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Adjustment boarding and alighting passengers on a bus transit line using qualitative information

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ABSTRACT

Obtaining data to use in an urban public transport operation planning and analysis is problematic, particularly in urban bus transit lines. In an urban environment and for bus services, most ticketing methods can be used to record passengers getting on board but not getting off, and current methods are unable to make a proper adjustment of boardings and alightings based on the available data unless they do alighting counts. This paper presents a method whereby counts are made at fewer stops and qualitative information on alightings and/or vehicle loads between consecutive stops is used to make the boarding and alighting adjustment as a previous step to obtain the real origin and destination (O/D) of passengers allowing the O/D matrix calibration by using the loads between stops. Qualitative information can be obtained by the vehicle's driver or an on board observer, avoiding the necessity of counting many stops in planning period. The method is applied to a real bus transit line in Malaga (Spain) and to a set of 50 different bus transit lines with number of stops ranging from 10 to 75. The results show that the proposed method reduces the adjustment errors with regard to traditional methods, such as Least Square Method, even in the situation where no qualitative information is used. When qualitative data is used on alightings and loadings, the reduction of the average error is over 50%.

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1. Introduction

When planning public transport networks, it is crucial to know the real origin and destination (O/D) of passengers. Surveys about the O/D of travelers are mandatory to obtain this information at every transport system. Once the O/D matrix has been obtained (based on the survey), it has to be calibrated with collected data. For that aim, in the case of bus services, the number of passengers between the bus stops (bus loads) is key information. To get this information, the transport planner needs to know the actual in and out movements of passengers at each stop along the line. Besides, bus loads are also crucial in the service operation activities, such as when deciding if an additional vehicle is required because the maximum load has been overtaken at peak time, helping to adapt the service to the demand as much as possible. Regarding to urban transit buses, collecting data on passenger boardings has progressed with the new electronic ticketing systems, like the smart card as a payment option as can be seen in the literature review made by Pelletier et al. [1], and thanks to the increased sophistication of mobile communication technologies [2]. Smart cards improve the quality of data [3] and the ticket validation systems provide information on the number of boardings. Therefore, this information is quite accurate and the only errors are due to potential device failures.

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However, the systems cannot be used to obtain data on the number of alightings, so passenger detection systems and surveys on board or at the stops are needed for that purpose. Several surveyors may be needed if there are several exits (e.g., in articulated buses) and high passenger volumes. Such data collection is much more costly and subject to more errors than boarding counts. So, improved techniques for collecting data on transit operation are essential to improvements in transit operating efficiency. Two-time mode cards have been adopted in certain exceptional cases [4] (i.e., Beijing Municipal Government Public Traffic) to record where passengers board and alight. Card scanners are placed at the entrance and at the exit, but the systems are not used on most of transport services at a global level, passenger tickets need to be scanned twice which means double investment.

New emerging technologies are being developed, such as images recognition, weight sensors or counting sensors but, so far, the pilot project experiences have failed because they still present too many errors (i.e., open field, shadows, partial vision, etc.) and it seems to give erroneous information, which at the end must be used as fuzzy data, that no traditional method is able to work with.

It is important to remember that in both, the case of interurban and underground transport systems, where passengers buy the ticket before boarding and in many underground networks the passengers must scan their tickets before they exit, this method would be useless. But it still remains a wide field to be applied on urban or metropolitan bus lines worldwide.

2. Background

Several methods have been developed to adjust data on a transit line when both boarding and alighting data are available [5]. In general, all methods seek to narrow the gap between observed values and adjusted values as much as possible, subject to contour conditions.

The existing methods can be classified into two groups, depending on the nature of the observed values and how they are processed:

- Group One: The adjusted values are based on their closeness to the observed values. The methods used are: the least squares method (LSM); the maximum likelihood adjustment; and the fuzzy regression adjustment [6]. In addition to the above methods, other authors have defined a stochastic method in which it is assumed that passenger boardings follow a Poisson distribution and the number of passengers alighting follows a binomial distribution [7].
- Group Two: These methods assume that the observed value is approximate and that the adjusted value is within a range created around the observed values. This group can include fuzzy optimization and the required interval regression adjustment. Using the fuzzy sets theory, fuzzy optimization adjustments allow soft constraints to be added to the relationships between volumes at transport nodes, seeking data reliability and the relationships between volumes. The adjustment with the required interval regression seeks the adjusted value within a crisp contour. This method is appropriate for those cases in which the analyst does not trust the accuracy of the observed data.

All the above methods require quantitative data to be able to make the adjustment, and obtaining such data is expensive. On the other hand, information on vehicle loads between stops is not often used to make the adjustment between boarding and alighting data. Rather, it is the final output of the adjustment.

At almost no extra effort, qualitative information on the number of passengers who alight at a stop or on loads between stops on a transit line could be obtained, along the lines such as: a few passengers, many passengers, half the load, or I do not know how many alighted at stop x_i; the bus was half full, almost empty or half full between stop x_i and x_{i+1}.

The above-mentioned methods are not able to use qualitative information, however. Although the methods in Group Two use fuzzy logic, they are based on quantitative values, so they can only be applied if a quantitative value is assigned to each observed value. Doing so would add an element of randomness to the results obtained. To explain this, let us suppose that there are five stops on a line and the boarding data is available (80, 20, 20, 20, 0) but the number of passengers alighting could not be quantified. To be able to apply the existing methods, a quantitative value would need to be assigned to each alighting. If that information is not available, one analyst could suppose that (0, 0, 0, 0, 140) have alighted, whereas another analyst might suppose (0, 80, 20, 20, 20). The results obtained by both analysts would be completely different.

In this paper, we present a new method that uses fuzzy optimization based on qualitative information about the number of passengers alighting at each stop and about the vehicle load between stops. The aim of the method is to use this information to enhance boarding and alighting adjustments, with two possibilities:

- One, the information on the alightings provided by surveyors (quantitative, at a high effort and cost) could be replaced by qualitative information on the number of passengers who alight at each stop and on the vehicle load between stops, which could be provided by the vehicle's driver. This would dispense with the need to hire surveyors to do the job, with the resulting financial saving.
- Two, to see the percentage of alightings that would not need to be counted while retaining the adjustment's accuracy, if we used qualitative information on the vehicle load between stops provided by the vehicle's driver.

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