL.

Passenger patterns can be investigated in different ways such as telephone, postal and at home/intercept surveys (Barabino et al., 2013a), and direct measures are also applicable. Van Oort (2011) conducted a customer survey on arrival behavior and showed that passengers start arriving at bus stops about 7 min before the scheduled time, if they plan their arrival using the schedule. Unfortunately, since buses may arrive after the published times, it is also important to know the percentage of passengers served within an acceptably short interval after their arrival. Once collected AVL data are processed and both passenger patterns are built, they can be integrated into the new punctuality measure.

A crucial phase for punctuality diagnosis is to decide routes, bus stops and time intervals in which measures must be performed. A typical *modus operandi* is to empirically pre-select critical routes by hunch and experience, which results in the analysis being too local and offers narrow conclusions. In order to add rigor in this phase, this paper presents a hierarchical procedure, comparing and selecting the most critical routes by a preventive measure of the proposed punctuality metric on all route directions of the transportation network at hand.

To sum up, the objectives of this paper are:

- Proposing a new measure of punctuality at bus stops, which integrates bus arrival or departure data and passenger patterns.
- Handling AVL data properly and represent passenger patterns.
- Presenting a hierarchical approach to evaluate this measure of punctuality on a bus network, in all route directions, for every bus stop and time period.