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Drivers of bus rapid transit systems – Influences on patronage and service frequency

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ABSTRACT

This paper reports the findings of a comparative analysis of bus rapid transit (BRT) performance using information on cross-section data of 121 BRT systems throughout the world, in which random effects regression is employed as the modelling framework for stand alone patronage and ridership models, and 3SLS for joint models in which frequency is treated as an endoneous effect on patronage. A number of sources of systematic variation are identified which have a statistically significant impact on BRT patronage in terms of daily passenger numbers such as fare, frequency, connectivity, pre-board fare collection, and location of with-flow bus lanes and doorways of a bus. In addition to the patronage model, a bus frequency model is estimated to identify the context within which higher levels of service frequency are delivered, notably where there exists higher population density, more trunk lines, the corridor provides bus priority facilities such as priority lanes for many bus routes, and where there is the presence of overtaking lanes at more than half of all stations along the heaviest section of the corridor. The findings offer important insights into features of BRT systems that are positive contributors to growing patronage which should be taken into account in designing and planning BRT systems.

1. Introduction

Public transport investment is touted as a key springboard for a sustainable future, especially in large metropolitan areas with growing populations. Public transport, however, is very much multi-modal and should not be seen as a single mode solution as is so often the case with many ideologues (Hensher, 2007a, 2007b). Hence, any commitment to improve public transport has a growing number of options to pursue. Although enhancement in rail systems typically loom dominant in many strategic statements on urban reform (Edwards & Mackett, 1996; Sislak, 2000), ranging from heavy rail to metro rail and light rail, there is a growing interest worldwide in making better use of the bus as a primary means of public transport, and not limited as a service that in many counties (especially Western societies) predominantly feeds a rail network (Callaghan & Vincent, 2007; Canadian Urban Transit Association, 2004; Hensher, 1999, 2007a, 2007b).

It is 20 years since the influential paper by Hensher and Waters on choice versus blind commitment to specific public transport modes (Hensher and Waters, 1994), and follow up papers by Hensher (1999 and 2007a) in which the merits of a bus based system were promoted as a serious alternative to light rail in particular, but also heavy rail in some situations. Central to the argument to give bus-based systems (especially bus rapid transit (BRT) systems) credibility is recognition that services for a metropolitan area must be regarded as a system in which the key elements of connectivity, frequency and modal visibility must be dominant considerations in establishing value for money public transport. Connectivity refers to the provision of door-to-door services with minimum delay and almost seamless interchanges, and visibility is knowing where the mode is coming from and going to, and when.[1]

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[1] Despite all the efforts to explain that bus rapid transit involves buses on dedicated roads, and not mixing with cars and trucks, the message has failed in many jurisdictions where the word 'bus' is immediately interpreted as buses in mixed traffic competing with cars and trucks. It is time for a radical move – a name change for BRT. We have been thinking about this for many years and we now believe that we should no longer be talking about BRT but about **Dedicated Corridor Rapid Transit** (DCRT). This places the matter fairly and squarely where it belongs – the corridor delivering transit services, with transit defined as all candidate public transport modes, or as defined online as "public transportation system for moving passengers". That is the big sell, and not whether it is steel track or bitumen.

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BRT as a 'mass transit' system has typically been characterised by high running speeds, passenger capacity, frequency and operating on an exclusive right-of-way (ROW). In assigning 'mass transit' in its name, BRT shares these characteristics with Mass Rapid Transit (MRT) and Light Rapid Transit (LRT) but with the major difference of the vehicles running with pneumatic tyres rather than on rails. BRT systems can be delivered at a fraction of the cost of a rail based system, between four to twenty times less than a LRT system and between ten to 100 times less than a metro system for the equivalent level of service (in contrast to vehicle) capacity per hour (Wright & Hook, 2007, see also Levinson et al. 2003; Menckhoff, 2005; Transit Cooperative Research Program 2007). It is this lower cost system, but one which emulates the performance and amenity characteristics of a modern rail system, which has led to the growing global interest in BRT as an urban passenger transport solution in situations typified by maximum peak hour ridership at least up to 20,000 passengers, but often in the range 20,000 to 45,000 passengers per hour.

In examining BRT systems around the world, it is clear that these characteristics are combined in a myriad of different ways, giving rise to the concept of a continuum of quality in a BRT system definition. It would be easy to define 'good' BRT as having the highest quality possible on each of these characteristics. But the real world evidence shows that BRT systems in place are a response to the needs of the urban area and have a mixture of quality standards for these characteristics, giving rise to a labelling of the spectrum from BRT 'lite (better than a high quality bus system) to 'good' BRT. In particular it is difficult to compare a BRT system with several state of the art characteristics perhaps in operation and frequency against a BRT system which is a good 'all rounder' in terms of desirable characteristics.

The primary purpose of this paper is to investigate the features of BRT systems that promote patronage growth. This paper is organised as follows. The following section defines the data used for econometric modelling. This is followed by two econometric model forms, random effects regression, and its advantages over simple regression for separate patronage and frequency models, and 3SLS for joint estimation that allows for endogeneity of service frequency on patronage. We then present the key empirical findings, and discuss how these influence BRT patronage in terms of total system passengers per day. Important findings are summarised and conclusions are drawn in the last section.

2. Ridership drivers of bus rapid transit systems

A number of studies have conducted reviews of BRT systems (see e.g., Deng & Nelson, 2011; Hensher & Golob, 2008; Hensher & Li, 2012; Hidalgo & Graftieaux, 2008). Among these existing BRT review studies, only Hensher and Golob (2008) and Hensher and Li (2012) conducted formal statistical analyses to comparatively assess BRT systems (e.g., their infrastructure costs and ridership). In the most recent study, Hensher and Li (2012) collected information on 46 BRT systems from 15 countries to investigate the potential patronage drivers. A number of sources of systematic variation are identified which have a statistically significant impact on daily passenger numbers. These sources include fare, headway, the length of the BRT network, the number of corridors, the average distance between stations; whether there is an integrated network of routes and corridors, modal integration at BRT stations, pre-board fare collection and fare verification, and quality control oversight from an independent agency, as well as the location of BRT.

The empirical study herein focuses on patronage drivers to deliver greater comparative and analytical power relative to traditional literature reviews, to determine which BRT system factors systematically affect BRT patronage. This study uses a sample of 121 systems, including BRT systems which have opened between 1974 and 2011. The results should be taken into account alongside the 'best practice' approach described above when designing and planning BRT systems.

2.1. Data

Information on 121 BRT systems[2] from 12 countries, opened between 1974 and 2010, was collected from Across Latitudes and Cultures – Bus Rapid Transit (ALC-BRT), a Centre of Excellence for Bus Rapid Transit development financed by the Volvo Research and Educational Foundations (VREF). The countries are Brazil, Colombia, Venezuela, Ecuador, Peru, Guatemala, Chile, Mexico, India, Turkey, Republica de Panama, and Australia. The data is a cross-section in the year when data were collected. The data is a cross-section that summarises performance in 2010.

A descriptive profile of the key data items is given in Table 1. In addition to a number of continuous explanatory variables such as fares and frequency, the role of a number of categorical variables has been investigated. These include whether the BRT system has pre-board fare collection, fare integration to a feeder system, doorways located at both the left and right, longitudinal location of with-flow bus lanes on sides, real time connection between buses and traffic signals (on-line priority for buses), and low-level platform and level boarding. All categorical variables are coded as dummy variables (yes or no) in the regression models.

2.2. Methodology

In Hensher and Golob (2008), ordinary least squares (OLS) regression is used to investigate potential sources of systematic variation in BRT patronage. A key assumption of OLS regression is that all observations are independent. However, in this study, multiple BRT systems are located within one country. Given this, observations within a single country could be correlated to some extent, given some common characteristics of the country. To capture this, instead of an OLS regression model, a random effects regression model (Eq. (1)) is used.

$$y_{it} = a + \beta' x_{it} + u_i + \varepsilon_{it} \tag{1}$$

Here, x is a vector of regressors associated with the ith country and tth BRT system; ε_{it} is a random error term, with $E[\varepsilon_{it}] = 0$ and $\mathrm{Var}[\varepsilon_{it}] = \delta^2$; u_i is a country-specific disturbance with $E[u_i] = 0$ and $\mathrm{Var}[u_i] = \varphi^2$, also $\mathrm{Cov}[\varepsilon_{it}, u_i] = 0$; i represents a country (in this paper, $i = 1, 2 \ldots 12$), and t is the number of BRT systems located within each country.

A random effects regression model operates by allowing each ith country to have a unique disturbance(u_i); hence within a set of observations drawn from the same country, the disturbances are no longer independent. The model is estimated by generalised least squares.

[2] Given that some variables have missing data (see Table 1), the final models reported have less than 121 observations, with the final sample size determined by the dependent or explanatory variable that has most missing observations. We acknowledge the limitations of a reduced data set but also suggest that imputing missing values in such a heterogeneous setting of BRT systems is fraught with problems. See Schafer and Graham (2002).