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Estimating the bus user time benefits of implementing a median busway: Methodology and case study

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ABSTRACT

This paper presents a general framework to estimate the bus user time benefits of a median busway including the effects on travel time and access time. Unlike previous models, we take into account the effects of geometry and the interaction with the demand structure. Models for predicting the bus in-vehicle time benefits of a median dual carriageway busway against mixed traffic condition on 2 and 3 lanes roads are estimated using data from a case study in Santiago (Chile), using a bus travel time model empirically estimated and considering different base case situations, including mixed traffic operations and bus lanes. Results of the application show that the expected in-vehicle time savings of a median busway might be reduced by access time losses due to increased walking distances and road crossing delays. Also, that net time benefits can vary significantly according to the base situation and the structure of demand considered. These findings point out to the need of including a wider set of impacts when studying the benefits of median busways, beyond in-vehicle time savings only. The empirical work presented here is completely based on passive data coming from GPS and smartcards, what makes easier and cheaper to conduct this type of analysis as well as to do it with a comprehensive scope at an early stage of the development of a BRT project. This framework can be extended to other types of dedicated bus lanes provided that a corresponding bus travel time savings model is available.

1. Introduction

Many growing cities around the world share the perspective of a future scenario of high congestion, rapid motorization growth, and difficult traffic conditions. Within this context, bus rapid transit (BRT) systems are viewed as an alternative for improving travel conditions because they can provide high-standard public transport services at a lower capital cost and with shorter construction times than rail-based systems, such as train or metro systems (Wright and Hook, 2007) with more flexibility to adapt to a rapidly changing environment (Cervero, 2013).

Segregated bus lanes (busways) are a key component of BRT systems because these lanes isolate the bus flow from the congestion caused by private cars and other vehicles, reducing travel time. Many segregated bus corridors, curbside lanes, and other types of segregated busways have been constructed around the world (Hensher and Golob, 2008; Wirasinghe et al., 2013). Within a BRT project, the infrastructure for dedicated bus lanes is typically the most expensive and most controversial component because these lanes affect other vehicles and the urban environment near the corridor. There are different approaches to implement dedicated bus corridors, which can vary from a painted bus lane to a specially built tunnel or

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elevated structure. Other elements such as stations, vehicles, fare collection systems, and operation control systems, are typically compatible with any type of dedicated bus lane infrastructure and can be evaluated independently.

Given the increasing interest in BRT systems around the world, it is timely to count with comprehensive approaches to estimate benefits and costs of such systems, that can be used as input to guide design decisions. In this article, we focus on median (central segregated) busways only, which have been implemented in several cities (e.g., Jakarta, Beijing, Seoul, Cleveland, Vancouver, Nantes, Bogotá, Curitiba, Santiago and many others). Central segregated bus corridors are a clear concept but can be implemented with varying features, including the number of bus and private vehicle lanes, and the presence of overtaking lanes at stations. These corridors are typically considered the best option for dedicated bus lanes because the private vehicle movements at intersections or property entrances do not affect bus operations and vice versa. Empirical evidence on the running time savings accrued by segregated busways abound (see, e.g., TRB, 2007; Wright and Hook, 2007).

Impacts of segregated busways on other stages of the users travel time, such as access and waiting times, are less apparent. In particular the impact of median busways on access times has not been properly assessed with numeric methods and have not been estimated in well-known BRT design guidelines, such as the guides by the Transportation Research Board (TRB, 2007) and by the Institute of Transportation and Development Policy (Wright and Hook, 2007). Moving a bus stop from the curbside to the median does increase access distance as users need to cross a number of road lanes to reach the stop, and extra sources of delays are present if a traffic signal is in place.

In the literature, there are several analytical models that optimize bus stop spacing by studying the tradeoff between access and in-vehicle time, that is introduced by increasing the number of bus stops (e.g., Mohring, 1972; Kuah and Perl, 1988; Chien and Schonfeld, 1998; Furth and Rahbee, 2000; Chien and Qin, 2004; Ibeas et al., 2010). It has been shown that with segregated busways optimal bus stop spacing increases, due to the increase in acceleration/deceleration delays at bus stops when buses reach a larger cruising speed, as is the case on segregated busways as compared against mixed-traffic operations (Tirachini, 2014). More sophisticated works on access time modeling go beyond the traditional framework that assumes demand uniformly distributed along bus corridors or urban areas, to incorporate information from Geographic Information System (GIS) platforms, that makes possible to identify more precise walking distances to bus stops that can be embedded in models to optimize bus stop location (Furth et al., 2007; El-Geneidy et al., 2010). However, all bus stop spacing optimization models do not estimate or analyze the effect of median busways on access time from the sidewalk to the median, which is introduced and estimated in this article.

Another issue that has been disregarded in the literature is that to build up a median busway in an existing road section may often imply a variation (likely an increase) of the signalized intersections density. It arises from the need to protect crossing pedestrians that will have to walk longer distances, the bus passenger movements between bus-stops and sidewalks and, in some cases, buses exiting the busway to make a turn in a nearby intersection. Also, traffic signal timing will be affected by changes in road geometry. These impacts may reduce the benefits in running time of the median busway especially in off-peak periods where signal cycle times will be longer than those needed without the busway.

Regarding the effect on waiting time, segregated busways in general reduce running times, which, depending on operational decisions, may be translated in an increase of service frequency and therefore a reduction of waiting times, or may be used by the operator to reduce fleet size, keeping frequency constant. However, even if the bus frequency is kept constant after the introduction of a busway, there is a likely effect of bus segregation on reducing travel time variability (Diab and El-Geneidy, 2013), which in turn induces a reduction of headway variability and therefore a reduction of average waiting times (Osuna and Newell, 1972; Eberlein, 1995; Hickman, 2001).

The objective of this paper is to provide a general framework to estimate the benefits of any type of median busway project and any base-case scenario in terms of bus user time, including both in-vehicle and access time costs, under reasonable assumptions and using easily accessible information that is likely to be available at the early stages of the planning process. The base case only assumes that buses use curbside lanes, in which even other types of bus priority, such as bus lanes, may exist.

We generalize traditional analyses that focus on running times, to include impacts on access distance and access time due to the implementation of median busways, which have been disregarded in the previous literature. The benefits of median busways are overestimated if their impact on increasing access time is ignored, as previously done in the BRT design and research literature. The main contribution of this paper is the developing of a formal model to quantify impacts of median busways not only on in-vehicle times but also on access times and the inclusion of effects derived from changes in road geometry.

The model is applied to a real median busway in Santiago, Chile, in which we show that the effects on access times are far from marginal. We account for the fact that in central corridors, passengers must access bus stops located at the center of the road from the location where their activities occur, which may imply some additional walking time and delay. The access time costs also depend on the type of infrastructure implemented.

The application relates to a dual carriageway median busway, where the base situation is mixed traffic (MT) on two or three lanes per traffic direction. A detailed model of the bus travel time for such a case has been estimated in Santiago, Chile, developed in Gibson et al. (2015), from which we derive a model to estimate in-vehicle time benefits.

The remainder of this article is organized as follows. A general model to estimate user benefits of a median busway is presented in Section 2. Section 3 presents a model to estimate in-vehicle time benefits derived from the case study of Santa Rosa. Section 4 presents the results from the application of the modeling framework proposed in Section 2 to the case study. Section 5 presents the conclusions of this study.