BRT TOD:
Leveraging Transit Oriented Development with Bus Rapid Transit Investments

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Abstract

Bus Rapid Transit (BRT) systems have gained popularity worldwide as cost-effective investments however some observers question their city-shaping abilities, in part due to a belief it delivers fewer regional accessibility benefits but also to the social stigma some assign to bus-based forms of mass mobility. This paper reviews the challenges of leveraging transit-oriented development (TOD) through BRT investments. Experiences in Seoul show high-capacity BRT systems can induce land-use intensification, however this is not automatic. Pro-active planning is essential as well. In two other cases reviewed, the absence of significant land-use changes near BRT stops in Bogotá and Ahmedabad was due not only to little strategic station-area planning but also factors like siting lines and stations in stagnant urban districts and busy roadway medians. The failure to leverage BRT TOD also reflects a fundamental tension between the role of stations as logistical versus place-making roles. This tension is discussed for a proposed BRT investment in Montevideo. Given that the majority of future urban growth worldwide will be in intermediate-size cities well-suited for BRT investments, the opportunities for making these not only mobility investments but city-shaping investments as well should not be squandered. The paper concludes that BRT TOD holds considerable promise toward placing cities of the Global South more sustainable mobility and urbanization pathways.

1. Introduction

Bus Rapid Transit (BRT) systems have gained popularity worldwide as a cost-effective alternative to pricier urban rail investments. However some question the city-shaping potential of BRT, in part due to a belief it delivers fewer regional accessibility benefits than rail but also to the social stigma some assign to bus-based forms of mass mobility. Notwithstanding the successes of cities like Curitiba and Ottawa at integrating BRT and land development (Cervero, 1998), considerable doubt remains in the minds of some as to whether BRT can induce less car-dependent, more sustainable patterns of urban growth in rapidly motorizing and suburbanizing cities. This paper probes the opportunities and challenges of leveraging transit-oriented development (TOD) through investments in BRT systems. While BRT is often conceived as being better suited to lower density, more outlying settings, it is believed that under the right conditions, BRT can also be every bit as influential as metrorail systems in inducing urban redevelopment and shaping urban growth in more sustainable formats.

2. Policy Context for TOD

Over the next several decades, around 90 percent of the world's urban population growth will be in the Global South (UN Habitat, 2011). If developing countries continue on their trajectories of the past decade -- i.e., annual population growth rates of 2.5 percent and a decline in built-up densities of 1.5 percent a year -- the world's cumulative area of built-up, impervious surfaces will double in 17 years and triple in 27 years (Angel, 2011). The long-term ecological consequences of converting land from natural habitats and open space to urban functions—diminished water supplies, the release of more pollutants into the air, heat-island effects, and lost agricultural land—could be devastating.

The role of transit in sustainable urban development is increasingly being recognized and promoted as way to moderate climate change and increase the mobility of the poor. At the 2012 Rio+ 20 Conference, international development banks announced a "game changer" commitment to sustainable transport and pledged substantial financial support over the next decade for this purpose (World Resource Institute, 2012).

BRT will no doubt have an increasingly prominent role in this global campaign for more sustainable transport and urban forms. This is partly because the bulk of future population growth will be in intermediate size cities, the very places where BRT is often more cost-effective than its pricier alternative, metrorail transit. According to UN Habitat (2011), most of the 2 billion new urban dwellers between now and 2030 will be in cities with populations of 100,000 to 500,000. Future growth of not only population but also economic outputs is likely to occur in intermediate size cities (Glaeser and Josh-Ghani, 2012).

BRT systems are being built at a rapid-fire pace throughout the developing world, thanks to their lower investment costs in comparison to metros and other rail options and their relatively short construction periods. Currently, BRT investments are found in more than 160 cities worldwide (Figure 1) and at least as many cities are various stages of contemplating, planning, designing, or investing in new systems. Of course, BRT systems spans a broad spectrum of design and service types, from "BRT lite" with minimal features (e.g., partially dedicated lanes and wider station spacings) to high-end exclusive-lane and full-service operations that offer speed advantages similar to those of metrorail systems. While the U.S. has more BRT systems in place than any other nation, with the exception of systems like the Orange line in Los Angeles's and Eugene, Oregon's EmX system , most fall in the category of BRT lite. China, which has been adding BRT lane-kms at a faster pace than any part of the world over the past eight years (Figure 2), features services on mostly the high-end of the spectrum, such as in Guangzhou and Xiamen.

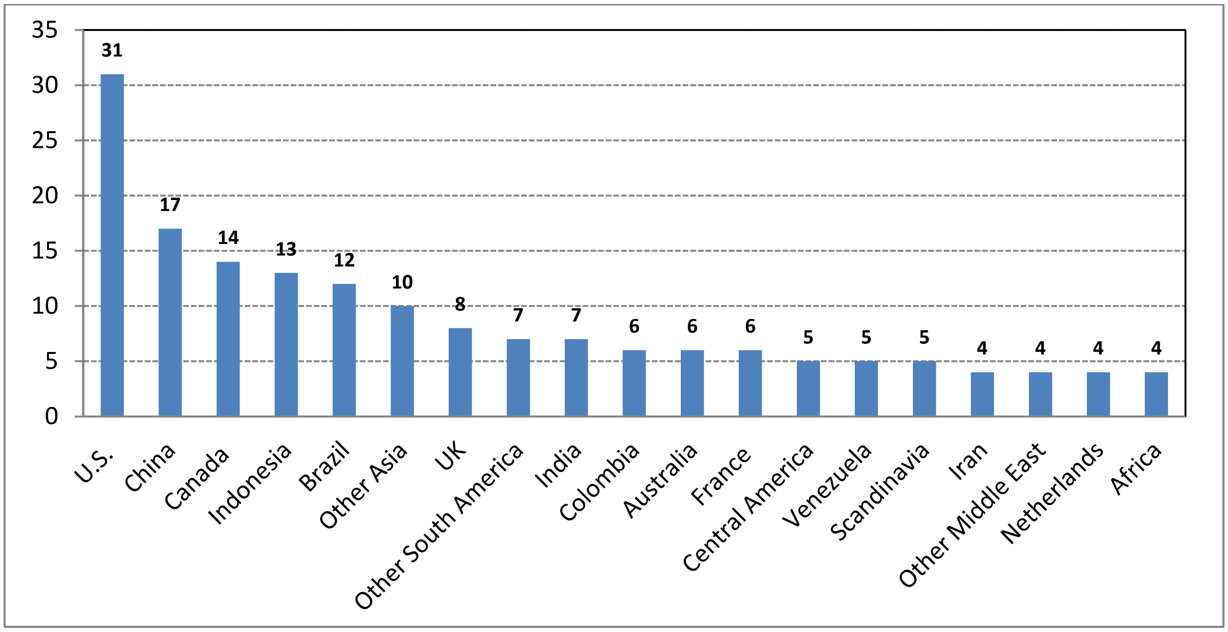


Figure 1. BRT by National and Regional Settings, 2011. Source: www.chinabrt.org and en.wikipedia.org./wiki/List_of_bus_rapid_transit_systems

Whether BRT can promote transit oriented development (TOD) —compact, mixed-use, pedestrian-friendly development organized around a transit station – on a significant scale remains an open question. TOD is widely viewed as an inherently efficient and sustainable urban form (Curtis et al., 2009). Experiences show that well-designed TOD not only increases ridership by drawing more travelers out of cars and into trains and buses, it can also serve as a hub for organizing community development and revitalizing long-distressed urban districts (Bernick and Cervero 1997; Cervero 1998).

BRT and TOD are often not mentioned in the same breadth. A 2002 survey of TOD in the U.S. found fewer than 8 percent were oriented to bus transit systems (Cervero et al., 2004). Yet buses are often the workhorses of regional transit systems, carrying a majority of public-transport passengers in all but the densest, biggest global cities. Moreover, since there is no one-size-fits-all TOD, and instead transit-oriented growth lies on a spectrum of built forms, bus-transit systems are well-positioned to occupy particular market niche of TOD types, generally with densities that are below that of metrorail systems (Calthorpe, 1993; Ditmar and Poticha, 2004; Chen, 2010).

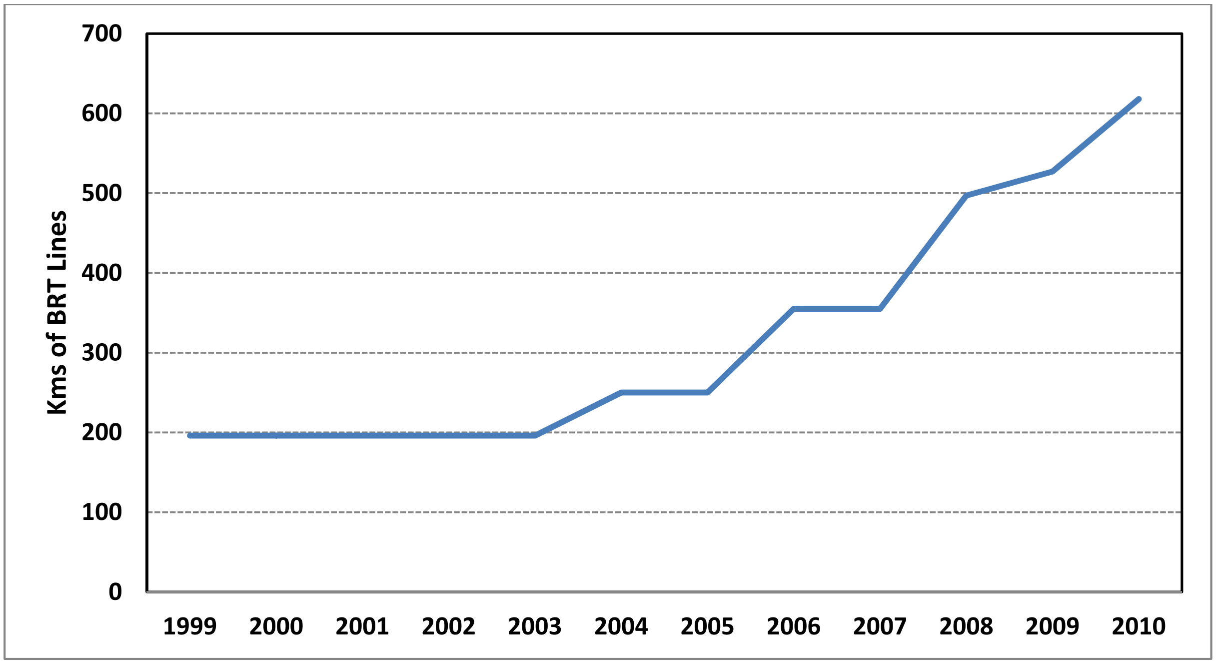


Figure 2. Growth in China's BRT Network Lengths (in Kilometers): 1999 to 2010.
Source: www.chinabrt.org

Bus-based systems are thought to have weaker city-shaping effects partly because they confer fewer regional accessibility benefits relative to faster, more geographically extensive rail operations (Vuchic, 2007). The absence of a fixed guideway or permanent infrastructure is also thought to dilute bus-transit's development potential in minds of real-estate developers, who never can be sure of the service features of future bus operations. Factors like the spewing of diesel emissions and the social stigma attached to transit-dependent (and thus often lower income) users also detract from bus-transit's image. Where bus-based systems begin to mimic the fixed-guideway, high-quality service features of rail-based systems, and shed negative social and environmental stereotypes, is where dedicated and exclusive (and sometimes fully grade-separated) lanes are provided. This is the cardinal feature of "high-end" BRT services. Dedicated-lane BRT not only holds the potential to confer regional accessibility benefits that are similar to those of metrorail systems, and thus exert comparable impacts on urban form, but also offers flexibility and versatility advantages that rail-based systems do not (Cervero, 1998; Currie, 2006). Notably, the same vehicle that provides speedy line-haul services can leave the guideway or dedicated lane, morphing into a feeder vehicle that circulates in lower density areas. Marrying the line-haul and collection-distribution portions of trips in a single vehicle makes BRT particularly well suited for smaller, lower density cities, an observation made by Meyer, Kain, and Wohl (1965) nearly a half-century ago. In *The Transit Metropolis*, bus-based systems are considered more "adaptive" to cityscapes, both serving existing built forms and shaping future ones (Cervero, 1998).

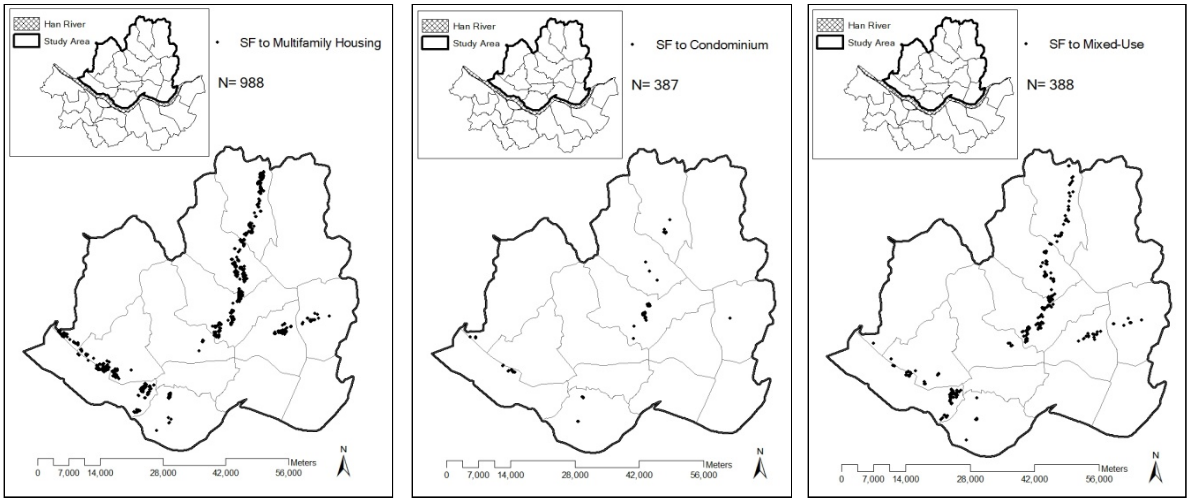
Empirical evidence on BRT's city-shaping impacts is limited. Levinson et al. (2002) reported significant development activities around BRT stops in Pittsburgh, Ottawa, and Adelaide, however the absence of control or comparison sites confounded the ability to associate this growth to the presence of improved transit services. Land-price capitalization benefits of BRT investments have also be reported in Brisbane (Levinson et al., 2002), Los Angeles (Cervero, 2004), Pittsburgh (Perk and Catala, 2009), Bogotá (Rodriquez and Targa, 2004; Rodriquez and Mojica, 2008; Munoz-Raskin, 2010), and Seoul (Cervero and Kang, 2011). In Los Angeles, land value impacts were very small and accrued only for commercial parcels (Cervero, 2004). In contrast, studies of the more substantial BRT system in Bogotá, Colombia have found appreciable land-value benefits (Rodriquez and Targa, 2004; Rodriquez and Mojica, 2008; Munoz-Raskin, 2010). There, multi-family housing units close to Bogotá's TransMilenio BRT rented for more per square meter than units located farther away (Rodriguez and Targa, 2004). There is also some evidence that creating pedestrian-friendly environments near BRT bus stops can further increase land-value benefits (Estupinan and Rodriguez, 2008).

3. Land Intensification Along Seoul's BRT Corridors

Rising land prices should put market pressures on intensifying urban activities however this has not always occurred, in part because of a failure of local governments to upzone affected districts or other counter-veiling factors, such as the routing of BRT lines in economically stagnant districts (where right-of-way might be relatively cheap but land development opportunities are limited). As discussed later, this appears to have been the case in Bogotá, Colombia. Seoul, South Korea, has had the opposite experience. In the case of Seoul, which in 2004 opened seven new lines of exclusive median-lane buses (stretching 84 kilometers, later expanded to 162 kilometers) and 294 kilometers of dedicated curbside bus lanes, the metropolitan government pro-actively encouraged intensification through regulatory and zoning reforms as well as neighborhood betterment strategies (such as streetscape enhancements). Seoul's land markets capitalized accessibility benefits conferred by BRT, particularly for parcels used for condominiums and higher-density residential uses. Land price premiums of 5 to10 percent within several years of BRT enhancements have been recorded for residences within 300 meters of BRT stops (Cervero and Kang 2011). For retail shops and other nonresidential uses, premiums have been more varied, ranging from 3 percent to 26 percent over a smaller impact zone of 150 meters from the nearest BRT stop.

The land use statuses of more than 52,000 single-family residential parcels were tracked for the 2001 to 2007 period, which spans the period when exclusive median-lane BRT services were introduced. More than 96 percent of parcels remained in single-family use over this six-year period. Among the remaining parcels, the dominant conversion was to multi-family housing followed by mixed land uses and condominiums. Figure 3 shows the locations of converted parcels, all aligned fairly close to BRT stops.

Multilevel binary logit models were estimated to predict three types of conversions from single-family residences: to multi-family residential rental units, to condominium owner-occupied units, and to mixed-parcels which typically involved a combination of commercial activities (e.g., retail, services, offices) and sometimes residential as well. All of these changes correspond to what might be considered an intensification of activities on parcels, from single-family residences to often higher density activities (i.e., more units in the form of multi-family housing and condominiums; adding of retail activities). To the property owner, intensification normally translates into higher valued properties and in some cases increases rental income.



Multi-family Conversions **Condominium Conversions** **Mixed Use Conversions**

Figure 3. Location of Converted Single-Family Residential Parcels in Seoul, South Korea

In the models, single-family housing was the reference group, assigned a value of 0 while land use changes to more intensive uses between 2001 and 2007 were coded as 1. Multilevel models accounted for the fact that parcels from the same neighborhood share common attributes like local road-network designs and demographic characteristics. Failure to account for shared upper-level (i.e., neighborhood) attributes of lower-level (i.e., parcel) observations can bias parameter estimates. Estimated multilevel models incorporated both fixed and random effects. Fixed effects represented variable coefficients that were constant across upper-level (i.e., neighborhoods) units while random effects indicated error-terms that vary across upper level units.

Table 1 presents the multilevel model results for the most dominant conversion – single-family to multi-family residential – and Table 2 shows the output for the two other land-use changes studied: single-family to condominiums and to mixed uses. Each data observation represents a land parcel, with a dependent variable value of 0 denoting no land use change and 1 representing a more intensive land-use conversion. Slightly better model fits were obtained when expressing ratio-scale explanatory variables in natural logarithmic form, thus these model results are presented.

For all single-family parcels in the sample frame, Tables 1 and 2 reveal that parcels within ½ kilometer of a BRT stop (generally associated with a walk of under 5 minutes) were more likely to convert to more intensive uses relative to parcels beyond ½ kilometer. Impacts across 100 meter distance bands were hardly simple, as plotted in Figure 4. Notably, the higher-end conversions – to condominiums and mixed-use buildings – were actually less likely to occur within the immediate vicinity of a BRT stop (i.e., < 100m). This could be due to the nuisance effect of being located near busy BRT and roadway corridors (e.g., people walking to and congregating around bus stops; noise impacts). Multi-family conversions, however, seemed immune to this nuisance effects. Beyond a buffer distance of 100 meters to a stop, single-family conversions were more likely to occur. At around 400 meters, the influences of distance to a BRT stop on land-use conversions largely evaporated.

Table 1. Multilevel Logit Model for Predicting
Single Family Housing to Multi-Family Conversions

(Note: 0 = no change in single-family unit; 1 = conversion from single- to multi-family housing)

	SF to Multi Family Housing		
Variables	Coefficient	t	p
Fixed Effects			
Distance to Bus Stops			
dummy (1, if Distance ≤ 100m, otherwise 0)	1.253	2.320	0.020
dummy (1, if 100 < Distance ≤ 200m, otherwise 0)	1.657	3.150	0.002
dummy (1, if 200 < Distance ≤ 300m, otherwise 0)	1.699	3.290	0.001
dummy (1, if 300 < Distance ≤ 400m, otherwise 0)	1.999	3.920	0.000
dummy (1, if 400 < Distance ≤ 500m, otherwise 0)	−0.120	−0.190	0.851
Other Location Factors			
ln(Network Distance to CGC Corridor)	0.078	0.130	0.898
ln(Distance to CBD: City Hall)	0.900	1.300	0.194
ln(Distance to Nearest Subway Stations)	0.032	0.350	0.726
ln(Distance to Arterial Roads)	−0.130	−3.450	0.001
Neighborhood Economic and Demographic Attributes			
ln(CPI-adjusted Land Value)	−1.462	−9.950	0.000
ln(Population Density)	0.607	2.410	0.016
ln(Employment Density)	−0.661	−0.380	0.703
ln(Proportion of College Degree)	1.233	2.500	0.012
ln(Proportion of 40 to 60 years old)	0.766	0.490	0.622
ln(Proportion of more than 60 years old)	0.352	0.220	0.823
Other Neighborhood Attributes			
ln(Park Density Ratio)	−0.349	−1.220	0.223
ln(Developed Land Ratio)	1.778	1.240	0.214
ln(Road Area Ratio)	−0.897	−0.290	0.774
ln(Retail Area Ratio)	−0.233	−1.210	0.226
ln(Proportion of Residential Permit per Total Permit)	0.241	0.780	0.438
ln(Proportion of Commercial Permit per Total Permit)	1.010	1.260	0.207
ln(CPI-adjusted Local Tax per Households)	0.859	0.790	0.428
ln(Job Accessibility within 30 minutes by Car)	−0.395	−0.630	0.526
Constant	1.846	0.110	0.910
Random Effects			
Standard Deviation of the Random Intercept	0.718		
ICC	0.136		
Summary Statistics			
Number of Parcel Observations (Level 1)	25,410		
Number of Neighborhood Groups (Level 2)	72		

(Note: 0 = no change in single-family unit; 1 = conversion from single- to multi-family housing)

Table 2. Multilevel Logit Model for Predicting
Single Family Housing to Condominium or Mixed-Use Conversions

(Note: 0 = no change in single-family unit; 1 = conversion from single-family housing to condominium or mixed-use development)

	SF to Condominium			SF to Mixed-use		
Variables	Coefficient	t	p	Coefficient	t	p
Fixed Effects						
Network Distance to Bus Stops						
dummy (1, if Network Distance ≤ 100m, otherwise 0)	−28.826	0.000	1.000	−1.185	−2.890	0.004
dummy (1, if 100 < Network Distance ≤ 200m, otherwise 0)	0.173	0.310	0.754	0.024	0.110	0.913
dummy (1, if 200 < Network Distance ≤ 300m, otherwise 0)	1.023	2.370	0.018	0.431	2.170	0.030
dummy (1, if 300 < Network Distance ≤ 400m, otherwise 0)	0.565	1.450	0.147	0.541	2.740	0.006
dummy (1, if 400 < Network Distance ≤ 500m, otherwise 0)	0.342	0.900	0.367	−0.087	−0.390	0.698
Other Location Factors						
ln(Network Distance to CGC Corridor)	7.127	2.290	0.022	0.959	1.270	0.204
ln(Distance to CBD: City Hall)	−22.832	−4.940	0.000	−1.310	−1.770	0.077
ln(Distance to Nearest Subway Stations)	0.805	2.340	0.019	0.462	3.720	0.000
ln(Distance to Arterial Roads)	1.112	6.060	0.000	−0.262	−4.830	0.000
ln(Distance to Bus Stops)	1.271	4.070	0.000			
Neighborhood Economic and Demographic Attributes						
ln(CPI-adjusted Land Value)	2.310	6.540	0.000	0.609	4.040	0.000
ln(Building Coverage Ratio)				−0.297	−0.430	0.665
ln(Floor Area Ratio)				0.411	2.600	0.009
ln(Population Density)	−7.614	−3.230	0.001	0.053	0.170	0.867
ln(Employment Density)	−46.629	−0.030	0.976	3.495	1.280	0.199
ln(Proportion of College Degree)	12.475	2.140	0.032	0.602	0.930	0.353
ln(Proportion of 40 to 60 years old)	−22.523	−1.500	0.134	−0.826	−0.390	0.697
ln(Proportion of more than 60 years old)	−46.801	−2.260	0.024	−5.827	−2.840	0.005
Other Neighborhood Attributes						
ln(Park Density Ratio)	−0.351	0.000	0.999	0.080	0.230	0.816
ln(Developed Land Ratio)	−106.385	−0.030	0.976	−0.172	−0.100	0.922
ln(Road Area Ratio)	95.790	0.030	0.979	−3.801	−0.850	0.393
ln(Retail Area Ratio)	2.598	0.010	0.990	0.505	1.440	0.149
ln(Proportion of Residential Permit per Total Permit)	13.544	0.040	0.968	0.723	1.460	0.144
ln(Proportion of Commercial Permit per Total Permit)	−20.038	−0.020	0.984	−0.721	−0.850	0.396
ln(CPI-adjusted Local Tax per Households)	22.288	0.010	0.991	−2.054	−1.340	0.179
ln(Job Accessibility within 30 minutes by Car)						
Constant	277.969	0.020	0.983	−28.466	−1.610	0.108
Random Effects						
Standard Deviation of the Random Intercept	4.886			1.002		
ICC	0.879			0.234		
Summary Statistics						
Number of Parcel Observations (Level 1)	2,387			24,810		
Number of Neighborhood Groups (Level 2)	65			72		

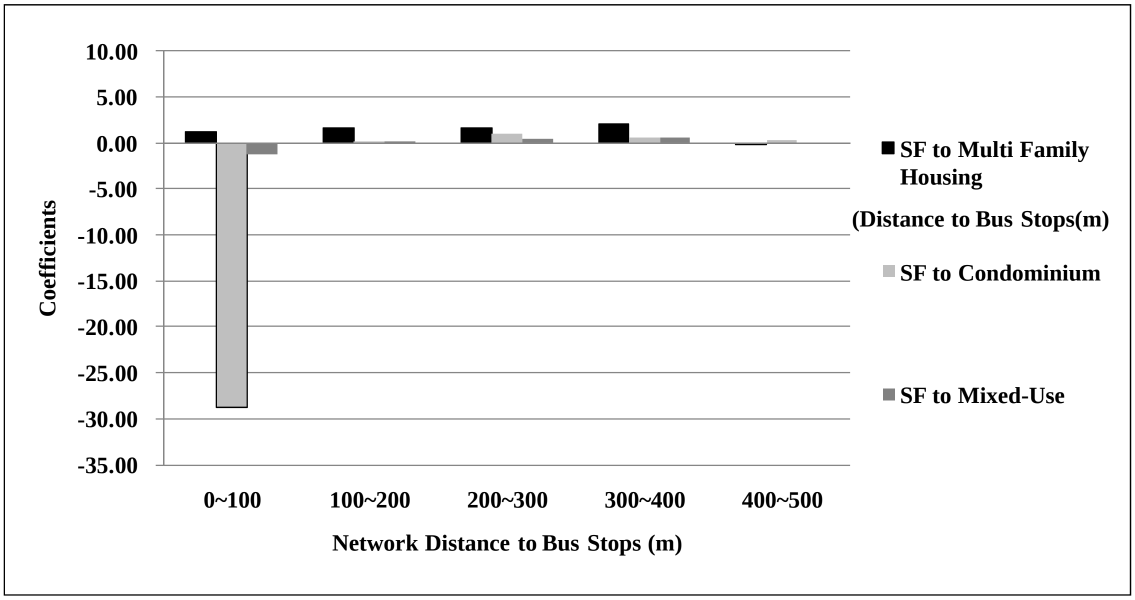


Figure 4. Coefficients of Each Land Use Change by Distance Intervals to Seoul BRT

Among other variables in the models, higher assessed land values of a neighborhood significantly increased the odds of converting single-family residences to the higher end uses. Property owners seemed particularly inclined to convert residences to condominiums, the most popular high-rise housing in Korea, in settings with relatively high average land values as well as college-educated residents. Less appealing in higher valued core areas of the city were conversions to multi-family housing. Table 1 also shows that higher permissible floor area ratios of a neighborhood contributed to mixed-use conversions. It should be noted that besides BRT, Seoul officials introduced other improvements, like timed-transfer service reforms and a sophisticated smart fare card systems, that also likely contributed to land intensification on BRT corridors.

4. BRT and Urbanism in Curitiba

Land intensification along BRT corridors have similarly occurred in cities like Curitiba and Ottawa where local governments proactively leveraged TOD through zoning reforms, pro-development tax policies, assistance with land assemblage, and supportive infrastructure investments (Cervero, 1998). In the case of Curitiba's celebrated BRT investments, local government mandated that all medium- and large-scale urban development be sited along a BRT corridor. Orchestrating regional growth has been the Institute for Research and Urban Planning (IPPUC), an independent entity charged with ensuring integration of all elements of urban growth.

A design element used to enhance transit accessibility in Curitiba was the "trinary"—three parallel roadways with compatible land uses and building heights that taper with distance from the BRT corridor. The first two floors of the busway. which do not count against permissible plot ratios (building height/land area), are slated for retail uses. Above the second floor, buildings must be set back at least five meters from the property line, to allow sun to cast on the transitway. The inclusion of upper-level housing entitles property owners to density bonuses, which has led to vertical mixing of uses within buildings. An important benefit of mixed land uses and transit service levels along these corridors, in addition to extraordinarily high ridership rates, has been balanced bidirectional flows, ensuring efficient use of bus capacity. The higher densities produced by the trinary design have translated directly into higher ridership. Concentrated commercial development has also channeled trips from residences beyond BRT terminuses to the trinary corridors. In 2009, for example, 78.4 per cent of trips boarding at the terminus of Curitiba's north-south trinary corridor were destined to a bus stop on the same corridor (Duarte and Ultramari 2012). Figure 5 shows daily ridership at stops along Curitiba's north-south BRT line superimposed on the corridor's skyline. Where densities rise, so generally does ridership. Curitiba today averages considerably more transit trips per capita than Rio de Janeiro and São Paulo, which are much bigger cities. Its share of motorized trips by transit (45 percent) is the highest in Latin America (Santos, 2011). High transit use has appreciably shrunk the city's environmental footprint. Curitiba's annual congestion cost per capita of $0.67 (in US$2008) is a fraction of São Paulo's (Suzuki et al., 2011). The city also boasts the cleanest air of any Brazilian city with more than 1 million in habitants, despite having a sizable industrial sector. The strong, workable nexus that exists between Curitiba's bus-based transit system and its mixed-use linear settlement pattern deserves most of the credit.

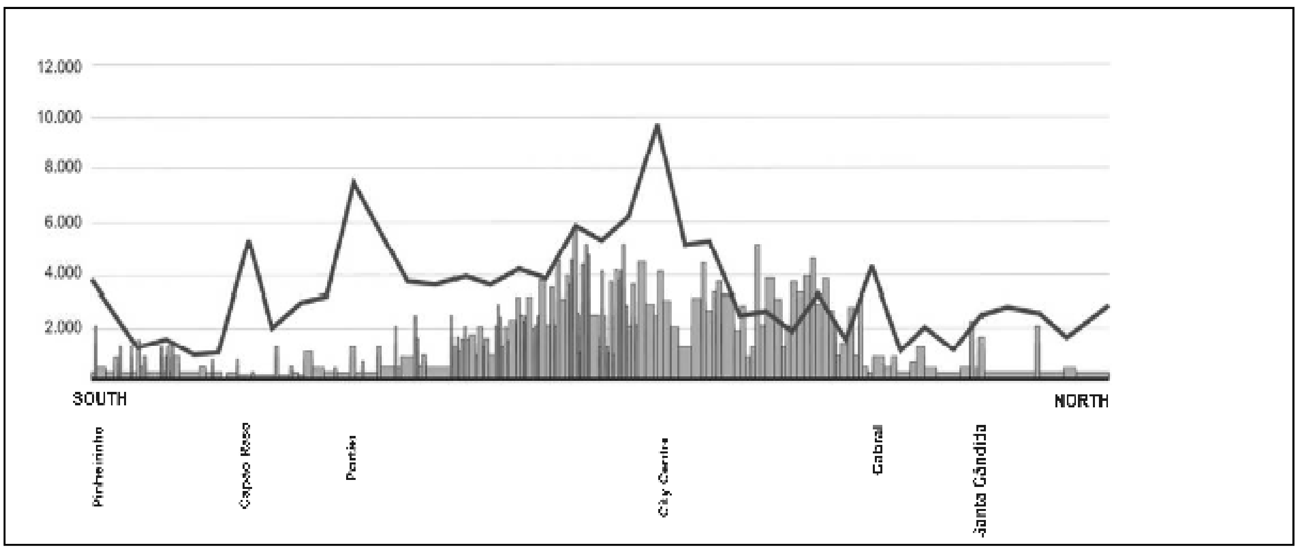


Figure 5. Correspondence Between Daily Transit Boardings (vertical axis) and Skyline Profile Along Curitiba's North-South Trinary Axis. Source: Duarte and Ultramari, 2012

Sustained political commitment has been pivotal to Curitiba's success. The harmonization of transit and land use took place over 40 years of political continuity, marked by a progression of forward-looking, like-minded mayors who built on the work of their predecessors. A cogent long-term vision and the presence of a politically insulated regional planning organization, the IPUCC, to implement the vision have been crucial in allowing the city to chart a sustainable urban pathway.

The Green Line is the city's first new BRT corridor in years, an 18- kilometer corridor that was converted from a federal highway. Like Bogotá's celebrated BRT, the Green Line has passing lanes, which greatly increase capacity by supporting express services. As important is an evolved view of BRT corridors as rights-of-way that also accommodate linear parks and bike paths. A recent law promotes the preservation of green space along BRT corridors by giving developers increased building rights in exchange for purchasing or preserving land along the corridor as parks. Formerly a national highway dotted with truck stops and lumberyards, this hodgepodge of industrial uses is slated to become a pedestrian-friendly mixed-use corridor that can accommodate up to half a million new residents.

One type of land-use activity where Curitiba's BRT investment has fallen short is the provision of housing for the poor. Most social housing built in the last 40 years for Curitiba's poor was sited far from main transit axes and transport corridors (Duarte and Ultramari, 2012). The availability of cheaper land and laxer environmental regulations on floodplain development prompted Curitiba's authorities to put the most disadvantaged households in the least transit-accessible locations. As noted later, this is one area where Curitiba planners can learn from the experiences of Bogotá, under its Metrovivienda program.

5. Challenges of BRT and Land-Use Integration in the Developing World

Cities like Seoul and Curitiba are more the exception than the rule. Despite some evidence of land value capitalization, BRT has failed to fundamentally reshape the city and intensify land development in most instance. This has partly been because they were viewed as mobility rather than city-shaping investments. Moreover, engineering, cost-minimization perspectives generally won out over urban-planning, development-maximization perspectives. In the drive to economize on investment costs, there has been a tendency to follow the path of least resistance. This has often meant siting BRT lines and stations in the medians of busy roadways, often with poor pedestrian access, because of relatively cheap available rights-of-way and the avoidance of building demolitions and relocation costs. Thus near-term cost-minimization principles were applied at the expense of suppressing longer term land development opportunities. Costs have also been minimized by routing corridors in economically depressed and marginalized urban districts where land is not only cheap but the risks of a Not-In-My-Backyard (NIMBY) backlash were minimal. There is, of course, nothing inherently wrong with siting transit lines in least-cost corridors however when it comes to the access points of these lines, namely stations, then officials must be prepared to off-line some stations, and incur higher upfront investment costs, in order to site stations on land parcels that are most likely to support TOD.

Next, two cases are presented where relatively little land development has occurred along BRT corridors: Bogotá, Colombia and Ahmedabad, India. In both cases, this was due principally to the siting and design of stations to minimize construction costs, with relatively little though given to leveraging land development. More myopic perspectives might have allowed BRT systems to be built quickly (for political gain) and cheaply but this has generally been at the expense of suppressing land development opportunities.

5.1 Challenges of TOD in Bogotá, Colombia

Bogotá, the capital of Colombia and home to 7.6 million inhabitants, has gained a reputation as one of the world's most progressive cities, underscored by the 2000 opening of what has been called the gold standard of BRT, the 84-km TransMilenio system. Delegations of officials and dignitaries from around the world visit Bogotá to marvel at its technological advancements. While its carrying capacity of some 45,000 passengers per direction per hour is said to match that of many metro systems, unlike Curitiba and Seoul, reshaping urban form and land-use patterns has not been a primary focus.

Bogotá's planners designed a trunk-feeder system, marked by segregated, exclusive-lane bus operations on several major arterial roads and feeder buses operating on regular roads that tie into end-of-the-line stations. The system was built over three phases (Figure 6). Phase one opened 42 km of high-capacity BRT services mostly in the medians of two major arterials. Phase two, which opened in 2007, added another 42 km of mostly median-lane services, and the third phase, currently under construction, will add 28 kms, for a 112 km system at build-out. Feeder buses, which add 200 kilometer of service coverage, operate at no-charge in low-income neighborhoods on the urban periphery. Today, TransMilineo's daily ridership exceeds 1.5 million, accounting for 74 percent of total public transport trips in the city (Suzuki, Cervero, and Iuchi, 2013).

Since TransMilenio's 2000 opening, Bogotá's population has grown by 21 percent. Building densities have increased throughout the city, but mostly in areas away from TransMilenio corridors. The initial TransMilenio lines were built quickly in response to worsening traffic congestion but also to build political momentum and curry political favor for future expansions. Aligning corridors in mostly economically stagnant zones that were largely built out has suppressed land development. So has the siting BRT in busy roadway medians, which limited land supplies for leveraging TOD and resulted in mostly unattractive pedestrian environment immediate to stations. Minimal pro-active station area planning or incentives for private property-owners to redevelop parcels also tempered TOD activities.

Cadastral data obtained from the city of Bogotá for the 2004-2010 period reveals the degree to which urban growth turned its back on TransMilineo. Stations' impact zones were set at 1000 meters, corresponding to BRT's walkshed. For feeder bus lines, a 500 meter impact zone was selected. Using data on floor area ratios (FAR – i.e., building area divided by land area) for all of Bogotá's registered residential and commercial buildings, Figure 7 shows that building densities increased by 7 percent throughout the city. For TransMilineo corridors, densities increased 5 percent in Phase I and slightly more in Phase II, and by 5 percent for the Phase III corridor now being built. Less densification occurred after Phase I than for subsequent phases partly because TransMilenio's initial lines were built along corridors which were already developed. The nearby stock of mostly old, decrepit 2-3 story residential buildings were left untouched following TransMilineo's opening.

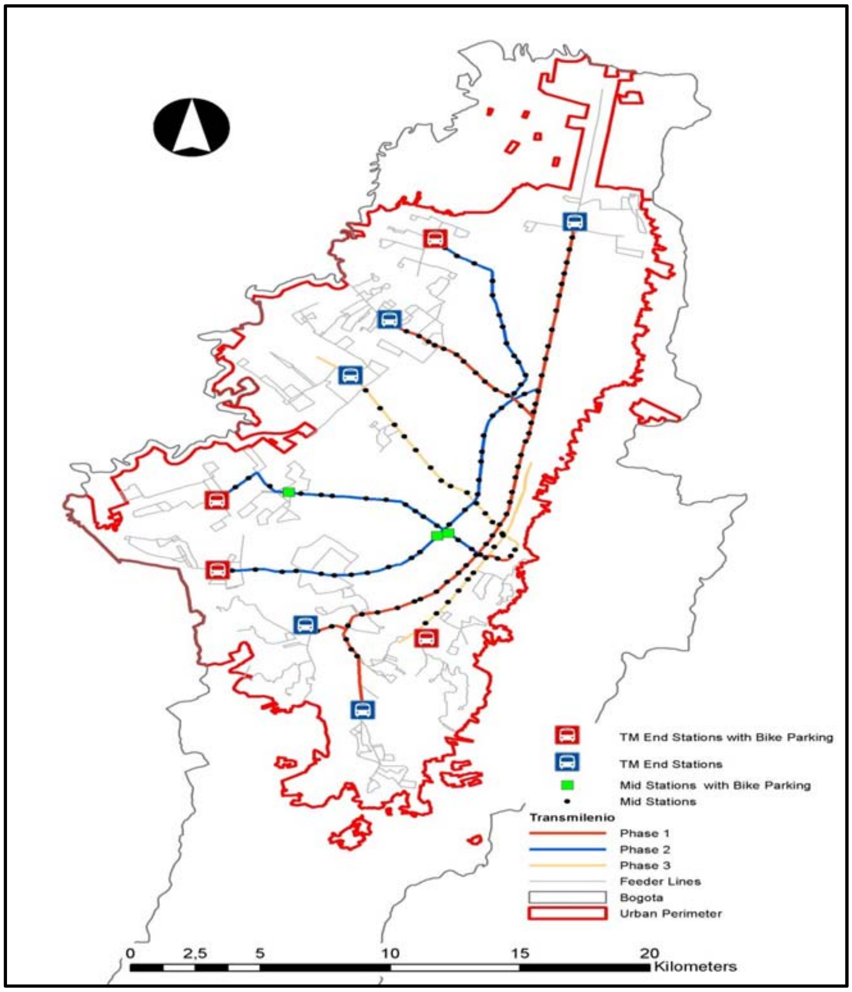


Figure 6. Bogotá's TransMilenio BRT System, Built Over Three Phases, and Connecting Feeder Lines

More building activities occurred near feeder lines, which witnessed a 7 percent increase in FARs between 2004 and 2010. The availability of comparatively low-cost vacant parcels and opportunities to convert informal housing to higher-quality formal housing accounted for higher levels of building near peripheral feeder lines. By comparison, the rest of the city, representing the non-impact-zone of BRT, saw a 10 percent increase in building densities over this period. Overall, the average building density increase was 6 percent for areas near trunk and feeder lines versus 10 percent for the rest of the city.

Figure 8 shows that in 2010, the highest building densities were mostly away from TransMilineo. The densest parts of the city were on the city's western periphery (comprised mostly of low-income housing situated beyond a walking distance of TransMilineo and its feeders) as well as along a north-south mostly commercial corridor that abuts the Andes mountains to the east, two to eight city blocks away from TransMilineo trunkline services.

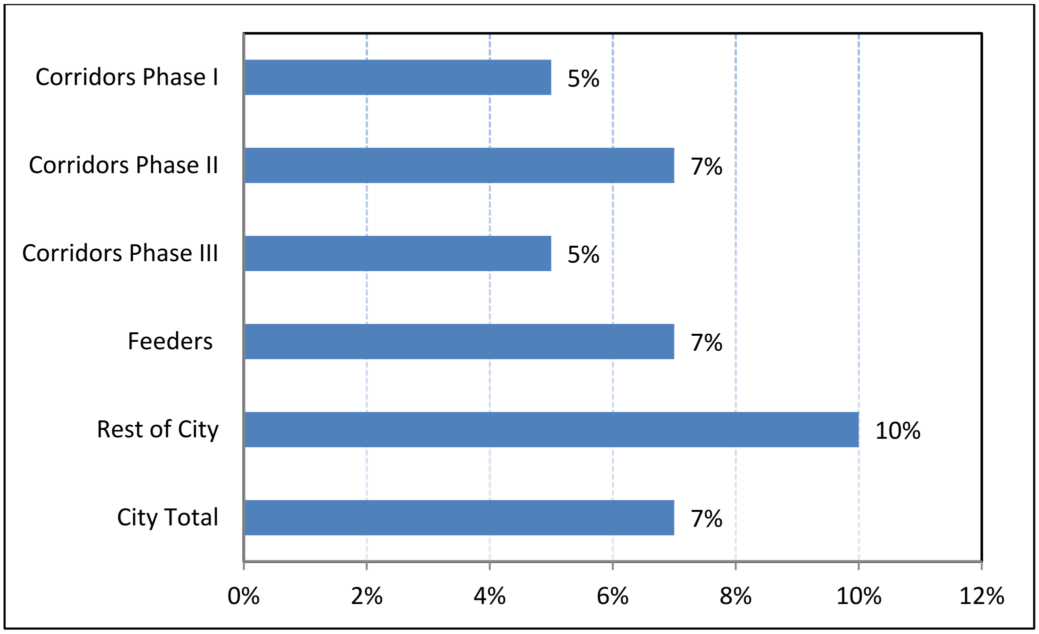


Figure 7. Percent Changes in Building Floor Area Ratios for Impact Zones of Bogotá's BRT Corridors and Feeder Lines Compared to the Rest of the City and Citywide Totals, 2004 to 2010. Source: Suzuki, Cervero, and Iuchi, 2013.

More fine-grained match-pair comparisons further reveals TransMilenio's weak land-use connection. Changes in building area footprints were examined for 1-km radii around BRT stations and control areas (non-BRT stations) that are otherwise very similar (e.g. in terms of neighborhood incomes, land uses, and sub-regional locations). Changes in building footprints between 1998 and 2011 were compared be BRT stations and control areas for four intermediate stations (i.e., stations not at the ends of lines) as well as three pairs of end-of-the-line stations. For intermediate stations, more building activity was found away from than near stations. Figure 9 shows one paired comparison for an intermediate station on a Phase II line toward the southwest of the city, near the low-income neighborhood of Kennedy. Far less new development occurred within 1000 meters of the BRT station than the control area off the line. For terminal stations, however, there tended to be relatively more new building activities than in control areas, as revealed by one of the matched-pair comparisons shown in Figure 10, for the Americas terminal station. Other researchers have similarly found more land-use densification near TransMilenio's terminal stations than control areas (Bocarejo, Portilla, and Perez, 2012). This higher degree of station-area activities was largely due to the commercial opportunities at terminals, representing busy transfer points between feeder buses and trunkline BRT services.

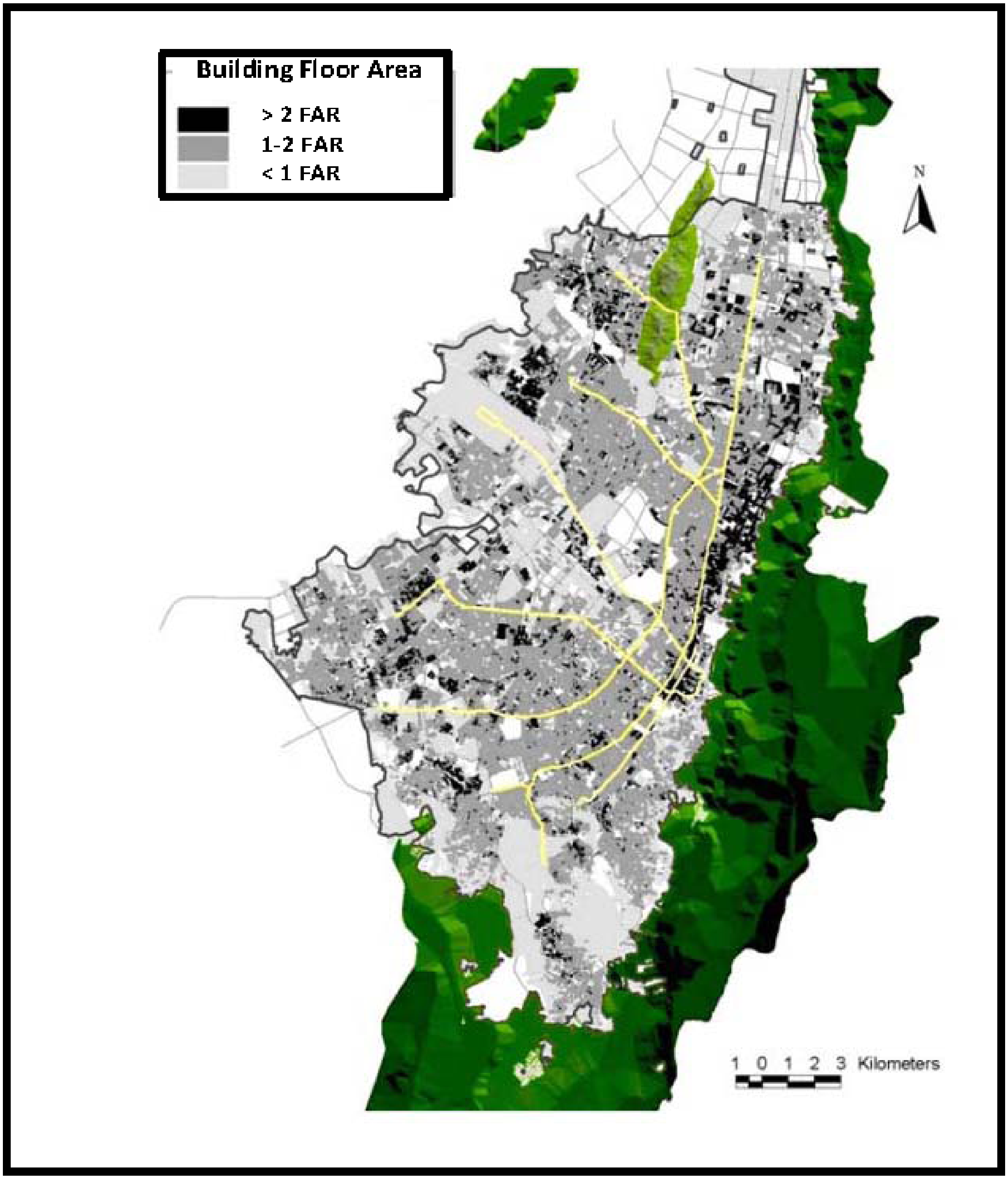


Figure 8. Bogotá's Building Floor Area Ratios with Reference to TransMilineo Trunklines (shown in yellow). Source: Suzuki, Cervero, and Iuchi, 2013.

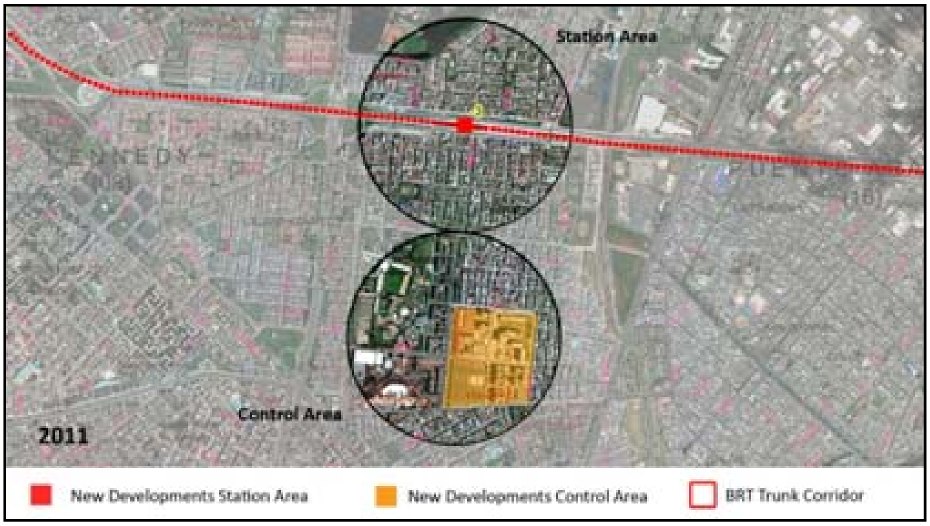


Figure 9. Footprints of new developments in Station Area and Control Area for an Intermediate Station, 1998 to 2011. Source: Suzuki, Cervero, and Iuchi, 2013.

Figure 10. Footprints of new developments in Station Area and Control Area for an End-of-the-Line Station, 1998 to 2011. Source: Suzuki, Cervero, and Iuchi, 2013.

The fact that comparatively little development has occurred around many of Bogotá's BRT stations supports findings from earlier assessments of transit investments and urban development (Knight and Trygg, 1977; Cervero and Seskin, 1995; Cervero and Landis, 1997), namely that transit cannot overcome weak local real estate markets. Station siting also matters. Placing stops in the medians of active roadways inevitably means a poor-quality pedestrian-access environment and thus little commercial development near the stations themselves. TransMilenio's design gave little weight to the pedestrian experience. The visually prominent skywalks that connect to BRT stops create lengthy, circuitous walks, can be noisy (resonating like steel drums during peak traffic conditions, by some accounts), and can be difficult for the elderly, disabled, and semi-ambulatory individuals to negotiate. Bogotá's experiences further show that planning matters. Neither the city nor neighborhood districts (where detailed land use planning is regulated and implemented) prepared station-area plans to orchestrate private development, change zoning (including increasing permissible densities), introduce complementary improvements (like streetscape enhancements) to entice private investments, or take any other pro-active steps to leverage new development.

The one area for which local leaders win kudos has been the bundling of transit investments and the provision of affordable social housing for the poor. In 1999, at the time Bogotá's successful Transmilenio BRT system was being built, an innovative land-banking/poverty-alleviation program, called Metrovivienda, was launched (Cervero, 2005a). Under Metrovivienda, transportation and housing are treated as bundled goods. The city acquires plots when they are in open agricultural uses at relatively cheap prices and proceeds to plat and title the land and provide public utilities, roads and open space. Property is sold to developers at higher prices to help cover infrastructure costs with the proviso that average prices be kept under US$8,500 per unit and are affordable to families with incomes of US$200 per month.

To date, four Metrovivienda sites have been created near one of Transmilenio's terminuses, each between 100 and 120 hectares in size and housing some 8,000 families (Figure 11). At build out, the program aims to construct 440,000 new housing units. Putting housing near stations helps the city's poor by "killing two birds with one stone" – i.e., providing improved housing and public transport services. Those moving from peripheral illegal settlements into transit-served Metrovivienda projects enjoy both "sites and serviced" housing and material improvements in access to major economic centers in the city. It is estimated that job-accessibility levels via transit within one-hour travel times increased by a factor of three for those moving from illegal housing to legal Metrovivienda projects (Cervero, 2005a).

An important aspect of the program is the acquisition of land well in advance of BRT services. Because Metrovivienda officials serve on the Board of Transmilenio, they are aware of strategic plans and timelines for extending BRT. This has enabled the organization to acquire land before prices are inflated by the arrival of Transmilenio. Acquiring land in advance has enabled Metrovivienda to keep prices affordable for households relocated from peripheral "clandestine" housing projects. Transmilenio also makes commuting more affordable. When living in the hillsides, most residents used two different public transit services (a feeder and a mainline), paying on average US$1.40 a day to leave and return home (Cervero, 2005b). With Transmilenio, feeder buses are free, resulting in an average of US$0.80 in daily travel costs.

Metrovivienda serves as a model of multi-sectoral and accessibility-based planning in a developing country. By coupling affordable housing with affordable transport, Bogotá leaders have improved access to jobs, shops, and services while reducing the joint costs of what often consumes two-thirds of the poor's income: housing and transport. Whether Metrovivienda makes a serious dent in the city's housing shortages and traffic woes remains to be seen, however most observers agree that it is a significant and positive step forward.

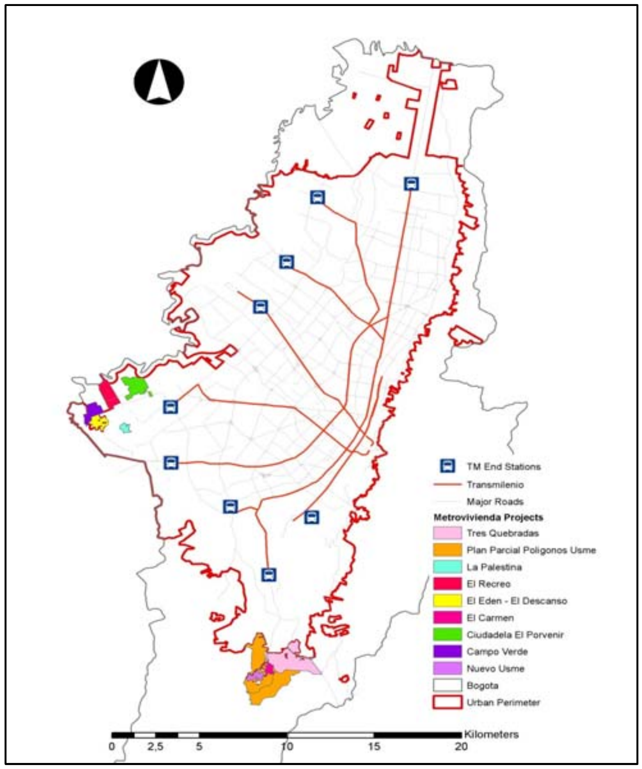


Figure 11. Bogotá's Metrovivienda Projects and TransMilenio BRT Lines. Source: Suzuki, Cervero, and Iuchi, 2013.

5.2 Challenges of TOD in Ahmedabad, India

In the 2009, Ahmedabad opened India's first and what today remains the country's largest BRT network. Called Janmarg ("People's Way), the current 45 km system was built to relieve mounting traffic congestion in India's fifth largest city. With some 5.5 million inhabitants, Ahmedabad is listed as one of the world's fastest growing cities (Forbes, 2010). The ingredients are thus there for BRT to shape future urban growth: rapid growth and motorization coupled with increasingly worsening traffic congestion that increases market demands for transit-accessible locations. To date, however, few significant changes have occurred near Janmarg stations.

As in Bogotá, Janmarg was envisaged and design as a mobility investment, not a city-shaping one. Short-term political priorities took precedence over long-term sustainability ones. Janmarg, slated to span some 220 kilometer at build-out (Figure 12), was aligned according to both cost-minimization and accessibility principles – 20 percent of Ahmedabad's population lives within one kilometer of the 45-km phase-one system and this share is expected to increase to 73 percent when the entire system is built. Janmarg lines were and are being selected to serve the city's fastest growing areas, more so than in the case of Bogotá, however little attention has been given to the physical integration of BRT stops with surrounding neighborhoods or increasing the share of future populations and workers near BRT. A fairly high-end system is being built by standards of Asian development cities – dedicated and exclusive lanes with some grade-separations and full-service bus stations – thus the city-shaping potential of Janmarg is high.

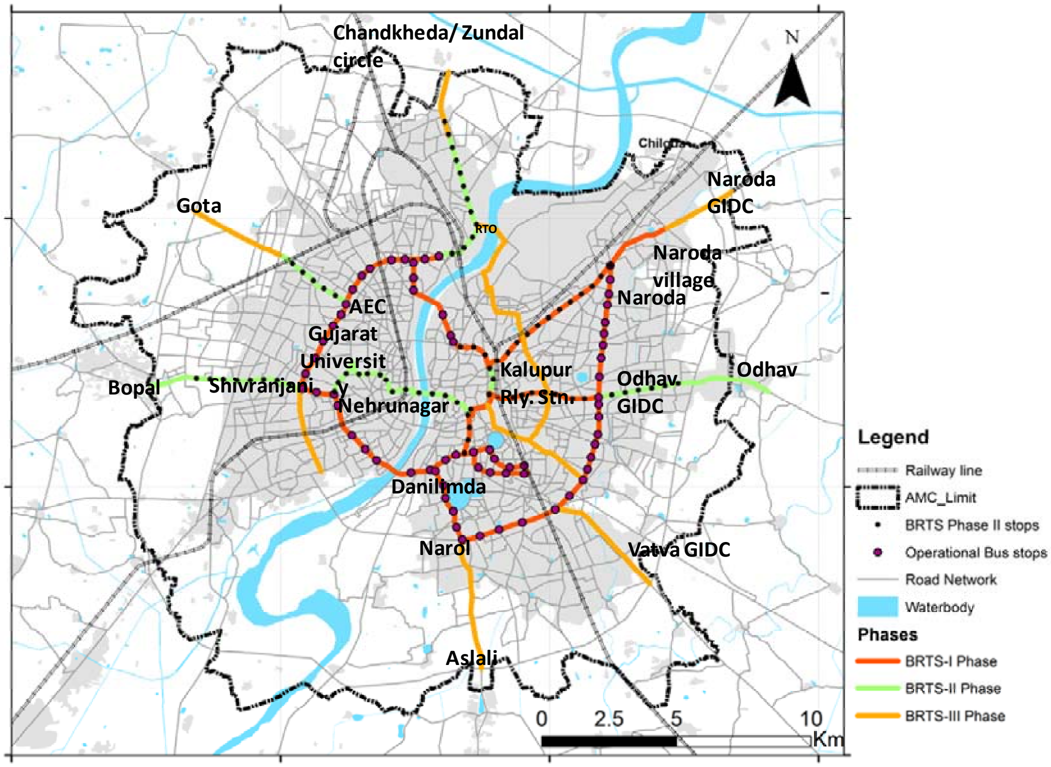


Figure 12. Ahmedabad's Janmarg BRT Sytems: Phases I (completed), II (currently under construction), and III (planned). Source: CEPT University, Ahmedabad.

To date, no land-use or TOD plans have been developed for any Janmarg stations. What land development is occurring has been left solely to private market forces. Janmarg serves mainly built-up areas of the city, where land for new development and densification is limited. Most high-end growth is now occurring in knowledge-based employment zones west of the city, featuring tall, modern buildings on superblocks with few pedestrian-ways in between and far removed from existing or planned BRT. There has been some brownfield redevelopment of former state-owned textile mills, once the economic backbone of the city, including sites near Janmarg stations. However redevelopment has been slow, mainly due to unsettled legal issues.

Notwithstanding the city's lethargic stance on TOD, land markets appear to be responding to Janmarg's presence. Prices of land near stations nearly doubled between 2006 and 2011 (Suzuki, Cervero, and Iuchi, 2013). Seeking to reap profits, individual property developers have built individual projects near some stations, however absent station-area plans, piecemeal development has failed to add up to coherent or well-integrated transit-oriented development. Interestingly, Ahmedabad is as well suited as any city in the developing world to prepare TOD plans due to its long-time use of what is called a Town Planning Scheme. This is essentially a land-readjustment program that allows local government to assemble irregular-shaped agricultural and informal plots of land and to create functional and fully serviced housing and mixed-use developments from the consolidated parcels. Since first introduced in 1915, nearly three-quarters of the city's 300 square kilometer land area has been developed under this scheme. Also conducive to TOD is Ahmedabad's ability to grant density bonuses as a means of generating revenues. In 2002, a law was passed allowing the sale of additional FAR for properties abutting streets 18 meters wide or wider, which includes all BRT corridors. The current permissible FAR of 1.8 can be increased to 2.25. In 2011, 4.5 percent of Ahmedabad's total revenues came from this "guidance value" density-bonus scheme. City officials are currently considering raising FARs for properties near a proposed metro and BRT corridors to 3.5. Recapturing the added value created by transit would all the city to generate much-needed funds to not only pay off transit capital investments but also to improve neighborhoods around stations themselves, as successfully done in Hong Kong under its Rail+Property program (Cervero and Murakami, 2009).

So far, Ahmedabad officials have opted to maintain uniform densities throughout the city, regardless of how close parcels might be to transit corridors. This has been done to disperse trips and thus decongest the city. It has also been done for socio-cultural reasons, namely to avoid creating a privileged class of land owners whose new-found wealth is create through government fiat. However keeping densities uniform also shifts growth to the periphery, in a more auto-oriented configuration. In the near term, the city may experience less traffic congestion as a result of density caps however over the long term, the resulting auto-oriented urban form that unfolds could backfire, creating more traffic congestion and air pollution for the region as a whole.

The practice of spreading growth to decongest the core had been adopted not only in Ahmedabad but virtually all large Indian cities. A sample of city centers in large Indian cities found an FAR of 1.6, lower than permissible densities in the suburbs (Bertraud, 2002; Glaeser, 2011). Like a tube of toothpaste, restricting growth in one place simply pushes new growth elsewhere, particularly from transit-served urban cores to more auto-oriented peripheral zones.

Several design shortcomings also need to be overcome if Ahmedabad is to spawn TOD. Janmarg was and is being designed as a closed system, requiring users to access stations sited in the medians of roadways by foot, bicycle, car, two-wheeler, three-wheelers, and surface-street buses. Little attention, however, has been given to perpendicular connectors to BRT stops. No secondary feeder systems were designed at the time Janmarg was built to ensure efficient and safe pedestrian, bikeway, and transit connections to mainline services. While a substantial network of cycletracks was built in conjunction Janmarg, for the most part bike-paths run parallel rather than perpendicular to the busway, thus functioning more as competitive than complementary systems. Moreover, there is no bicycle parking at stations. What few pedestrian ways exist near Janmarg stops are often occupied by motorcycles and fast-moving three-wheel vehicles.

6. Conflict of Node and Place

The absence of TODs along BRT corridors in rapidly growing parts of the world partly reflects the inherent tensions between the place-making versus logistical roles of stations (Bertolini and Spit, 1998; Dittmar and Ohland, 2004). On the one hand, stations are logistical nodes wherein cars, buses, taxis, delivery trucks, pedestrians, and cyclist converge for accessing transit and allowing inter-modal transfers. On the other hand, stations and their environs are places for creating or rebuilding community hubs. Whenever the logistical needs of a station win out, the resulting road designs and parking layouts often detract from the quality of walking, creating more of a transit-adjacent development (TAD) than a transit-oriented one (TOD). Besides being the "jumping off" point for catching a train or bus, the TOD model embraces other community purposes -- community hubs and gathering places for public events, like open-air concerts, farmers markets, public demonstrations, and civic celebrations. TODs thus serve both functionally and symbolically as the centerpieces of communities. Accordingly, TOD aims to not only increase transit ridership but also enliven community life, build social capital, and increase commerce and economic activities.

With limited institutional capacities and resources to conduct strategic planning, many cities designing and building TODs give little thought to the functional roles of specific stations. Stations planned for a more residential orientation will be best suited for place-making roles. Those with more commercial and logistical orientations are apt to be better suited for nodal and intermodal roles. Failure to define the function roles of stations and create a typology of TODs can result in some stations taking on a schizophrenic persona – trying to play both place-making and logistical roles and as a result doing neither particularly well.

The tension between place and node is today being played out along a BRT corridor now being built in Montevideo, Uruguay. Montevideo, a city of 1.35 million inhabitants (one-half of Uruguay's population, has embarked on the construction of an exclusive-lane BRT system. Local officials have opted to focus on leveraging mixed-use TOD at the northern end-station, called Colon Terminus (Figure 13), of the soon-to-open Garzon corridor. As a major intermodal transfer point, Colon Terminus's urban development potential is with large-scale commercial development, like office space or a sub-regional shopping center. As interchange points for intersecting and criss-crossing feeder buses, the terminus is less desirable as a residentially oriented node, particularly for middle-income households. A kilometer to the south likes the Colon township, which has a number of features that could work in favor of a successful, rejuvenated residential-and-transit-oriented district in Montevideo. Among these are a pedestrian-scale design that imparts old-world charm and a historical urban fabric complete with a main street, small-block grid street pattern, varied building facades and store fronts along the main street, and an attractive civic square (Figure 14). The town square was recently upgraded and from a transportation point-of-view is strategically located, nestled between a current commuter rail station and a BRT stop along the Garzon corridor that is currently under construction. The combination of these "livability" factors positions a redeveloped and rejuvenated Colon town center to play a significant place-making and community-building role. Having two high-quality services – BRT and commuter rail – near each other could also give rise to an active multi-modal environment in the town center area. The marked improvements in regional access via public transit enjoyed by the area could create market pressures to invest and redevelop the area. Such market forces could be leveraged and facilitated by pro-active planning and investments on the public sector part, such as the preparation of a Colon Town Center TOD plan. It is noted that Colon business interests had actively lobbied to site the Colon terminus in the historical town center. If this had been done, it would have seriously jeopardized the capacity of BRT to help leverage redevelopment and urban renewal in the town center. This is because the terminus functions mainly as a logistical node, not a people-oriented place. Terminuses are functionally quite "messy", the loci of interchanging feeder buses, taxis, delivery trucks, and the like. High traffic volumes combined with noise and engine fumes would detract from the place-making potential of a BRT stop in a historical center like central Colon. For this reason, it will likely end up being to old-town Colon's advantage that the terminus was located a kilometer to the north, thus buffering the town center from vehicle-interchange activities and allowing people- versus vehicle-oriented urban re-generation to potentially occur.

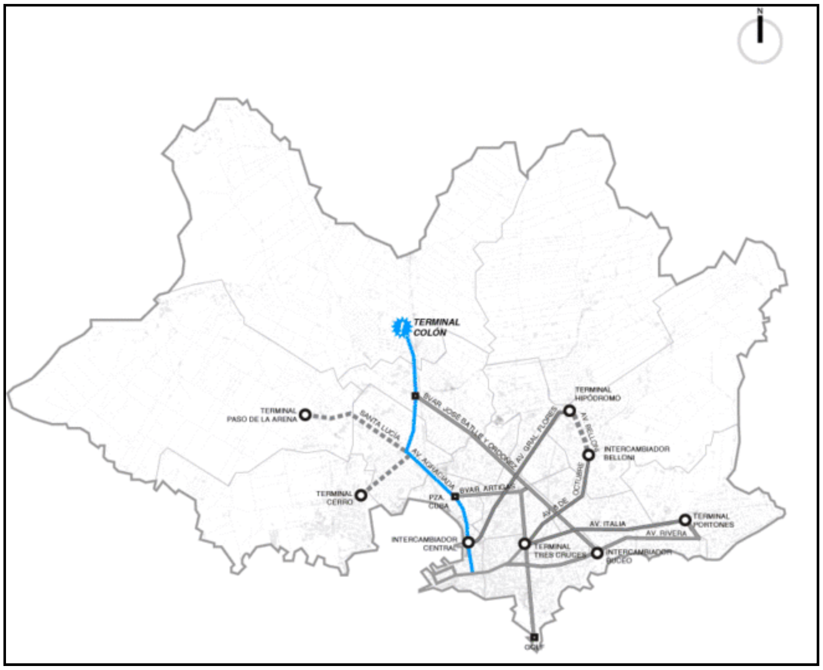


Figure 13. Montevideo's Planned BRT Network, featuring Terminal Colon as a TOD Activity Center

7. Conclusion

A fairly fundamental change in thinking about the role of large-scale infrastructure investments like BRT is needed, particularly among public officials and city leaders in the developing world. Notably, BRT should be conceived as more than a *mobility investment*. It also presents an unprecedented opportunity to restructure urban and regional growth in ways that promote the many dimensions of sustainable urban growth. BRT can also be a *city-shaping investment*, providing a backbone for guiding growth in a more compact, mixed-use urban form – one that not only promote transit riding and less driving, but also curbs costly suburban sprawl and preserving precious farmland and open space.

The cases of Bogotá and Ahmedabad reveal that in the absence of proactive planning and attempts to entice private development near stations, few land-use changes occur. In both cases, long-range strategic planning and urban development objectives have been largely usurped by near-term engineering and cost-minimization objectives, resulting in lines being routed and stations sited in areas with minimal development potential. In truth, similar stories could have told of BRT experiences in Bangkok, Jakarta, and many other rapidly growing cities facing political pressures to get systems built quickly and at an affordable cost. Moreover, experiences have not been much different in the developed world, whether for light-rail investments (Cervero, 1984) or metrorails (Cervero and Seskin, 1995).

Figure 15. Colon Town Center Area. Upper Left image: Colon Square, featuring refurbished sidewalk Upper Right iImage: Main Street; Botton Left image: Colon train station; Bottom Right image: BRT stop under construction in Colon District.

Fortunately, there are good-case examples that showcase the positive impacts of proactively leveraging development opportunities from BRT investments. Curitiba's experiences are well-known and for the most part reveal the payoffs of linking good urban planning practice with BRT investments over multiple decades. Seoul's experiences reveal that in a crowded, congested, and land-constrained city, access improvements conferred by BRT prompted property owners and developers to intensify land uses along BRT corridors, mainly by converting single-family residences to multifamily units, apartments, and mixed-use projects. However market forces were steered by pro-active planning that among other things created high-quality walking environments along BRT corridors. In addition to Seoul, a number of Chinese cities, notably Guangzhou, have designed high-quality connections to BRT stops, in contrast to cities like Ahmedabad where pedestrian access was a secondary consideration (Figure 16). Guangzhou's BRT features seamless pedestrian connections through gently sloped footbridges and same-level integration with the second floors of adjoining commercial buildings (Figure 17). A network of green connectors ensures high-quality perpendicular connections for pedestrians and cyclists reaching stations from two or more blocks away (Figure 18). Owing to the combination of high-quality BRT services and pedestrian connections to stations, high-rise commercial development is gravitating to Guangzhou's BRT corridor, increasing real estate prices by 30 percent during the first two years of BRT operations (Suzuki, Cervero, and Iuchi, 2013).

Figure 16. Contrasting approaches to pedestrian access to median-station BRT: Guangzhou (left), Seoul (middle), Ahmedabad (right). Sources: ITDP China, Cervero and Kang (2012), and author's photo.

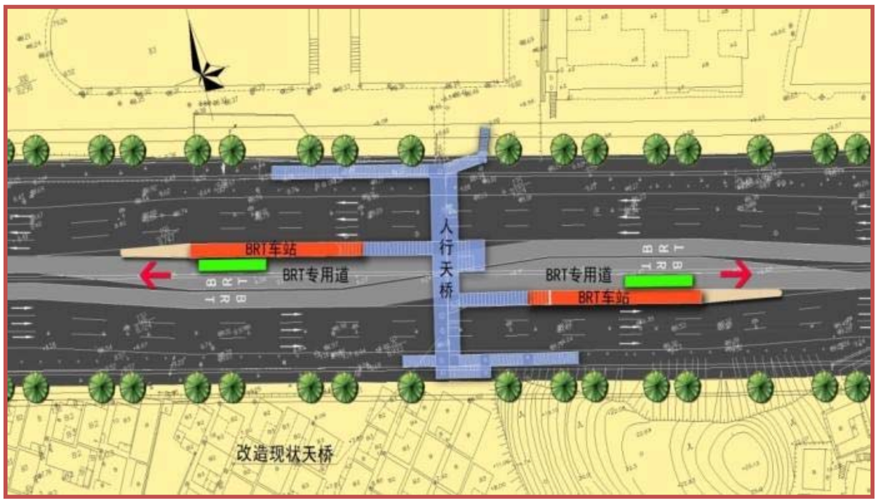


Figure 17. Planned View of Pedestrian Integration with Guangzhou's BRT stops. Source: ITDP China, 2012.

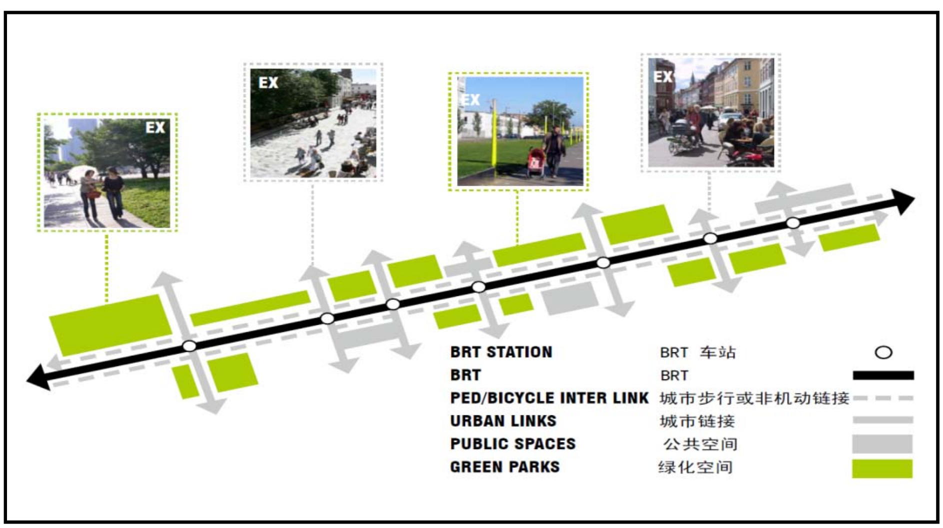


Figure 18. Green Perpendicular Connectors to Guangzhou's BRT stations. Source: ITDP China, 2012.

A number of significant barriers need to be overcome if future BRT investments are to significantly shape urban form in rapidly growing cities of the world. Among these will be the need to balance the current focus on short-term problem-solving with an ethos of forward-looking, strategic planning. The fragmented institutional structures for planning transportation systems and managing urban growth will also have to be revamped. Financial constraints also stand in the way of TOD. Moreover, plans need to extend beyond a single sector, as in the case of Bogotá's Metrovivienda scheme which ties BRT to slum clearance and the provision of affordable, sites-and-serviced housing. One way to overcome barriers and bring about change would be for international aid organizations and donor agencies to tie financial assistance for BRT projects to bona fide local efforts to improve the coordination and integration of transit and land development projects. Prodding local governments to introduce value-capture schemes would generate much-needed revenues to help jump-start TOD. As experiences in cities like Hong Kong shows, a virtuous cycle can be set into motion in which denser, high-quality TOD generates income which can go into creating future high-quality TODs, which further increases income and so on.

As urban growth shifts to cities in the developing world, unprecedented opportunities exist for linking land development and transit infrastructure. Given that the vast majority of urban growth is projected for smaller and intermediate size cities, a bus-based form of TOD interlaced with high-quality infrastructure for pedestrians and cyclists is best suited for placing many global cities on a sustainable pathway Many cities of the developing world have the prerequisites needed for BRT investments to trigger meaningful land-use changes, including rapid growth, rising real incomes, and increased motorization and congestion levels. Supportive planning and zoning, public-sector leveraging and risk-sharing, attention to facility siting and design details to maximize development potential, and the institutional capacity to manage land-use shifts are also needed.

Acknowledgement

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