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# Does Bus Rapid Transit Influence Urban Land Development and Property Values: A Review of the Literature

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ABSTRACT *Despite the proliferation of bus rapid transit (BRT) systems over the past few decades across developed and developing world cities, the impacts* across *these systems on the urban spatial development and property markets have not been comprehensively studied. The current paper attempts to fill this gap in the literature by reviewing the methodologies, underlying theories, and findings presented in the individual academic studies on BRT land-use and price impacts, mostly drawing on those that have focused on Latin American and Asian systems. The review shows that the land-use and value impacts have been less uniform across systems compared to such operational performance metrics as speed and travel time improvements. While predominantly relying on cross-sectional modeling techniques, the approaches used to evaluate land-use changes induced by the transit systems are not uniform either, with only some studies explicitly measuring changes in types of land* use *as opposed to simply land or rental price. The study also concludes that more rigorous evaluation is needed as to whether the BRT systems have improved accessibility for the populations that inhabited the corridors previously or whether, instead, the desired land value increases have in fact resulted in significant population displacement.*

## 1. Introduction

Bus rapid transit (BRT) is a bus mode that is being increasingly used across the world (Wirasinghe et al., 2013) and that is beginning to make a significant mark in the USA (Breakthrough Technologies Institute, 2008). More than 130 BRT systems started operation in the past decade (Suzuki, Cervero, & Iuchi, 2013), and there are now about 146 cities with BRT systems or priority bus corridors around the world, serving nearly 24 million passengers per day (Global BRT Data, 2012). BRT is a growing market in the USA and worldwide: according to Lowe and La (2012), at least 390 firms across the value chain serve markets directly relevant to BRT.

Cities in the developing world are growing at an unprecedented rate and their population is projected to increase by 3.5 billion between 2000 and 2050, accounting for 95% of the increase in the world's urban population. As the majority of

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future urban growth is expected to take place in medium-size cities (UN-Habitat, 2011) with limited fiscal capacities, BRT systems are likely to offer an affordable high-quality transit solution (Hensher, 2007), especially when combined with high-quality infrastructure for pedestrians and bicyclists (Suzuki et al., 2013). Moreover, the flexibility and cost effectiveness of BRT make it an excellent choice for cities and transit agencies facing both increasing demand for transit and increasingly constrained budgets (Weinstock, Hook, Replogle, & Cruz, 2011).

Indeed, over the last two decades, most of the largest metropolitan areas in Latin America and Asia, from Curitiba and Bogotá, to Beijing, Jakarta, and Ahmedabad, have implemented BRT systems to better serve their rapidly growing populations. Yet, despite the already considerable accumulated experience with this public transit form and the good knowledge of the systems' operational performance (Hensher & Golob, 2008; Hensher & Li, 2012; Hidalgo, Carrigan, & Cooper, 2010; Wright, 2001), to date little literature is available that summarizes the impacts of these systems on the urban form, spatial development, and land and property markets. More generally, relatively little effort has been put in retrospective evaluations of land use — transportation policies (Boarnet, 2011), and this largely applies also to those related to BRT systems. Yet, understanding the economic impacts of BRT is becoming increasingly important, since any land value premiums associated with BRT systems could be part of a strategy for financing BRT projects.

The likelihood of new public transport systems promoting land development in their surroundings depends on such factors as the increment of accessibility they offer, availability of vacant land, economic conditions, and land-use and transportation policy. Policy tools available for leveraging transit to encourage specific types of land-use development include density bonuses and support for joint development, among others, as well as various fiscal and financial incentives such as tax increment financing (Cervero et al., 2004). Particularly in a developing city context, BRT systems, if complemented by supportive policies, can also serve as means for promoting social and affordability goals, for instance, by incentivizing the concentration of affordable housing in BRT-accessible corridors.

While research on the land-use and price impacts of BRT systems anywhere is still at a nascent stage as indicated by the fairly limited number and geographic coverage of studies available for review, the literature on Latin American and Asian bus corridors is increasingly expanding, reflecting the rapid growth in BRT popularity and implementation in these two regions. Yet, comprehensive evaluations across *multiple* BRT systems to date have only been carried out in terms of assessing the systems' technical performance and cost recovery. The current paper attempts to fill this gap in the literature by reviewing the methodologies, underlying theories, and findings presented in the individual academic, peer-reviewed studies on BRT land-use and price impacts, mostly drawing on those that have focused on Latin American and Asian BRT systems. First, the paper provides an overview of the broad landscape of BRT-focused research worldwide, specifically, technical and operational performance evaluations. Next, the review assesses the theoretical assumptions and methodologies underlying the research that attempts to quantitatively model land-use and/or property value impacts of BRT proximity, followed by a summary of both quantitative and qualitative evidence that these studies jointly provide. Finally, the paper concludes and provides guidance for future research.

## 2. The BRT Performance Literature: An Overview

There is currently no official definition of what constitutes BRT (Weinstock et al., 2011), although the Institute for Transportation and Development Policy is currently leading an effort to establish a minimum standard for BRT based on the technical knowledge of the international BRT community (Lowe & La, 2012). As noted in a number of studies, such as those by Wright and Hook (2007), Rodriguez and Targa (2004), and Thomas (2001), BRT can be characterized as a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of dedicated or segregated right-of-way infrastructure, rapid and frequent operations, and distinct branding and marketing. BRT that operates on separate rights of way is called a busway (Wirasinghe et al., 2013). In turn, the importance of measuring how passengers value each of the resulting travel quality characteristics, such as in-vehicle travel time, is important for forecasting future travel demand when new systems are being put in place (Currie, 2005). And, while the technical performance literature suggests that BRT systems are generally able to provide mobility improvements comparable to rail-based modes, the specific attributes with which each specific system excels are important not only for the demand for transit services but, in the longer term, also household and firm location decisions vis-à-vis the transit corridor. The individual characteristics of each BRT system will also influence whether the system mostly serves the city's residents or, instead, is used by visitors and 'leisure travelers'. As has been pointed out by Currie (2005), good ride quality benefits passengers traveling further, while quality of stations is only appreciated once each time it is used.

### 2.1. *Technical Characteristics*

Curb bus-only lanes and median bus-only lanes are two commonly used types of the on-street running ways of BRT systems. BRT can also be broadly categorized into on-street, on-freeway, and off-street systems (Xu & Zheng, 2012). Providing separate or segregated running ways for BRT is a common practice in North America, while median arterial bus ways are widely used in South America (Levinson et al., 2003). Exclusive right-of-way are effective at increasing bus travel speeds, allowing BRT systems to compete with most heavy rail and exclusive right-of-way light rail systems (Federal Transit Administration [FTA]/US Department of Transportation [USDOT], 2004; Transit Cooperative Research Program [TCRP], 2003). Most new BRT systems in Latin America use high-platform stations, further improving egress times (FTA/USDOT, 2007).

Numerous reports on the technical aspects of BRT systems have been written by the National Bus Rapid Transit Institute (Perk, 2012) as well as by Vuchic (2005, 2007), Moebs (2011), and Wirasinghe et al. (2013). Research on the technical aspects of BRT lanes includes Zimmerman and Levinson (2004), Chen, Yu, Yu, and Guo (2007), Miller (2009), Rathwell and King (2011), Iswalt, Wong, and Connolly (2011), and Xu and Zheng (2012), while studies on vehicle specifications have been produced by Diaz and Schneck (2000), Zimmerman and Levinson (2004), and Caicedo, Ocampo, and Sanchez-Silva (2012). Diaz and Schneck (2000), Kulyk and Hardy (2003), and Wright (2005) analyzed the merits of different BRT operational and control systems, while research on BRT fare collection systems includes, among others, Levinson, Zimmerman, Clinger, and Rutherford (2002), and Tirachini and Hensher (2011).

### 2.2. *Operational Performance*

A large share of the BRT operational performance literature compares BRT to light rail transit (LRT) (Carey, 2002; Polzin & Baltes, 2002; Vuchic, 2002) and focuses on the Latin American experience. Among the most comprehensive in terms of the time period covered, Wright (2001) analyzes the history of planning of Latin American busways since the 1970s. Also referring to the importance of the Latin American precedent, Levinson et al. (2002) discuss the history and performance of BRT systems in the USA. A study that focuses on a specific US-based yet also Latin American-inspired BRT system is that by Callaghan and Vincent (2007).

Research on BRT system *reliability*, specifically, has been carried out by Wirasinghe (1993), Wirasinghe and Liu (1995), Liu and Wirasinghe (2001), FTA/USDOT (2004), Vuchic (2007), and Rahman, Kattan, and Wirasinghe (2011). *Travel time_reductions* have been the focus of Echeverry, Ibanez, and Hillon (2004), Ernst (2005), Callaghan and Vincent (2007), Molina (2010), Rabuel (2010), Vincent, Delmont, and Hughes (2012), and Tiwari and Jain (2012). Gardner, Cornwell, and Cracknel's (1991) early study, in particular, revealed that some features implemented in Brazilian bus corridors, such as bus overtaking at stations, increased the systems' operational speed and capacity. The importance of *comfort* in choosing BRT services was analyzed by Baltes (2003) in his study of the Orlando BRT and by FTA/USDOT (2009a) in a study on Los Angeles. Similarly, Lin and Wu (2007) analyzed the South-Center Corridor BRT line of Beijing, while Sands et al. (2008) surveyed the passengers of Mexico City's MetroBus on their perceptions of service quality.

With the rapid adoption of BRT across these and other cities, several studies have already attempted to identify common trends in system performance, although with varying degrees of attention paid to the factors driving the differences in indicators such as ridership, operational efficiency, and cost recovery. Levinson et al. (2003) examined 26 cities worldwide that have BRT, focusing on the design features and operating practices of the applications that accompany BRT services. Among the most comprehensive in terms of geographical coverage, Hensher and Golob (2008) evaluated 44 BRT systems worldwide, while Hidalgo et al. (2010) focused on the operational and financial performance of BRT systems in 13 cities in Latin America and Asia. Currie and Delbosc (2011) undertook an empirical analysis of factors influencing ridership on 77 bus routes in Melbourne, Sydney, Adelaide, and Brisbane. They built on the research of Hensher and Golob (2008) to explore further the factors affecting BRT ridership by focusing on both BRT and non-BRT bus systems. Finally, Hensher and Li (2012) identified performance-related sources of variation in daily BRT ridership in 46 BRT systems across 15 countries, opened over the last 35 years.

Weinstock et al. (2011) have developed a BRT Standard, aimed at ranking the operational performance of BRT systems. Bogotá and Guangzhou were reported to have the highest scores among international cities; in the USA, Cleveland and Eugene were ranked the highest. Cain, Flynn, McCourt, and Reyes (2009) and Bayle, Mulley, and Tirachini (2012) analyzed which factors might be most important for performance when designing and implementing BRT in the future. Cain et al. (2009) found that the performance of bus systems increases in the following order: local bus; express bus; mixed traffic with signal priority; use of shoulders; use of existing medians; and exclusive with signal priority.

## 3. Property Value and Land-Use Impacts Literature: Substantive Focus

Estimation of property value changes induced by transit investments has become one of the commonly used approaches for making inferences about their land-use and economic development impacts. This is also the primary approach of most of the studies reviewed here. The impact of BRT on land-use and development may take a relative long time to observe, while the impact of BRT on property values is likely to occur sooner. The reviewed studies mostly focus on one, not both of these effects.

Up until a decade or so ago, most empirical work in this area focused on new highway impacts on property values (Cervero & Landis, 1995), generally reporting net positive property value effects. In more recent literature, studies such as Baum-Snow (2007) have demonstrated the important impact of highways on employment location in urban areas. The literature more specific to transit impacts — at least those studies focusing on developed country cities — has overall been fairly inconclusive. More than 50 studies have been completed since the 1970s on the topic of LRT impacts alone (Duncan, 2010). Most of these were reviewed by Catalá, Reader, and Perk (2012), concluding that the vast majority of the studies find positive impacts on property values from nearby rail transit, yet the results are relatively small in magnitude. According to reviews by Diaz (1999) and Cervero et al. (2004), the premiums for home prices range from about 3% to 45%. However, the vast majority of studies to date have been based on single-family home sales; research on the accessibility premium for multifamily rental housing has been particularly scarce (Wardrip, 2011).

The earliest developed country-focused research — similarly inconclusive — exploring the relationship between land values and accessibility to BRT-type transit in particular were studies on high-occupancy vehicle bus lanes in North America (Knight & Trygg, 1977; Mullins, Washington, & Stokes, 1990). While Knight and Trygg concluded that exclusive bus lanes had no impact on either residential or commercial development, Mullins et al. (1990) found that the BRT in Ottawa — if not in Houston, Pittsburg, or San Francisco — had some effect on land development in areas surrounding stations. As also acknowledged in several of the studies reviewed here, the research examining the BRT's ability to induce land development is still scarce. Rodriguez and Targa (2004), who in their study investigate the relationship between accessibility to the location of BRT stations in Bogotá and multifamily apartment rents, point out that only in a few cities (Ottawa, Curitiba, and Brisbane) has the BRT been a cornerstone of an integrated transportation and land-use strategy.

Most of the existing BRT studies have focused on developing countries, especially the BRT 'pioneers' in Latin America (Bayle et al., 2012). Before 2009, no recent quantitative modeling studies had been conducted to assess the property value impacts of BRT in the USA (Perk, 2012). Indeed, until recently, many of the BRT systems operating in the USA might have been considered too new to find evidence of capitalization into property values.

Several of the studies reviewed here, like Rodriguez and Targa (2004), focus on Bogotá's TransMilenio system, which was first opened in 2000 and has seen several expansions since then. In a 2007 paper, Muñoz-Raskin focused on the BRT's effects on the properties within a ten-minute walking distance; Perdomo-Calvo, Mendoza-Álvarez, Mendieta-López, and Baquero-Ruiz (2007) estimated the impact of TransMilenio on the price of adjacent properties. Rodriguez and

Mojica (2009) examined a slightly different type of impact — the land value changes resulting from the BRT network expansions occurring elsewhere in the city for properties that were already served by BRT. Finally, Bocarejo, Portilla, and Pérez (2013) look at the densification and other land-use impacts of TransMilenio.

Another system whose land-use impacts have been studied extensively is the Seoul BRT. Of the studies reviewed here, Kang (2010), Jun (2011), and Cervero and Kang (2011) are three that have contributed to this literature. While Kang (2010) examined the location of different industry types vis-à-vis BRT stops, Jun (2011) investigated the redistributive effects of the BRT on development patterns and property values. Cervero and Kang (2011) studied changes in both land-use compositions and land values following BRT improvements over several time points, examining impacts on both residential and non-residential properties. Like Bogotá, Seoul operates dedicated median-lane BRT services, supplemented by an extensive network of curbside BRT lanes. What distinguishes Seoul from Bogotá, however, are the other reforms, such as land reclamation campaigns, that were introduced in parallel to improvements in BRT services that supported a more transit-oriented built form.

Finally, in a study focusing on Beijing Southern Axis Line 1, Deng and Nelson (2010) examined whether the travel time savings resulting from the BRT have influenced land development around stations, since understanding the property value impacts of the BRT could be valuable for designing future BRT project financing schemes.

## 4. Differences in Approach

### 4.1. *Theoretical Frameworks*

Land-use impacts of transit systems can be twofold: (1) on regional growth through increased productivity and (2) locally, around stations, as a result of the improved accessibility to locations of interest within the region (Bollinger and Ihlanfeldt, 1997). The latter, more explicitly so than the former, is the subject of analysis of the reviewed studies.

There is a general consensus among most authors in categorizing the factors affecting property values as physical, environmental, and accessibility factors, while some have also considered historical factors and land-use patterns (Debrezion, Pels, & Rietveld, 2007). The most accessible places within a city are likely to foster development and high land values, since accessibility increases travel options for residents (Emerson, 1990; Fejarang, 1994; Wessels, Pardo, & Bocarejo, 2012). It has also been argued that transit investments do not so much generate new growth as redistribute where it takes place (Cervero, Ferrell, & Murphy, 2002; Giuliano & Agarwal, 2010; Wardrip, 2011). Moreover, housing cost premiums are more likely to be observed in strong markets (Weissbourd, Bodini, & He, 2009) and around transit stations that are walkable, mixed-use, and pedestrian-oriented (Bartholomew & Ewing, 2011; Cervero et al., 2004; Kahn, 2007).

The land rent theory, advanced in an urban context by Alonso (1964) and Muth (1969), has been core to how different authors have modeled the relationship between accessibility and land values. The main point of the theory is the assumption that the implicit prices of the different attributes of heterogeneous goods can be inferred by observing the consumers' willingness to pay for each unique set of those attributes, such as structural and site characteristics (e.g. transit accessibility) in the case of housing. The differences in willingness to pay for land in different locations lead to a rent gradient that declines with distance from the central business district (CBD). However, investments in transport infrastructure reduce this demand friction around the CBD to some degree, attracting households to settle around the stations (Debrezion et al., 2007).

Access to a BRT station is therefore expected to provide advantages to certain parcels over others (Rodriguez & Targa, 2004). However, the degree to which accessibility benefits of transportation investments will be capitalized in land values will depend on the sensitivity of users to the access improvements (Rodriguez & Mojica, 2009) and on the *types* of prices that are being investigated — e.g. rents versus sales prices — as each will be associated with different kinds of users. The hedonic pricing methodology, introduced by Rosen in 1974, helped attribute the changes in property values to features comprising the properties. However, the lack of data and appropriate measuring techniques usually implied that simple measures of accessibility have been used: trip purposes other than work or shopping have rarely been included (Debrezion et al., 2007).

Of the BRT impact studies, Deng and Nelson (2010), Cervero and Kang (2011), and Bocarejo et al. (2013) are among the most detailed in explaining the theoretical assumptions underlying their models. One of the key suppositions they reference is that high-quality public transport systems can greatly improve the accessibility of its catchment area by shortening travel time. Therefore, the impacts of transport improvements on land development are likely to include both property value increases *and* accelerated development of land use (Deng & Nelson, 2010). Cervero and Kang (2011) refer to both land price and use changes that are expected to occur, albeit at different times of a BRT's life. Bocarejo et al. (2013) hypothesize that the real estate market response will reflect relatively higher willingness to pay for access by office and commercial tenants as compared to residential ones.

The reviewed studies also differ in terms of the specific variables they either include directly in the study design *ex ante* or reference later to explain results. One of the themes that appear in some but not all of the studies is the potentially confounding effect of the various *negative* effects, or *nuisances* associated with BRT corridors — primarily noise and pollution. In general, while evidence of nuisance effects is inconclusive (Parsons Brinckerhoff, 2001), studies that do not separate nuisance effects from price increases potentially underestimate the latter (Wardrip, 2011). Some studies even show a property value-dampening effect of transit presence in lower-income neighborhoods (Gatzlaff & Smith, 1993; Hess & Almeida, 2007). In the BRT research, these concerns have been explicitly modeled in Rodriguez and Targa (2004), Rodriguez and Mojica (2009), and Deng and Nelson (2010). Rodriguez and Targa (2004) hypothesize that the effects related to proximity to the right-of-way are negatively capitalized into land values, and the nuisance effects are in fact a core question of the study; however, the approach could be criticized for not considering the possibility of each property being exposed to multiple pollution sources. Rodriguez and Mojica (2009) and Deng and Nelson (2010), too, include a 'nuisance' variable explicitly. In contrast, Cervero and Kang (2011) use it in their *ex post* explanation for why the higher-end residential property conversions in Seoul were less likely to occur within the immediate vicinity of a BRT stop.

Another theme that emerges in some, but not all, of the reviewed studies is that of BRT *captivity* (Beimborn, Greenwald, & Jin, 2003), or, more broadly, the availability of transportation alternatives. As suggested in Beimborn et al. (2003), captive users are more likely to live close to bus stops; among choice transit users, differences in travel times between automobiles and BRT, for instance, are not as important as walk access. The extent of transit captivity in a given corridor will presumably also affect the real estate market dynamics and the types of land-use changes that take place when the BRT systems are put in place. Of the reviewed studies, Rodriguez and Mojica (2009) control for access to non-BRT competing bus services operated on other major roads. Bocarejo et al. (2013) do not model BRT captivity explicitly but suggest in their conclusions that the system has significantly improved transit coverage in peripheral areas which is inhabited by low-income, 'transit-captive' segments of Bogotá's population.

A third important difference across the reviewed studies is the extent to which they consider the role of supportive land-use and transport *policies* in bringing about land-use changes along BRT corridors. It has been argued that complementary local policies that support high-density and mixed developments increase the extent to which BRT systems can in fact facilitate transit-oriented development (TOD) and increase property values (Wirasinghe et al., 2013; Yildirim, 2004). Cervero and Landis (1995), too, have suggested that it is in combination with policies such as supportive zoning and government-assisted land assembly that transportation investments shape urban patterns. FTA (2009) reviewed the policies in support of TOD near BRT in a number of US cities, concluding that policies and the local climate may be more important factors than the systems' physical permanence. Earlier, a 1997 study by Project for Public Spaces suggested that in places such as Boston, Houston, Seattle, Miami, and Pittsburgh the BRT facilities have been able to generate positive development impacts when the local land-use policies have been supportive. Overall, California appears to be the front-runner on legislation and policies that support BRT, with no noticeable differences between the incentives offered for BRT and LRT (FTA, 2009). In Pittsburgh, the designation of Enterprise Development Areas laid the foundation for BRT TOD to be implemented (Pultz & Koffman, 1987).

Of the reviewed quantitative studies, the role of supportive policies is also highlighted in Deng and Nelson (2010), who claim that the BRT's potential to stimulate land development will depend on government collaboration to facilitate improvement of the integration of BRT and land development. Rodriguez and Mojica (2009) explained the policy *relevance* of their study by suggesting that the capitalization of BRT expansion in the prices of properties already served by the system will determine the viability and extent of using value capture techniques to recoup some of the price increases. Finally, Bocarejo et al. (2013) are perhaps the most critical of the *lack* of supportive policies in the implementation of the BRT system they analyze — that of Bogotá. In contrast, in Curitiba, the government instituted strong land-use controls and was thereby able to effectively guide growth to encourage development patterns along structural axes that reinforce and encourage use of the bus system (Miller & Buckley, 2000).

A slightly different set of considerations that are present in a number of the reviewed studies relates to the relative roles of government *policies versus markets*. Levine (2006), among others, has emphasized the limited power of zoning and other regulations, arguing that, while requirements for dense development can accommodate market forces that are present, they cannot force a product the market is not willing to provide. Among the land-use impact studies, only Bocarejo et al. (2013) explicitly discuss the role of institutional regulations versus market power in inducing the changes observed along BRT corridors. The reviewed administrative acts reveal that most of the significant changes introduced to regulations in Bogotá were proposed and supported by the private sector.

Finally, the potential *displacement* effects of BRT systems are also acknowledged in only a few of the reviewed studies. Hidalgo and Graftieaux (2008) consider displacement in the immediate sense, advocating the use of existing right-of-way to reduce land acquisition and involuntary displacement. Cervero and Kang (2011), on the other hand, consider the possibility of lower-income households being displaced as a result of the very land price increases that are often portrayed as a benefit of BRT investments. The authors suggest redressing such inequities through the use of the revenues recaptured from benefitting property-owners to underwrite the costs of affordable housing for the displaced residents. In the case of Boston Silver Line BRT, FTA/USDOT (2005) found that the new riders were younger and higher-income than those previously using the regular bus — a sign that at least some degree of gentrification had taken place.

### 4.2. *Differences in Research Design*

In the land-use and price impacts literature, cross-sectional approaches have been used most frequently (Deng & Nelson, 2010). Duncan (2010) argues that the before–after methodology requires access to data over a much longer time period, but is more optimal compared to cross-sectional. Boarnet (2011) points out that in reality we know little about people's preferences for particular neighborhood types and even less about whether such preferences are fixed or malleable over time — for instance, as a result of the implementation or extension of a BRT service. Bollinger and Ihlanfeldt (1997) warn that, while the matched-pair methodology is even better than before–after analysis, there is no easy method of determining how closely matched the selected pairs are. In addition, they also advise addressing the possibility that stations were placed in areas with *historically* high or low population or employment density. Tsutsumi and Seya (2008), among others, emphasize the need to consider spatial autocorrelation when implementing a hedonic approach to avoid overestimation of the derived benefits. In selecting the study areas affected by BRT systems, Deng and Nelson (2010) point out the importance of avoiding restricted land-use types, such as institutional land, and to make sure that also the selected control areas have the same sub-market classes to its paired treatment areas. The authors also suggest that explicit tests should be performed on individual property sub-markets within the owned housing market, predicting that some of them — such as smaller- and lower-income homes — might more readily respond to transit access. More fundamentally, however, no single economic theory indicates the functional form that models should adopt for estimating price or land-use change effects, essentially leaving the choice up to researchers themselves (Perk & Catalá, 2009).

4.2.1. *Cross-sectional versus before–after data*. Temporal characteristics of the data differ even across studies focused on the same BRT system. In evaluating the impacts of Bogotá's TransMilenio, Rodriguez and Targa (2004) used a cross-sectional model and distinguished between local accessibility, which measures the ease of physical access to a BRT stop, and regional accessibility, which measures the BRT travel time to where passengers want to go. Perdomo-Calvo et al. (2007), on the other hand, used Propensity Score Matching to compare selling prices of buildings in two areas of Bogotá. In contrast, Rodriguez and Mojica (2009) applied a before–after approach with hedonic price functions, using properties that already before had access to a BRT station but that now also benefited from the expanded reach due to extensions of the network. To overcome the challenge of inflation and other confounders affecting property values, the authors also analyzed properties from an area 'not directly contaminated' or affected by the BRT investments. It is unclear, however, whether these represent 'true controls' in the sense that they are not affected by complementary transit systems (i.e. feeder lines) or some other urban investments altogether. Finally, Bocarejo et al. (2013) used a cross-sectional hot spot analysis tool from ArcGIS to establish spatial clustering of indicator values, thus being able to spatially describe the impact of the BRT system based on the clustering patterns.

Deng and Nelson (2010) applied longitudinal analysis to estimate apartment price changes in both treatment and control areas before and after the opening of the BRT in Beijing. In Seoul, Cervero and Kang (2011) developed hedonic price models and a multi-level binary logit, designed to estimate land-value and land-use changes, respectively. Since many of the property value-affecting attributes can be measured at different geographic scales (e.g. parcels versus neighborhoods), multi-level techniques were used to estimate best-fitting models. The sample frame for the study was essentially comprised land parcels whose nearest bus stop became a median-lane stop once the BRT improvements were introduced in 2004. Thus, this study is also an exception to the general approach of defining treatment areas by using an isometric buffer around BRT stations. The study predicted three types of conversions from single-family residences: to multi-family residential rental units, to condominium owner-occupied units, and to mixed-parcels, all of which correspond to what might be considered 'intensification' in land use.

Of the few quantitative modeling studies that have focused on US-based BRT systems, Catalá et al. (2012) used a before–after hedonic regression of property price changes near the Boston Silver Line. The key variable in these results was the *network*, as opposed to Euclidian, distance from the unit to the nearest Silver Line BRT station. In addition, the analysis also accounted for spatial autocorrelation. Perk and Catalá (2009) used a cross-sectional hedonic model to quantify the BRT impacts on single-family homes along the Pittsburgh Martin Luther King (MLK) Jr. East Busway. The regression modeled the linear distance of each parcel to the nearest BRT stop as well as to each BRT stop. The use of the straight-line distance is relevant if the *perceived* distance from properties to transit is deemed to be most important (Hess & Almeida, 2007) and provides an upper-bound measure of the effect of distance. In addition, the authors also created incremental distance buffers around the BRT corridor, later transformed into dummy variables. Finally, Hodel and Ickler (2012) applied both cross-sectional and time-series hedonic modeling to investigate the single-family residential property value impacts along the Eugene, OR, EmX BRT line. They used a linear pricing model, analyzing trends of house values across varying distances.

The model also accounted for the possibility that stops closer to the downtown may have a different effect compared to those on the east end of the town.

4.2.2. *Type of price evaluated*. Like several others (Rodriguez & Mojica, 2009; Rodriguez & Targa, 2004), Deng and Nelson (2010) base their analysis on the *asking* price, acknowledging the difficulty faced when trying to obtain actual property transaction data. Yet, the use of asking price instead of the actual market price might be problematic, as it is not linked to an equilibrium price. In contrast, Cervero and Kang (2011) used the *assessed* land values, obtained from Seoul's Assessor's Office. Of the US studies, Perk and Catalá (2009), too, used data on the assessed property values, while Catalá et al. (2012) and Hodel and Ickler (2012) evaluated changes in the actual sales price of properties.

Differences also exist with respect to whether the sales or the rental price impacts are being evaluated. While the large majority of studies focus on the former, examples of the latter include Barrios (2002) and Targa (2003), who studied the impacts of BRT proximity on property lease values and land rent values, respectively.

## 5. Study Findings

According to Levine (2006), the physical development outcome on a particular site can be viewed as the product of the feasibility and the legal constraints: i.e. it is an outcome of the interaction of the site's economic conditions with the allowed uses. Others, such as Boarnet (2011), have suggested that major transportation infrastructure investments do contribute to the economic conditions of specific sites and are therefore a powerful determinant of urban development patterns, particularly employment location. As shown by the meta-analysis by Debrezion et al. (2007), due to the differences across these systems in terms of connectivity and the level of service provided, one should not expect to see highly comparable property value impacts in their surrounding areas.

### 5.1. *Qualitative Evidence*

There is a large amount of qualitative and anecdotal evidence that the implementation of BRT services can lead to development (Breakthrough Technologies Institute, 2008). In the case of BRT system effects on land values and uses in Latin American cities, the qualitative findings are relatively encouraging. In Curitiba, BRT played a catalyzing role toward sustained economic development (Rabinovitch & Hoehn, 1995; Rabinovitch & Leitman, 1996; Wright & Hook, 2007), as it was developed in unison with the city itself (Cervero, 1998; Fouracre, 1975). As suggested by Wright (2001), the *strategic siting* of busway stations improved customer access to shopping, employment, and services, which was also supported by the coordination of new residential construction around bus arteries. In Guayaquil, the BRT system became the centerpiece of an urban renewal program that redeveloped public spaces (FTA, 2006; FTA/USDOT, 2007). Also Bogotá's TransMilenio has been characterized as a central part of the city's urban renewal program, bringing with it other improvements such as new public spaces, pedestrian streets, and about 150 miles of bicycle paths connecting with the BRT (Vincent, 2007).

Still, most of the cases study literature has tended to focus on developed countries. Deng and Nelson (2012), and Currie (2006) have suggested that BRT stations often facilitate TOD, while Levinson et al. (2002) have argued that BRT systems can be integrated into urban environments in ways that foster economic development. The authors base their conclusions on the examples of Boston, Ottawa, and Brisbane, where BRTs have been part of integrated transit and land-use strategies. Among the earliest, a 1996 study of Pittsburgh's MLK Jr. East Busway found that approximately \$300 million worth of development had occurred along the route since 1983 (Wohlwill, 1996). Later, Perk (2012) estimated that the East Busway had resulted in over \$500 million in development. As part of the property impacts analysis of the Boston Silver Line BRT, Catalá et al. (2012) also examined the changes in land uses along the corridor, finding an increase in the number of parcels that converted to Condominium classification. FTA/USDOT (2009b) found that the development had accelerated along the Boston Silver Line corridor, resulting in at least \$93 million in new development. However, no direct link between new development and the BRT has been proven (Schimek, Watkins, Chase, Smith, & Gazillo, 2007).

Breakthrough Technologies Institute (2008) presents case studies on BRT-based TOD in Brisbane, Cleveland, Boston, Ottawa, El Monte, and York, concluding that most BRT-related TOD research has focused on Boston, Ottawa, and, to a lesser extent, Pittsburgh. A 1996 TCRP report concluded that Ottawa had experienced a significant level of development activity near its Transitway stops. FTA (2009) reported that over a billion Canadian dollars had been invested in new construction around the stations. Vuchic (2002) suggested that the city is known for having good coordination between transportation and land-use planning, which has led to land development near major stations.

Also in Orlando, the BRT has been said to have played a vital role in the economic development of the downtown (Baltes, Perk, Perone, & Thole, 2003) and has the potential to do so in Los Angeles and Eugene. In Orlando's downtown, about five million square feet of office space and six new apartment communities have been developed, possibly due to the LYMMO BRT FTA/USDOT (2009b). Kimbler (2005) suggested that availability of transit service, including BRT, to employees and area residents in Orlando has allowed the downtown to continue developing at a high rate. The impacts of the Cleveland BRT corridor were described in Amundsen (2001), who argues that real estate development along the Euclid Avenue HealthLine received a major boost when plans were unveiled for a BRT line. In contrast, preliminary evaluations of the Las Vegas BRT impacts suggested that it had not yet induced transformations in the general development patterns (FTA, 2009).

### 5.2. *Evidence Supported by Quantitative Modeling*

Table 1 summarizes the quantitative evidence on several BRT systems in Latin America, Asia, and the USA — specifically their technical and operational performance characteristics and property value impacts.

The findings of the reviewed studies that examined the impacts of Bogotá's TransMilenio are largely, if not entirely, in agreement with one another, with differences possibly explained by some of the studies focusing on sales while others — on rental — premiums. Rodriguez and Targa (2004) find that the coefficient for the distance-to-corridor variable (which serves as a proxy for noise and other nuisances) has the opposite sign of the coefficient for access to BRT stations.

**Table 1.** Operational performance and property value impacts of selected BRT systems

| BRT system | Type | Operational performance | Property value impacts |
|---|---|---|---|
| Bogotá TransMilenio | Median-lane exclusive busway | Hidalgo et al. (2010): 1.6 million daily passengers; peak loads at 43 000 passengers/hour/direction; speed of 28 km/h | Rodriguez and Mojica (2009): property asking prices 13–14% higher near BRT compared to control areas<br>Perdomo-Calvo et al. (2007): residential properties located near BRT valued by between 5.8% and 17% higher<br>Muñoz-Raskin (2007): premiums for properties within five minute of feeder lines<br>Rodriguez and Targa (2004): 6.8–9.3% reduction in property rents for every five minutes of additional walking time to a BRT station<br>Targa (2003): every 100 m from a BRT station result in a 3.7% reduction in land rent value<br>Barrios (2002): land rent price elasticity of −0.421 for every 100 m from the corridor |
| Beijing Southern Axis BRT Line 1 | Median-lane exclusive busway | Deng and Nelson (2010): 120 000 average daily passengers; speeds up to 22 km/h; travel times reduced by 40% | Deng and Nelson (2010): asking prices of apartments in the BRT catchment area 11% higher than in control areas |
| Seoul BRT | Median-lane exclusive busway and curbside lanes | Cervero and Kang (2011): over 100 000 daily passengers; average bus operating speeds doubled from 11 to 22 km/h | Cervero and Kang (2011): land price premiums up to 10% for residences within 300 m of BRT stops and more than 25% for non-residential uses within 150 m |
| Pittsburgh MLK Jr. East Busway | At-grade and grade-level dedicated busway, signal priority | FTA/USDOT (2004): 30 000 ridership; 12-minute peak headway; 52% travel time reduction | Perk and Catalá (2009): property values increase by $2.75 when moving from 1001 to 1000 feet away from a station |
| Eugene Emerald Express | Median-lane exclusive busway for 60% of the route | Community Planning Workshop (2009): 50% ridership increase compared to previous bus route (to 2700 per weekday); time savings of one minute | Hodel and Ickler (2012): 0.18% price increase for residential properties within one minute of walking distance to a station |
| Boston Silver Line | Bus-only lane for much of the route, transit signal priority | FTA/USDOT (2004): 85% increase in ridership in the corridor (to 14 105); four-minute peak headway; 26% travel time reduction | Catalá et al. (2012): premium of 7.6% for condo sales near BRT |
| Los Angeles Metro Rapid | Operates in mixed-traffic conditions along freeways, signal priority | FTA/USDOT (2004): >265 000 riders for all corridors combined; 4–30 min peak headway; 17–29% travel time reduction | FTA (2009): residential properties within $\frac{1}{2}$ mile from stops sold for less, while commercial properties sold for more, relative to the rest of the city |

Muñoz-Raskin's (2007) analysis by socio-economic strata shows that middle-income properties were valued more if they were closer to the system; in contrast, for high-income housing, greater proximity was valued more for properties in the proximity of *feeder* lines. Echoing Rodriguez and Targa's (2004) findings on the nuisance-related effects — and possibly the fact that the accessibility benefits of TransMilenio are smaller depending on where specific socio-economic groups tend to travel — Muñoz-Raskin (2007) also shows that, on average, low-income housing saw value *discounts* in the case of new properties in the immediate walking proximity to both trunk stations and feeder lines as compared to the properties 5–10 minutes away.

Rodriguez and Mojica (2009) found that areas near the BRT saw considerable increases in industrialization, while the opposite happened in control areas. However, the reverse trend was detected for commercial development, while institutional land uses grew in both areas. The findings on the relative intensification of industrial versus commercial development in the BRT vicinity are somewhat at odds with the suggestions made by authors like Tumlin and Millard-Ball (2003), who have observed that office or retail development generally tends to employ more workers and thus produce more riders than industrial uses, which should also be reflected in the sectors' relative land demands near the BRT stations. Rodriguez and Mojica (2009) also detect some other, possibly anti-intuitive trends in terms of the BRT influence. For instance, they find that the percentage of vacant space increased only in the intervention area, and population density in fact declined in both areas. Possibly, this could reflect a state in the real estate market in which equilibrium has not yet been reached.

The above results on density changes in Bogotá contrast with the findings by Bocarejo et al. (2013) that the city's overall density between 2001 and 2008 increased by 8% and, in fact, the increase was mostly higher in areas near the BRT than in the control areas. Based on the spatial hot spot analysis, the highest increases were concentrated in areas served by feeder buses. In contrast, the lowest changes were clustered in the city's south, where the main land use is not residential. Comparatively much less conclusive are the authors' findings on the BRT's impacts on building activity: the municipal land divisions in the treatment areas experienced a slight increase in housing built area compared to those in the control group while the opposite was observed for commercial construction. Compounding these already complicated patterns are the findings derived from the three difference-in-difference models that the authors develop (one per land use): these suggest that the BRT system did not in fact have any impact on building activity.

Of the reviewed Beijing-specific studies, only Deng and Nelson (2010) measure land-use impacts explicitly; however, also Lin and Wu (2007) suggest that the Beijing South-Center Corridor BRT can be expected to affect land use in the future. Deng and Nelson (2010) show that much of the detected elevated residential construction activity can be attributed to the BRT-related accessibility enhancements in the southern area. The authors also find that the capitalization effects are more evident over time and stronger in areas that previously lacked alternative mobility opportunities. The strongest evidence of the BRT having truly had an impact on land-use patterns in the city is provided in the authors' surveys of the BRT corridor residents and business owners, with three-fourth of the respondents identifying the BRT as an important factor in their location choice. Also, the authors' longitudinal analysis of property values confirms the enhanced value placed on BRT accessibility.

Finally, examining the impacts of Seoul's BRT, Jun (2011) shows that the service has contributed to increased development density in urban centers, attracting firms from the suburbs. However, it has had a limited effect on the redistribution of residential activities, implying a lower sensitivity of residential locations to the BRT-related accessibility improvements. Cervero and Kang (2011) find that the BRT improvements prompted property owners to convert single-family residences to higher density apartments and condominiums. Moreover, parcels within $\frac{1}{2}$ kilometer of a stop were generally more likely to convert to more intensive uses than parcels further away. In terms of property values, higher premiums are estimated for non-residential uses as compared to residential ones.

### 5.3. *Role of BRT Technical Specifications*

In the BRT land development and property value impacts literature, it has been argued that significant physical running way investments suggest a permanence of the system also in the future, in turn, attracting private investment in development (FTA/USDOT, 2009b). In contrast, enhanced BRT flexibility can be seen as a drawback (Jarzab, Lightbody, & Maeda, 2002). Station design, too, can influence development along BRT routes (Kaplowitz, 2005). The *Bus rapid transit practitioners guide* (Kittelson & Associates, Inc., Herbert S. Levinson Transportation Consultants, & DMJM+Harris, 2007) provides guidelines for cities that wish to support and encourage TOD around BRT stations, citing the sense of permanence, frequency and speed as potential attractors for development interest. Currie (2006) found that the key factors determining the ability of bus-based transit to spur development were, among others, permanence, parking availability, noise and pollution, frequency, and speed. Zhang (2009) has argued that carrying capacity, along with other operational and contextual factors, determines the level of service of bus systems, which, in turn, is positively associated with land-use impacts.

Specifically, the experience in Boston and Las Vegas suggests that developers respond to services that incorporate vehicles that are attractive and that limit air pollutant and noise emissions FTA/USDOT (2009b). The presence of identifiable station structures was cited as a key reason for speculative development along Cleveland's Euclid Avenue BRT, in addition to the extensive streetscape renovations and enhancements (FTA, 2009). According to Bayle et al. (2012), Curitiba BRT stations have had a great influence on the development of the different areas, acting as magnets of commercial activity and residential development. Finally, in Ottawa, Breakthrough Technologies Institute (2008) found that many developers reported permanence of the BRT as an important factor for investment, and that exclusive running ways and dedicated lanes as well as the size and quality of stations most contributed to the sense of permanence.

## 6. Conclusions

Despite the large variation in specific technical design features and the extent to which the operation of buses is physically segregated from other traffic, virtually all of the reviewed BRT systems appear to have significantly enhanced reliability and delivered sizeable travel time savings. Still, total daily ridership varies considerably across the systems, from several tens of thousands in some US cities to over a million in Latin American ones. Along with disparities in ridership, headway times, and other operational performance indicators, also the property value and land-use impacts of the BRT systems have been uneven. The Latin American and Asian city-focused quantitative studies, albeit mostly cross-sectional, tend to identify somewhat higher BRT premiums compared to the ones focusing on the USA. Incidentally, several of the reviewed US systems also tend to be characterized by poorer operating conditions — exclusive busways for only part of the routes or operation in mixed-traffic conditions. On the other hand, the USA and Canadian city-focused *qualitative* case studies suggest that the BRT has played an important role in inducing real estate development and TOD. In particular, positive property development effects have been observed in cases where the BRT has been part of an integrated transit and land-use strategy and where significant investments have been made to create a sense of permanence of the system and to improve its environmental and esthetic quality.

Speaking to the importance of the BRT environmental performance and station siting and the potentially highly variable user perceptions of BRT accessibility benefits, several of the reviewed studies — in particular, those looking at Bogotá's TransMilenio and the Los Angeles Metro Rapid — provide strong quantitative evidence of the uneven effects of BRT on different property sub-markets. Specifically, they show that, largely due to environmental nuisance effects and lower accessibility value, residential (as opposed to commercial) and low-income real estate activity might in fact be dampened by BRT presence.

As an overall conclusion applicable to most of the BRT systems included in this review, Cervero and Kang (2011) point out that a transit system alone is likely to be a necessary, but by itself insufficient, factor in intensifying land-use development and increasing land values. Indeed, the reviewed studies jointly demonstrate that the presence of such transit systems does not guarantee that specific development impacts will occur, but that they are more likely to occur under conditions in which the BRT vehicles operate on exclusive runways and where supportive policies complement strong markets.

While there has been a substantial amount of research conducted on BRT systems worldwide, a question that still largely remains to be answered concerns the actual user groups that have benefited the most. Thus, a more rigorous evaluation is needed as to whether the BRT systems have improved accessibility for the populations that inhabited the corridors previously or whether, instead, the desired land value increases have in fact resulted in significant population displacement. In future research, another potentially important empirical estimation issue is that of the *net* effects of BRT services — the possibility of more accessible locations potentially seeing price increases while others experiencing prices *decreases*. Future research should also more thoroughly explore the question of which of the physical characteristics of BRT corridors and not just the systems themselves induce the price premiums found in the reviewed studies. Specifically, future studies should attempt to capture station area features such as walkability and the availability of retail services.

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