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Land development impacts of BRT in a sample of stops in Quito and Bogotá

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ABSTRACT

Despite the growing popularity of bus rapid transit (BRT), little is known about its impacts on land development. In this paper we examine the land development impacts of BRT in Bogotá and Quito, two cities that have made a variety of BRT investments over the last two decades and with Curitiba, they have been world pioneers of BRT. Relying on 10 years of data, we use a quasi-experimental research design to quantitatively examine changes in land development in both cities. Outcomes include land market characteristics such as built area added per year (both cities), units added (Quito), building permits issued (Bogotá), changes in land use (Bogotá), and property price changes (Quito). We compare how outcomes vary over time for treatment corridors – those that received BRT service at various points throughout the decade, relative to control corridors in both cities, and in Bogotá also relative to a road-expansion corridor. In Bogotá, control corridors were corridors slated to get BRT but that had not received any BRT service yet, whereas in Quito they are adjoining areas. Results reveal heterogeneous impacts in both cities. Although increased building activity tends to concentrate in treatment areas, comparisons with controls suggest that the impacts are context dependent. Some stations showed very high development activity and others less so. Development induced along the road extension in Bogotá was considerable. In both cities, the strongest effects appear to concentrate in end-of-line terminals and stops built in the early 2000s. Whether BRT stimulates land development depends on institutional factors such as developer appetite, market conditions, land availability, and land regulations.

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1. Introduction

Bus rapid transit (BRT) has emerged as an innovative solution to the mobility needs of world cities. As with other mass transit alternatives, BRT can increase the attractiveness of transit, may help mitigate CO_2 emissions, and can be a catalyst for transit service reorganization. The success of BRT is largely the result of its cost-effectiveness and relative flexibility. BRTs often can carry as many passengers as most conventional light rail systems at a fraction of the cost. In coordination with supportive urban development, BRT can also decrease motorization (Combs and Rodriguez, 2014). In addition, when development along a BRT corridor is supportive of mass transit, other transit benefits can be attained. For example, the flow of passengers is balanced out and neighborhoods are reinvigorated.

As with rail systems, however, the operating cost-effectiveness of BRT hinges on the ability to have demand concentrated along system corridors (Dimitriou and Gakenheimer, 2011). Therefore, in most cases BRTs have been built in corridors with proven demand. This approach is naturally consistent with the view that travel is derived from the need to access destinations. Under the prevailing view, the transportation system is subservient to and conditioned by the existing spatial structure. Yet, a different paradigm in planning for mass transit is emerging. This new paradigm leverages the ability of mass transit to shape urban development. It focuses on using mass transit to stimulate land development that is intimately linked to the transit system and mutually beneficial. For the last four decades such paradigm has been actively practiced by cities like Stockholm and Copenhagen around their rail investments (Cervero and Kockelman, 1997) and is now being used to invigorate and regenerate well-located parts of the city (Knowles, 2012).

The use of mass transit as an instrument to shape land development is not limited to rail, but can also include BRT. As shown by the case of Curitiba (Gakenheimer et al., 2011), BRTs may also attract dense development that will in turn benefit the BRT system

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in the future. Notwithstanding Curitiba, and despite the importance of future land development as a strategy that can complement and build on the strengths of BRT, there is limited empirical evidence regarding the development impacts that BRT investments cause. The land development and redevelopment impacts of BRT investments are the focus of this study. We examine Bogotá and Quito, two cities that have made important BRT investments over the last two decades. Together with Curitiba, Quito and Bogotá have been world pioneers of BRT. In the next section of the paper we review the literature on the land development impacts of BRT. Then, we summarize the methodology used, present and discuss our main findings, and conclude.

2. BRT impacts on land development: Evidence to date

The virtuous cycle between transit investments and land development describes how infrastructure investments create accessibility benefits for dwellers and land owners. Because the number of parcels benefiting from enhanced access is finite, and assuming that access is a scarce good, households and firms valuing such benefits in a competitive market are expected to be willing to pay more for properties with good access over other properties, all else held equal. As a result the access benefits provided by a transportation investment are expected to be capitalized into property prices (Fig. 1). This capitalization frequently has three expected effects. First, developers will be more likely to invest in the property as their expected returns are higher than property investments elsewhere. Second, as a result of higher expected returns, investors are likely to acquire land in anticipation of the BRT investments. And third, developers will seek to amortize the higher property costs by building up. This virtuous cycle supports the potential of BRT to spur development around stations and along corridors. Because planning terminology has specific connotations in different cities, we understand land development as development of parcels, blocks, or larger urban areas that include public spaces such as streets, plazas, and parks. It refers to a broad range of urban processes such as greenfield development, redevelopment, revitalization, regeneration, and even renewal.

In Curitiba, BRT has been used as a tool to spur development that is considered transit friendly and mutually reinforcing. Development is considered transit-friendly or transit oriented when it has a strong pedestrian orientation that supports passenger access, it prioritizes pedestrian safety, is dense and with a mixture of land uses, has a variety of residential, office, and retail options, and encourages multimodal transportation. Curitiba's development around BRT stations has some, but not all, of these characteristics (Rodriguez and Vergel, 2013). Notably absent are the pedestrian orientation of development and the prioritization of pedestrian environments around the stations.

Despite Curitiba's experience, there is little research supporting the relationship between BRT investments and changes in urban development. Furthermore, little is known about the planning, institutional and market characteristics that spur built environment changes around BRT stations. This is an important gap given the immense popularity of BRT—156 cities have introduced BRT elements into their transit network (GlobalBRTData, 2015), the strategic and operating importance of BRT's potential to guide development, and its impacts on transit demand, societal equity, the environment, and public health.

The majority of research on BRT and development has focused on examining associations between access to BRT stations and property values, although the evidence is equivocal. In Latin America, the relationship between residential property values and distance to BRT corridors and feeder routes in Bogotá (Colombia) has been examined (Munoz-Raskin, 2010; Perdomo and Mendieta, 2007; Rodriguez and Targa, 2004). Studies using quasi-experimental research designs have produced inconsistent findings, with some studies finding property price increases of between 15% and 20% (Rodríguez and Mojica, 2009) and others finding null results (Perdomo, 2011). In Ecatepec (Mexico), the announcement of a BRT corridor had no impact on property values (Flores-Dewey, 2011).

In east Asia, two studies of China's first BRT, the Southern Axis in Beijing, found no significant associations (Ma et al., 2013; Zhang and Wang, 2013) while one study found that properties within 300 m of a BRT station had a 7.4% higher value than those within 300–500 m, and 15% higher than those within 500–1000 m of the station (Deng and Nelson, 2010). For the city of Guangzhou, also in China, a study found that proximity to the BRT corridor increased used apartment values up to a point (at around 1–2 km) and then began to decrease presumably due to the deleterious effects of corridor activity (Salon et al., 2014). In Seoul, Korea BRT investments were associated with residential property price increases of between 5% and 10% for residences within 300 m of BRT stations and between 3% and 26% for retail and other non-residential uses within 150 m (Cervero and Kang, 2011), while also in Seoul Jun (2012) found limited effects of BRT on residential property values within the influence area of the system.

Emerging research has examined actual development outcomes around BRT corridors, BRT stations, and in the influence area of BRT feeder routes. In Bogotá the expansion of the BRT was associated with increases in urban density but not changes in land uses (Bocarejo et al., 2012). Cervero and Dai (2014) suggest that in Bogotá's case, the mobility functions of BRT superseded its place-making functions, yielding a cost-effective mobility system in the short term but with disappointing city-shaping impacts. In Beijing, six years after its inauguration, planners and real estate experts were decidedly positive about the impact of the Southern Axis BRT on high density residential development and real estate activity (Deng and Nelson, 2013). By contrast, in Jinan (China), the oversupply of auto-oriented land uses, midblock crossings on the corridor, lack of pedestrian infrastructure and connectivity, and parking issues were barriers to the introduction of BRT-oriented development (Thomas and Deakin, 2008). Finally, in Seoul (Korea), the BRT contributed to increases in development density in urban centers (Jun, 2012).

Relative to rail, BRT is perceived to have several disadvantages in stimulating urban development. First, BRT's ability to stimulate economic development may be limited because of its limited locational rigidity and permanence (Dittmar and Poticha, 2004). Accordingly, developers and firms are assumed to be more likely to locate residential, commercial and office developments along a rail line than along a BRT line. Hensher (1999) finds this reasoning unconvincing and for proof suggests that only one BRT line (in Australia) has been taken away. Furthermore, the disappearance of rail in the US and Australia during the last century is also a

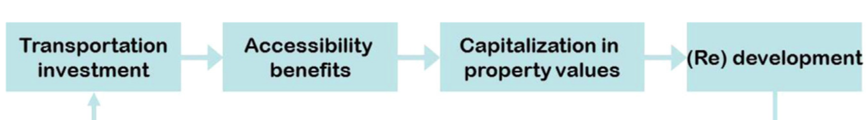

Fig. 1. The virtuous cycle of property development and redevelopment.

testament to the limited permanence of public transportation modes, regardless of the technology.

A second perceived concern is that BRT may be disfavored due to the noise, pollution, and negative image often associated with bus services. These noise and air pollution effects suggest that development impacts need to be examined beyond the properties abutting the right of way, as these effects decay rapidly with distance. Conversely, rail has the allure of newness (Currie, 2006). The stigma of bus-based services appears to be related to technological choices (diesel engines, tire choice, chassis design) that can be addressed, rather than inherent weaknesses of the mode. In fact, Currie (2006) cites other work suggesting that Australian BRT users tend to have socio-demographic characteristics that appear more like users of rail markets than users of regular bus markets.

In summary, the evidence on the impacts of BRT on land development is equivocal. Some studies have suggested important impacts while others have failed to document either price or development changes. Other research has indicated the importance of market and non-market characteristics in explaining whether transit oriented development materializes. The question motivating this study is: What are the land development changes associated with the introduction of BRT in two cities that have been early adopters of this transit mode?

3. Methods

3.1. Study areas

We selected Quito and Bogotá, two cities with considerable experience and well-established BRT systems. Bogotá has a mature BRT system, now with eleven trunk corridors and 135 stations covering 112.9 km (GlobalBRTData, 2015). Quito was an earlier adopter of BRT, introducing it in 1995. Currently Quito has five BRT corridors, accounting for 69.3 km of network and 112 stations (GlobalBRTData, 2015). In this paper, we use the term "station" to refer indifferently to stops or terminals, with the latter being the end-of-line terminus for a route or set of routes and the former any station between termini. All corridors in both systems have achieved either silver or gold status in the BRT Standard (ITDP, 2013). Bogotá and Quito are also similar in terms of spatial structure, with activity radiating out from a Spanish-era colonial central city. In addition, both are located at high elevation and are surrounded by significant mountainous terrain.

Despite similarities in geography and the adoption of BRT, there are several differences that motivate the selection of these two cases. First, Colombia and Ecuador have different land planning frameworks. Ecuador is just beginning to implement a land planning framework similar to Colombia's, while Colombia has almost two decades of experience with a fairly sophisticated framework. For example, Bogotá has many decades of experience with the use of land management tools and the use of betterment levies for road construction, and at least a decade of experience with value capture tools applied to changes in zoning. Second, in some corridors Quito used electricity to power the BRT while Bogotá has relied on diesel fuel.

There are additional unique land market characteristics of importance in Bogotá. First, by late 1990s homeowners were recovering from a major bust in home prices that left many owners under water. Prices only began to recover by 2004. Second, the city is bounded by geographic constraints that limit its growth: Mountains to the east and south and a river to the west. The city is running out of developable land and as a result property prices have increased. Third, congestion has also increased over the past decade, as short-term measures like prohibiting the circulation of cars based on the last digit of license plates have been outlived. By 2007 the economy began to improve, partly due to high fossil fuel and mineral prices and because of increased investor confidence, a trend that continues today.

As Bogotá, Quito also faced a steep recession by the end of the 1990s. In 1999, for example, inflation was 60%. In 2000, then president Mahuad made the US dollar the country currency and with it, implemented an economic reform with far-reaching consequences. By 2005, the real estate market began its recovery (Ospina Lozano, 2010). A second characteristic is specific to Quito and contrasts with Bogotá. Significant population growth in Quito has taken place in valleys areas away from activity centers. Although Bogotá has witnessed high growth in surrounding municipalities (several times greater than the growth rate of the city of Bogotá), this growth pales in comparison with the growth in areas surrounding the Quito city center. Thus, the land market in Quito has used the valley lands around it as an important relief valve for land demand and supply. Transit fares are a third factor that differentiates the two cities. Even though fares are flat for BRTs in both cities, they have increased at varying rates. In Bogotá there have been periodic and consistent fare increases, resulting in the current fare of ~US$0.90, whereas Quito has kept its fare at US $0.25 for more than a decade.

3.2. Land development changes

We examine BRT station areas before and after the implementation of BRT relative to control areas. In Bogotá, we also examine development induced by the extension of a major arterial road. This allows us to compare the growth induced by the BRT with the growth induced by the road investment, relative to non-intervention areas. In the parlance of Shadish et al. (2002), this is the untreated control group design with dependent pretest and posttest measurements. This quasi-experimental design allows us to better assess threats to validity as related to maturation effects over time. However, by definition, the control and intervention or treatment groups are nonequivalent and therefore concerns about treatment selection remain. In our case, this would occur if intervention stations received BRT service because of station characteristics related to land development, such as the potential for redevelopment or the high concentration of population in that given area. In fact, most BRT systems tend to be planned to maximize ridership, which means that stations in areas that can contribute ridership are more likely to be served by the system. Since consolidated areas are less likely to see development activity than greenfield areas, all else held equal, the selection bias of BRT alignment location means that stations that have high residential or employment activity are *less* likely to see development changes and the current study would be biased towards finding no impacts. Furthermore, with this design we cannot isolate the effects of the BRT investment from other local market trends preceding or coinciding with the BRT investment and that may affect treatment and control areas differently. Thus, any results would be indicative of impacts but not fully able to attribute them to the BRT investment.

3.2.1. Bogotá

Seven stations in Bogotá were examined (Fig. 2, in red), with opening dates in parenthesis: Calle 26 (2000), Calle 80 Terminal (2000), Calle 100 (2001), Usme Terminal (2001), Norte Terminal (2001), Suba Terminal (2006), and Humedal Cordoba (2006). Terminals are end-of-line stations where many feeder transfers occur. All other stations are what TransMilenio calls simple or transfer stops. Relative to a larger sample of stops and terminals in Bogotá, the stops and terminals studied had similar road segments density, block size, and mixed of land uses (as measured by entropy) (Table 1). Only population density for the terminals studied

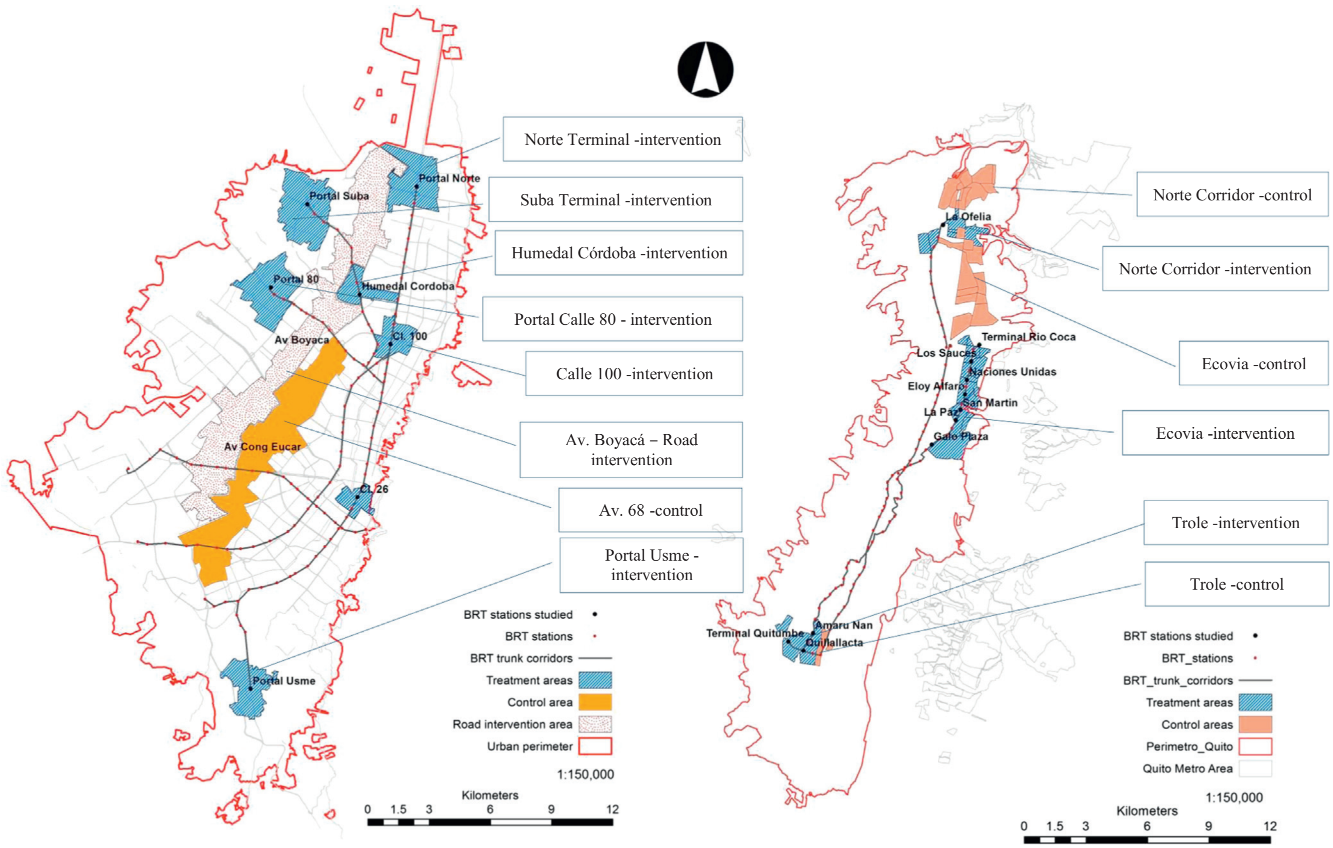

Fig. 2. Intervention and control zones for Bogotá (left) and Quito (right). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

is significantly higher than for stops and terminals not studied. Opening dates of the stops and terminals studied suggest that a clean before and after analysis with controls can only be achievable for the Suba Terminal and the Humedal Cordoba stop. All other stops and terminals had TransMilenio service since 2000 or 2001. For these stations the examination of development changes after the BRT was implemented allows us to understand market dynamics post-BRT.

Spatially, we examined activity in census zones located within 1 km of each terminal and 500 m of each stop. We also include the areas within 200 m of feeder routes, which have an integrated fare with TransMilenio. Feeder routes are included because prior research has shown the importance of feeder routes in explaining travel behavior and resident motorization decisions (Combs and Rodriguez, 2014). To determine whether a census zone was to be included in the study area, we determined that if less than 15% of the zone was contained within the area, then the zone was excluded from analysis.

We used one control area that can help identify the impact of broader trends and maturation effects in the real estate market and another intervention area that benefited from the extension of a major arterial road. For the control area, we sought to identify zones that had a BRT planned but that had not been built yet. This ameliorates (but not entirely resolves) concerns about selectivity bias, given that some corridors were picked first to have BRT for a reason. We also sought corridors that were similar in area and in distance to major destinations. As a result, we identified control and road intervention areas are not station-based, but rather,

Table 1
Bogotá stops[a] and terminals[b] examined relative to a sample not examined.

	Stops examined ($n=3$)		Terminals examined ($n=4$)		Stops and terminals not examined ($n=24$)[c]	
Variable	Mean	SD	Mean	SD	Mean	SD
Population density (persons per sq. km)	125.67	39.09	253.62	93.52	129.69	90.79
Road segment density (segments per sq. km)	332.74	66.27	347.28	180.43	384.78	128.76
Centrality (km to central activity node)	2.12	3.67	10.17	2.33	5.75	3.55
Green areas[d]	112.04	56.71	88.81	33.47	62.60	39.72
Block size (sq. m)	6882.97	841.29	13,662.26	14,820.78	6491.78	3189.58
Entropy (0–1)	0.73	0.09	0.63	0.07	0.65	0.22

[a] Data collected by the authors within a 250 m buffer area.
[b] Data collected by the authors within a 500 m buffer area.
[c] Includes the following stops and terminals out of a total of 148 in the entire system: Marly, Portal Americas, Ferias, Calle 142, Calle 127, Calle 106, Virrey, Calle 85, Calle 72, Profamilia, Tercer Milenio, Restrepo, Boyaca Calle 80, Carrera 43, Americas Carrera 53A, Pradera, Banderas, Transversal 86, Ricaurte NQS, Paloquemao, Universidad Nacional, Gratamira, Suba Tv 91, and Venecia.
[d] # parks, squares, pocket parks, green areas, and boulevards.

Table 2
Quito stops[a] and terminals[b] examined relative to a sample not examined.

Variable	Stops examined ($n=8$)		Terminals examined ($n=3$)		Stops and terminals not examined ($n=19$)[c]	
	Mean	SD	Mean	SD	Mean	SD
Population density (persons per sq. km)	53.92	19.28	58.38	25.05	33.38	17.95
Road segment density (segments per sq. km)	324.68	106.61	230.03	37.26	169.60	168.07
Centrality (km to central activity node)	6.43	2.82	11.03	2.47	2.82	0.31
Green areas[d]	28.65	37.42	28.44	19.49	52.80	0.00
Block size (sq. m)	11,066.49	3864.60	15,535.36	2,422.08	4139.83	3164.46
Entropy (0–1)	0.86	0.13	0.82	0.15	0.19	0.43

[a] Data collected by the authors within a 250 m buffer area.
[b] Data collected by the authors within a 500 m buffer area.
[c] Includes the followings stops and terminals out of a total of 111 in Trolébus, Ecovía, and Corredor Norte lines: Plaza Grande, Estadio, Vaca De Castro, Aeropuerto, Terminal La Y, Terminal El Recreo, Integración España, Terminal Moran Valverde, Colegio Montufar, El Floron, La Colon, Solanda, Villaflora, Quimiag, Eplicachima, El Comercio, Ayapamba, Puente de Guajalo, and Capuli.
[d] # parks, squares, pocket parks, green areas, and boulevards.

corridor based (Fig. 2). The control area comprises the zone within 500 m of Av. 68 (also known as Avenida del Congreso Eucarístico) from Autopista Sur to 80th street, of 12 km. in length. This control area does not have TransMilenio but in the original plans (in 2000) it was supposed to have TransMilenio service by 2011. Current plans suggest TransMilenio may operate before the year 2020.

The road intervention area comprises the zone within 500 m of Av. Boyacá between Autopista Sur and 170th street. The road defining this intervention area is 22 km in length and for about half of its length runs parallel to the Av. 68 control area. This road intervention area does not currently have TransMilenio service but it was originally planned to extend to this corridor in 2009 and is now planned to open in 2018 at the earliest. In addition, the Av. Boyacá itself was extended between 1999 and 2003, almost doubling its length and providing the opportunity to compare the land development impacts of the extension to the impacts of the BRT.

For all intervention and control areas in Bogotá we examined three outcomes: a) new area built, in square meters per area of each zone by year (2001–2010); b) the number of building permits issued per area of each zone by year (2001–2010); and c) changes in actual land use between years, in square meters per area of each zone (for 2005, 2008, and 2011). These data were obtained from the National Department of Statistics (Departamento Administrativo Nacional de Estadística, DANE) and the Planning Secretariat of the Capital District (Secretaría Distrital de Planeación).

Data on new area built every year comes from the national Census of Buildings conducted every three months by the DANE for the major metropolitan areas in Colombia. Regarding the building permit data, one shortcoming is that it may incorporate speculative behaviors by developers which may or may not translate into actual building activity. Permits lag construction activity by one to three years, but in some cases the permit can lag five or more years. The longer lags became particularly pronounced when Bogotá approved a land management policy to curb land speculation. The policy allows the municipality to identify priority development parcels, which requires that land owners develop the parcels within a two to three year time frame. Land owners (erroneously) believe that by having a building permit their land would be exempted from being considered a priority development parcel. The land use change outcome focuses on the area (in square meters) that changed its land use (say from commercial to residential); it does not include changes in zoning for uses that have not materialized. For example, an undeveloped lot zoned for residential that is rezoned as commercial but that remains undeveloped would not be counted in the land use change data.

3.2.2. Quito

Three city zones covering nine stations were included. The first zone is in the Corredor Norte, comprising three stations: Terminal de la Ofelia, La Delicia stop, and Cotocollao stop. These stations were inaugurated in 2005. The second zone contains only Quitumbe Terminal, part of the extension of the Trolebus BRT corridor. This terminal first opened in 2008, and received additional BRT service (from other southern BRT corridors) in 2010 and 2012. The third zone, served by the Ecovia BRT, covers Avenida 6 de Diciembre, from Av. Rio Coca south. It contains the Ecovia North Terminal known as “Rio Coca”, and the Jipijapa, 24 de Mayo, Naciones Unidas, and Eloy Alfaro BRT stops. Service along this corridor was inaugurated in 2004 and 2005. Of the stops and terminals included, Eloy Alfaro stop and Quitumbe Terminal were included in an earlier study (Rodriguez and Vergel, 2013), where Quitumbe was described as a terminal located far from activity nodes, containing single-family, affordable housing, with vacant land, and with land uses that are not supportive of BRT. From hereon we refer collectively to the stations based on the corridors to which they belong: Corredor Norte, Trolebus, and Ecovia. Relative to a larger sample of stops and terminals in Quito, the stops/ terminals studied are more likely to be located further away from the center of town, have high population density, less green space, higher average blocks size, and more land use mixing (Table 2). As controls we sought station areas that had similar regional accessibility and were proximate to the intervention areas. Since the BRT network of Quito already has completed its current expansion plans after including the South-west and South-east corridors, we chose a matching approach based on stations instead of corridors. This approach also means that we excluded feeder routes to focus solely on the BRT stop and terminal areas. Selected controls were double-checked with a local land market expert to ensure adequacy. Controls included the area of Av. Diego Vasquez de Cepeda, north of Terminal La Ofelia (control for Corredor Norte zone), Avenida Maldonaldo at Condor Nan (control for Trolebus zone), and Avenida 6 de Diciembre north of Av. Río Coca (control for Ecovia zone). Study and control zones for the two cities are shown in Fig. 2 (right panel). Of note, in 2005 the Av. Diego Vasquez de Cepeda (control for Corredor Norte zone) had BRT trunk service for 10 months (July 2006–May 2007), but lackluster demand led to service cancellation and a removal of the stations.

For intervention and control areas in Quito we examined three outcomes separately for single-family homes (attached or detached), offices, and condominiums (heretofore referred as apartments): (a) the number of new housing units offered per area of each zone by year (2002–2011); (b) the new area built, in square meters per area of each zone by year (2002–2011); and (c) the average offering price ($/m2) of new units in the market per year

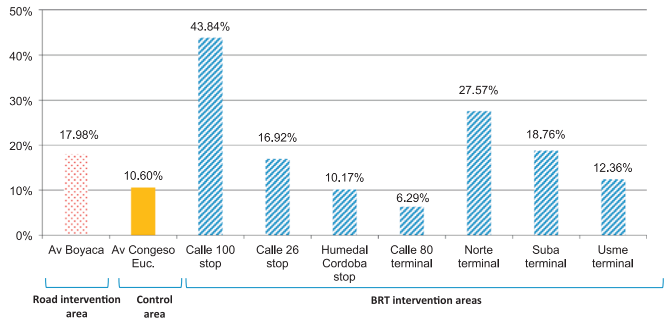

Fig. 3. Square meters built from 2001 to 2010 as percentage of zonal area, selected areas in Bogotá.

(2002–2011). Dollar figures were adjusted for inflation using the consumer price index of Ecuador. The timing of the opening of stations is such that the longitudinal data collected allow for a before and after analysis in all cases, although for the Trolebus zone the after period only contains three years. All outcome data were purchased from Inteligentarium, a local firm that collects information of all new projects that contain more than three units (development projects with three of fewer units are excluded from the data). The data were aggregated to homogenous zones created by Gridcon Cia Ltda. For prices, overall averages were weighted by the area of each project.

3.3. *Statistical analyses*

In the two cities, it is clear that the intervention and control zones are of different physical areas—some are larger or smaller than others (Fig. 2). This explains why, when examining all land market outcomes except for average prices, outcome values are normalized (divided) by the area of each zone. Since in both cities the data represent a census of the given populations around the stations, we limit our use of statistical analyses to examine trends over time with ordinary linear regression in Stata 11 (College Station, TX).

4. Results

4.1. *Bogotá*

4.1.1. *Area built*

Fig. 3 shows the total increase in built area between 2001 and 2010 for the control zone, each of the terminals and stops, and the road intervention area examined. Zonal areas vary widely: the Av Boyacá control zone contains 3300 ha and the Av Congreso Eucaristico control zone 2200 ha. Terminals studied have a total of 3400 ha and the stops 7200 ha, of which the Suba Terminal has 751 ha and the Humedal Cordoba stop has 273 ha. The Av Boyacá road intervention zone increased its stock of built space by 5.9 million m^2 or almost 18% of its zonal area, while the Av. Congreso Eucaristico increased its stock by 2.4 million m^2 or 10.6% of its zonal area. Of the intervention stops and terminals, some have high activity and others less so. When normalized by zonal area, locations with smaller areas (e.g., Calle 26 or Calle 100) had higher ratios than locations with larger areas (e.g., Calle 80 Terminal). This is partly explained by land use regulations. The “Calle 26” stop is close to the traditional city center, an area where high density development is allowed. The “Calle 100” stop has commercial and office land uses in an area defined as a health services node facing Autopista Norte. Both BRT stops experienced these developments only several years after the introduction of the first phase of the BRT system (not shown).

Among terminals, Norte Terminal had the highest activity followed by Suba Terminal, relative to control zones. The Norte Terminal includes land developments from areas in close proximity where redevelopment processes have increased densities significantly in recent years. Usme had less concentration of building activity, partly due to constraints related to land management around the BRT Terminal (Pinilla, 2013), but also due to the presence of affordable housing in the west and southwest parts of the city. The Calle 80 BRT Terminal had the least concentration, especially due the presence of already-developed compact neighborhoods.

The addition of built area over time in Bogotá is shown in Fig. 4 (left panel). It shows a distinct pattern that favors building activity in areas that received or will receive the BRT investment and the road investment. Although slopes are increasing, the time trend for the BRT and road intervention zones have slopes that are higher than the slope of the time trend for the control zone ($p=0.015$).

Table 3 provides additional detail by displaying the data from 2001 to 2005 and 2006 to 2010. This is useful to understand the impact of the Suba Terminal and Humedal de Cordoba stop, both of which were inaugurated in 2005 and are lumped in the intervention group of Fig. 4. The Suba Terminal increased its building activity by almost 60% relative to the before period, while the increase for the Humedal Cordoba stop was 35%. The increase in Humedal Cordoba is consistent with a small area plan led by private developers to build middle- to high-income multifamily high-rises. The other TransMilenio stop examined had even larger increases in building activity (161%) while other terminals saw their building activity decrease by 37%. By contrast, the road intervention zone (Av. Boyacá) saw an increase of 114% while the control zone (Av. Congreso Eucaristico) saw a decrease of 22%.

4.1.2. *Building permits issued*

Fig. 5 shows the total change in building permits between 2001 and 2010 for control zones and each of the terminals and stops examined. Consistent with the previous results for building activity, the Calle 100 stop had a high density of building permits (1.9 permits/ha), while Humedal Cordoba and the road intervention area had the lowest (0.75 and 0.74 permits/ha, respectively). However, permits around terminals tell a different story. Among the terminals with high densities of permits, Usme and Suba Terminals had the highest activity (2.29 and 2.12 permits/ha, respectively), while the Norte Terminal had the lowest density of permits among terminals studied (0.80 permits/ha). Permits issued in the Av. Congreso Eucaristico control zone were 1.04 per ha of zonal area.

The change in building permit density over time is shown in Fig. 4 (right panel) for all intervention and control zones. As with built area, it shows a distinct pattern that favors permitting activity in areas that received or will receive the BRT investment relative to the control zone, and in this case, also relative to the road intervention area. The trend for the BRT intervention zones has a slope that is higher than the slope of the time trend for the control zones or the road intervention zone ($p<0.00$). When considering the data from 2001 to 2005 and 2006 to 2010 (Table 4), permit density for the Suba Terminal increased by 24% relative to the before period. The Humedal Cordoba stop increased its permitting activity by 16.4%. The other TransMilenio stops and terminals had even larger increases in permitting activity, while the control zones increased permit density by 24%, led by Av. Congreso Eucaristico seeing an increase of 28% and Av. Boyacá an increase of 10%.

4.1.3. *Changes in land use*

Examination of changes in land use (Table 4) shows that most

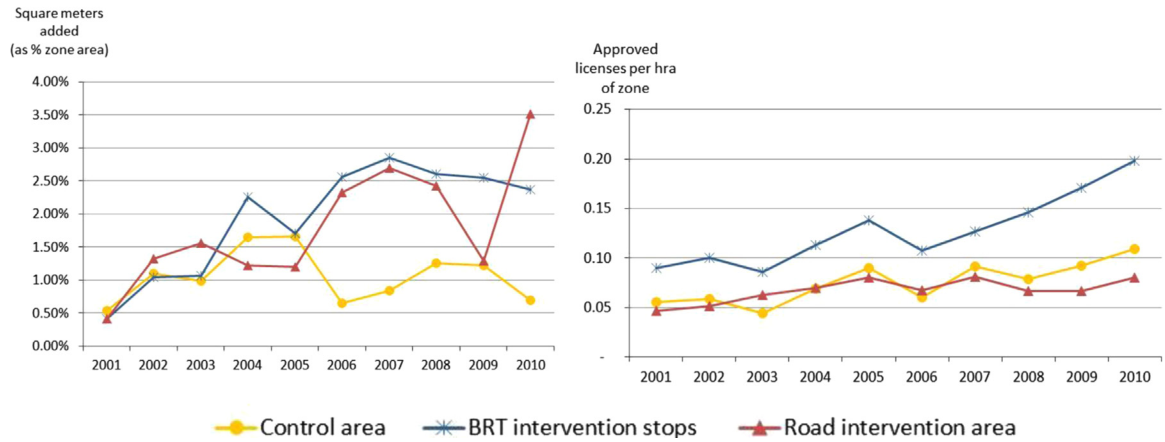

Fig. 4. Square meters built as percentage of zonal area and building licenses approved per hectare of zonal area, 2001–2010.

Table 3
Square meters built and licenses approved for intervention and control zones, before and after intervention.

	Square meters (% of area)			Permits issued (per ha)		
	2001–2005 (%)	2006–2010 (%)	% Change	2001–2005	2006–2010	% change
Suba terminal	7.31	11.45	56.54	0.65	0.81	24.63
Humedal cordoba stop	4.31	5.86	35.81	0.20	0.24	16.41
All other terminals	5.90	3.75	−36.46	0.58	0.89	53.88
All other stops	7.87	20.57	161.46	0.25	0.39	57.27
Boyacá road intervention zone	5.72	12.26	114.15	0.31	0.34	10.04
Av. Congreso Euc. control zone	5.94	4.66	−21.54	0.32	0.41	28.46

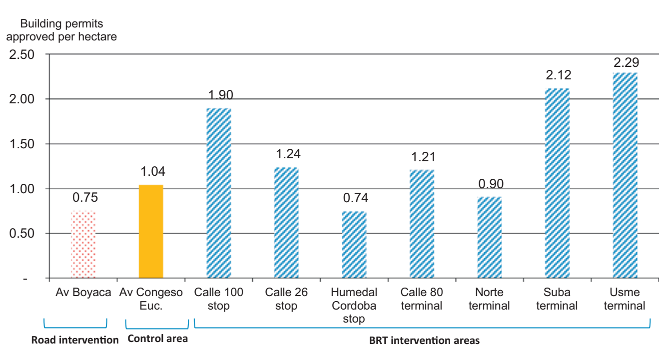

Fig. 5. Total building permits approved per hectare of zonal area 2001–2010, Bogotá.

changes resulted in additional residential and commercial uses, and that these tended to occur in the BRT intervention zones. The changes are most pronounced for the two zones for which before and after data are available: Humedal Cordoba stop gained commercial uses and gained but then lost some residential uses, while Suba Terminal gained commercial and residential uses and lost some public spaces. Both had high levels of changes in land uses ("Total change" Row in Table 4) relative to control stops and other terminals. Land use changes in the control zone and in the road intervention zone tended to be smaller. The gains in commercial and residential uses came from losses in institutional, industrial, and public spaces. Variations in industrial land use show why the entire Av. Boyacá zone is unique as a road intervention area. The zone gained industrial space while most other zones lost or had the same area devoted to industrial uses over time.

4.2. Quito

The three outcomes (housing units, area built, and price per square meter) are presented next for apartments, houses, and offices, 2002–2011. As with Bogotá, there is considerable variation in the area of zones, with areas ranging from 57 ha for the control zone of Trole to 490 ha for the control zone of Ecovía.

Table 3 shows the average yearly figures for the before and after periods for intervention and control zones. For apartments, Ecovía and Corredor Norte added more units per year in the after period than the control zones. Even though Trole more than doubled the number of units per year in the after period relative to the before period, its control zone had even higher growth. The differences are similar for yearly area built per ha, with Ecovía and Corredor Norte exhibiting higher growth than the control zones. In terms of prices, appreciation was lowest for Ecovía and highest for

Table 4
Square meters of change in land use per hectare of zonal area, 2005–2008 and 2008–2011[a,b,c].

	Humedal Cordoba		**Suba terminal**		**Other terminals**		**Other stops**		**Road intervention zone**		**Control Zone**	
	2005–2008	2008–2011	2005–2008	2008–2011	2005–2008	2008–2011	2005–2008	2008–2011	2005–2008	2008–2011	2005–2008	2008–2011
Commercial	0.73	4.70	0.80	2.49	0.33	2.33	−6.07	−2.55	0.20	1.37	−0.20	0.23
Institutional**	−5.81	0	−0.22	0	−0.73	0	−0.96	0	−0.18	0.00	−0.04	0.00
Public spaces***	0	0.09	0.04	−2.25	2.55	0.26	0	0	0.21	0.12	1.12	0.22
Industrial	0	0	0.08	0	−0.95	0	−0.95	0	−0.46	0.83	−0.34	0.03
Residential	12.59	−4.57	3.96	6.39	0.25	4.81	1.59	−16.85	0.61	−0.03	−2.45	0.55
Total change(| |)	19.13	9.35	5.11	11.13	4.81	7.40	9.58	19.40	1.66	2.34	4.15	1.04

[a] Numbers do not add up to zero because some land use categories were omitted.
[b] Includes public and private, as well as recreational areas.
[c] Includes public lands, roads, and public space.

Table 5
Yearly units, area built, and prices of houses and apartments for intervention and control zones, Quito 2002–2011.

	Yearly units (per ha)			Yearly area built (m^2 per ha)			Yearly price/total built m^2 (2012 $)		
	Before	After	Change	Before	After	Change	Before	After	Change
SINGLE FAMILY									
Ecovia[a]	0	0	–	0	0	–	0	0	–
Control	132.3	109.7	−17.1%	39.2	35.7	−8.7%	749.6	759.13	1.3%
Trole[b]	149.2	305.8	105.0%	33.3	93.2	179.9%	445.5	604.3	35.7%
Control	3.3	–	−100.0%	4.0	–	−100.0%	507.7	–	−100.0%
Corredor Norte[a]	12.3	1,338.3	10,825.2%	10.1	45.6	350.1%	696.4	798.8	14.7%
Control	298.8	297.3	−0.5%	88.9	91.2	2.6%	718.7	752.8	4.8%
APARTMENT/CONDOMINIUM									
Ecovia[a]	2.5	4.7	84.1%	234.6	420.1	79.1%	1137.9	1237.3	8.7%
Control	0.7	1.2	76.3%	54.5	69.1	26.6%	750.9	836.7	11.4%
Trole[b]	0.3	0.80	178.8%	19.6	58.9	200.7%	474.1	613.3	29.4%
Control	0.3	1.0	208.1%	19.4	61.8	219.0%	750.5	924.3	23.2%
Corredor Norte[a]	1.2	1.7	41.4%	104.1	152.4	46.4%	748.4	860.8	15.0%
Control	0.6	0.5	−4.9%	55.3	59.8	8.1%	678.3	756.7	11.6%
OFFICE									
Ecovia[a]	0.3	1.6	454.4%	27.8	134.5	383.5%	3.6	18.8	421.4%
Control	0	0	–	0	0	–	0	0	–
Corredor Norte[a]	0.04	0.03	−33.3%	1.9	1.2	−33.3%	0.1	0.1	−39.2%
Control	0	0	–	0	0	–	0	0	–

[a] The before period is 2002–2005 and the after period is 2006–2011.
[b] The before period is 2002–2007, and the after period 2008–2011.

Trole and the Corredor Norte.

Trends for single family homes mirror trends for apartments except that Ecovía did not have any activity (Table 5). This is not surprising given the consolidated nature of the development along this corridor. However, the Trole zone exhibited important growth in single family housing. Even more remarkable is the dramatic expansion in the number of housing units per ha in the Corredor Norte relative to the control zone. These same growth trends are supported by the yearly area built for each zone. In terms of single family home prices, the Trole zone had the highest appreciation followed by the Corredor Norte zone.

Examination of the same outcomes for offices suggests a different pattern. All new office space activity was concentrated in the Ecovía corridor and Corredor Norte. None of the controls or of the Trole zones had any new office activity and activity decreased in Corredor Norte. Office prices per total built square meters, and the yearly units per hectare increased by more than fourfold over the study period.

The change in new square meters per ha and in price time is shown in Fig. 6 for Corredor Norte. This figure visually confirms the trend shown in Table 5, with prices of the intervention and control zones tracking closely but with an offset ($p < 0.00$). From 2006 on, the trends begin to diverge although this difference is not statistically significant. With the exception of 2009, a more pronounced difference between the Corredor Norte zone and its control is shown when considering m^2 per ha offered. Such difference began to increase even before the BRT investments were made in 2005. Similar trends exist for Ecovia and Trole (not shown) although differences with the control zone are not as pronounced.

5. Discussion

This paper fills a gap regarding the understanding of development impacts of bus rapid transit by examining three land development outcomes before and after the implementation of BRT investments in a sample of stations in Bogota and Quito. Although only one outcome was common across the two cities (change in built area), all the outcomes examined are good (but imperfect) indicators of land development activity in each of the study and control areas. Our findings suggest that, in both Bogotá and Quito, the majority (but not all) of the intervention areas for which before and after data were available outperformed their respective control areas for all outcomes examined. Relative to a major arterial expansion area, the BRT intervention areas had similar building activity (in terms of m^2 built) but had a higher density of changes in land use and a higher density of building licenses issued. Overall, our results indicate that BRT has the potential to influence land development, but conditions are very context dependent.

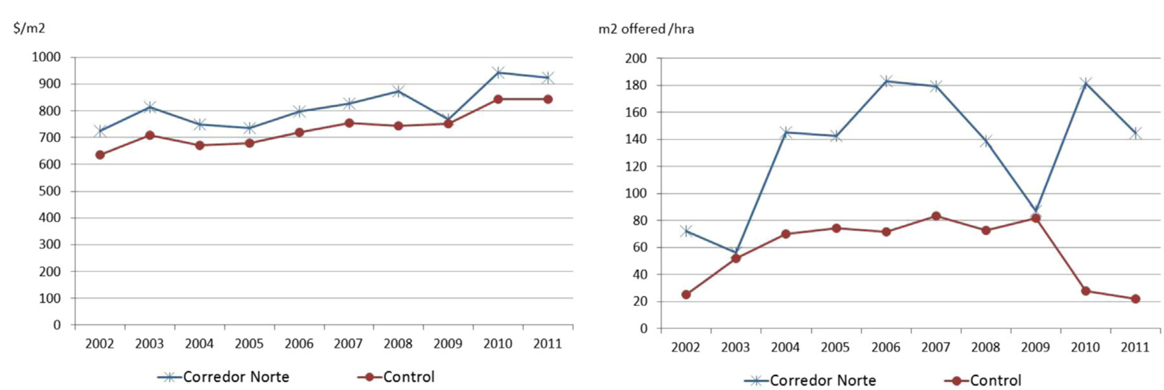

Fig. 6. Yearly square meters offered per hectare of zonal area and price per square meters, 2002–2011, Quito.

Drilling down to the specific outcomes and cities, we find that the outcomes studied for Bogotá tell different but related stories. The two types of BRT intervention areas exhibited different effects. The first type of intervention area contained stations built early in 2000 and 2001 and for which we only had data for the period after their inauguration. These stations routinely outperformed control areas in terms of new area built and permits issued, although we cannot ascertain whether this effect is the result of other characteristics and trends specific to these intervention areas. The strongest effects of building activity and building permit data emerges for terminals and stops that were built in the early 2000s, as opposed to the most recent Suba Terminal and Humedal Cordoba stop. The findings confirm the importance of having an ample time lag to detect land development impacts. Even the decade that was examined in this study might be too limited to fully capture more long-term development effects of mass transit investments.

The second type of intervention area in Bogotá contained stations for which before and after data were available. These stations had high growth in the floor area built and significant land use changes, but not as many building licenses issued as other areas. Specifically, the land use change data shows convincing impacts of TransMilenio on land uses relative to the control areas. Land uses rearrange with BRT investments. Residential and commercial uses increased, whereas open space significantly decreased. The type of development that took place around these stations explains why there were fewer licenses. Developments in these locations tended to be larger and hence a single license may cover significant new area.

Part of the inconsistent results for Bogotá have to do with the effects of the Av. Boyacá road intervention area. This corridor almost doubled in length in the late 1990s. As a result, the corridor exhibited significant building activity (but, as the before and after stations, fewer licenses). The road extension made developable land accessible by car and transit. This opened significant land areas for development, attracting important construction activity. In this sense, the Av. Congreso Eucarístico is the better control zone as it has remained stable and without major extensions or infrastructure investments. Although the type of development differs, the increase of development at Av. Boyaca shows developers' appetite for accessible areas, regardless of whether the access benefits originate in transit or road improvements.

For all Quito intervention and control areas we had before and after data. Results show heterogeneous impacts that are heavily depend on real estate submarkets. For example, the Ecovía zone is located in what planners in Quito call the "hipercentro" –an extension of the historic center that now houses important financial and related economic activities. The development emphasis there has been on offices and apartment buildings, and most development activity has involved redevelopment from single family homes to these higher and more intense uses. The other two intervention (Trole and Corredor Norte) and their control areas had very limited or no office activity. Ecovia routinely outperformed its control area except for price per m^2, which increased at a slightly lower rate than its control area. By most measures, development effects of Corredor Norte zone relative to the control zone are the strongest and most consistent of the three intervention zones in Quito, even if the control corridor briefly had BRT service. The presence of temporary BRT service in the control corridor suggests that the difference detected here may be smaller than they should be. The results depict increasing real estate activity reflected in increases in price, built area, and supply of housing units.

Single family homes in the Trole zone around Quitumbe increased in number, overall area built, and price. These findings should be interpreted in the context of the development of the zone over time. That zone was the focus of important affordable housing developments before Trole investments were made. The arrival of Trole has made the Quitumbe terminal area more desirable. Prices have increased accordingly, with the unintended effect that it is no longer viable to build affordable housing in the area.

We emphasize that our results are suggestive, but not conclusive, given the design used. Any changes in development policies and real estate submarkets impacting intervention or control areas differently may likely influence the results. Although use of statistical methods to control for these changes would be desirable, we have too few observations in each city (seven station areas, one control corridor, and one corridor with road extensions) to be able to do this effectively. Similarly, it is possible that our estimates are biased if builders may anticipate the development by increasing their building activity before the opening of the BRT. In a market with high uncertainty of whether public actions will be implemented and when they will happen (like Bogota or Quito), the anticipation effect is likely to be dulled. Also of concern is that the stations selected may not represent what happened in other stations in each city, and that our outcomes missed some important development behaviors, such as renovations and refurbishments that may not require a building permit or additional area built. Further research may better examine these impacts at the parcel level, where development decisions occur, and over longer periods of time.

There are very few studies against which the current study can be compared. The only one study in Bogotá that has examined some common outcomes, changes in population density over time around TransMilenio stations were evident (Bocarejo et al., 2012). The same authors concluded that built areas for commercial, office, or residential uses did not change with investments in TransMilenio. By contrast, for Bogotá the current study examines changes in built area, permitting, and land use. There are also important differences as the current study extends until 2010 and uses control areas that are more closely matched to the intervention areas.

Examining the experience of Bogotá and Ahmedabad, Cervero and Dai (2014) discuss the missed opportunity and disappointing results of the BRT in articulating a growth strategy for the city. However, they also express optimism at the potential for BRT to induce development that is compact, walkable, and transit supportive. Our findings provide a complementary, more nuanced, station-based depiction of the development impacts of BRT in Bogotá and Quito. Certainly, in some stations we detected significant changes, most of which were largely the responsibility of the private sector.

In terms of prices, other studies previously reviewed have focused on price changes, with ambiguous results that also seem depend on the study area. Our Quito case was the only one to include property prices as outcomes. Before and after comparisons between intervention and control areas shows that for apartment buildings prices increases 3% for Corredor Norte, 5% for Trole, and decreased 2.5% for Ecovía. For single family houses, prices in Corredor Norte increased 9.4%. This is in line with the price estimates reviewed before, but we warn that our price changes also reflect changes in the qualities of properties being offered in the market. Other price changes (for other corridors and development types) could not be computed because either the control or intervention area had no activity in one or both of the periods.

Finally, we consider our results relative to how these stations ranked in an analysis of their transit-orientation (Rodriguez and Vergel, 2013). Interestingly, the most active zones in terms of land development emerging from the current analysis in both Quito and Bogotá (Suba Terminal, Calle 100, Ecovia zone, Corredor Norte zone) were not identified as being strongly oriented towards transit. They failed in their pedestrian supports and the connectivity of the transit stop or terminal with the built environment around it. This paradox highlights a potential failure of planners to channel developer interest in these areas towards transit oriented development. That planners and policymakers have played reactive role in encouraging development along the BRT represents a failure of system to catalyze developer interest into outcomes that were more congruent with the needs of the BRT system. By contrast, of the stations included in this study, stations from Bogotá (Calle 80 Terminal, Suba Terminal, and Norte Terminal) and Quito (Ecovia zone) were classified as having the most promise in terms of their BRT orientation but they were not leaders in land development activity. Clearly, developer interest, development activity, and availability of land are important conditions for transit oriented development, but by no means sufficient.

6. Conclusions

This examined the land development impacts of BRT investments in Bogotá and Quito using a quasi-experimental research design. The results suggest heterogeneous impacts of BRT on development, heavily dependent on local context. In most, but not all cases, areas served by BRT had more land development activity than control areas. Market factors such as prices and land availability figure prominently in the results of real estate market activity. For example, land supply seems to play an important role for Suba Terminal and Corredor Norte, in Bogotá. In other cases it was land scarcity and high prices that propelled denser redevelopment, renewal, and regeneration (Ecovia, Calle 100). Still, development activity remained limited in some stations that have continued to have relatively low prices (Usme) and established development (Calle 80 Terminal). Our evidence also provided a more nuanced description of development trends in the two cities. For example, Bogotá's move towards larger developments was identified in the data. Redevelopment activities in Quito were also corroborated with the data.

The question of whether BRT stimulates land development was answered with a resounding, it depends. Further research should examine why such a heterogeneous landscape of development activity around BRT was identified. It is likely that in some instances developer appetite, market conditions, land availability, and land regulations were such that significant development took place. In other instances development was more limited.

For planners and decision-makers, the findings provide several lessons. First, is the importance of working with developers in creating built environments that support and are supported by the BRT. Unfortunately, a gap appears to remain between the transit orientation of a zone and market activity and developer interest. It is here where planners can take initiative to champion their vision of transit oriented development and work with developers to realize mutually beneficial conditions. Second, the findings also underscore the importance of understanding the land market in order to identify possible areas of intervention. A piecemeal approach to TOD, embedded in a regional strategy, is likely to be more successful than an ambitious all-at-once TOD strategy. Not all stations are early for TOD at once. Early wins that take advantage of developer interest and market conditions are more likely to yield successful outcomes for the region.

Third, the results highlight the difficulty of providing affordable housing in the context of mass transit investments. If land continues to capitalize the accessibility benefits of BRT, and planners make little provision for affordable housing (or for public spaces and other common pool resources), most land will go to the highest and best use. But, are those uses really best? When such uses are provided at the expense of lower income groups being marginalized and isolated, they may not be the best use for society. This further supports the recurrent view that a more holistic attempt at urban revitalization and regeneration is required; one that involves moving away from the atomistic development process that yields little benefit to the city, to one in which developers, land owners, and society gain.

Acknowledgments

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