Bus Rapid Transit and Urban Development in Latin America

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Latin American cities have been leaders in the implementation of bus rapid transit (BRT) systems—a transportation mode often characterized by infrastructure improvements that prioritize transit over other vehicles, provide off-vehicle fare payment, and allow quick vehicle access. More than 45 cities in Latin America have invested in BRT, accounting for 63.6 percent of BRT ridership worldwide.

In Curitiba, Brazil, BRT has been used as a tool to spur development that supports and reinforces the overall transit system. The city introduced exclusive bus lanes in 1972 and encouraged mixed-use, high-density development along the five main corridors that converge in the downtown center and have guided urban growth for decades. Curitiba's new green line is predicated on similar principles: to encourage urban development that enhances and facilitates transit use. The case of Curitiba suggests that the success of BRT can increase with the presence of concentrated land development along the transit corridor. Other studies have examined whether BRT can actually stimulate land development.

Transit-oriented development (TOD) is the term used to describe development that is compact and has a mixture of land uses, often including residential, commercial, and office uses, as well as high-quality pedestrian environments that effectively connect with transit. Development is considered transit-friendly or transit-supportive because it can concentrate demand along corridors, balance passenger flows, and create opportunities for multimodal travel. U.S. evidence suggests that residents of TODs do use public transportation more than other commuters. Although the majority of TODs are built around rail systems, TOD can be a strategy to complement and build on the strengths of BRT as well.

TOD Typologies

Researchers and practitioners have developed a variety of TOD typologies, but none have focused specifically on BRT. The type of development that could happen around BRT stops is critical for planning development around them, for understanding how TOD fits within a regional growth strategy, for raising awareness and engaging the public, and, ultimately, for increasing the success of the system.

The literature on TOD suggests important potential differences in the characteristics and types of such development. One approach relies on the expertise and experience of planners, architects, and urban designers. Peter Calthorpe (1993) used urbanity to identify urban and neighborhood TODs with such distinguishing features as the quality of transit service, land uses, development intensity, and urban design. The geography of these TODs could vary from greenfield development to infill and redevelopment. A similar typology developed for the state of Florida in 2011 focused on center size (regional, community, neighborhood), but also included another dimension that was specific to the transit mode (Renaissance Planning Group 2011).

Dittmar and Poticha (2004) blended geography and urbanity in their TOD typology that includes urban downtown, urban neighborhood, suburban town center, suburban neighborhood, neighborhood transit zone, and commuter town. The same approach has taken hold in most recent applications of TOD typologies. For example, Sacramento, California, defined TOD as urban core/downtown, urban center, employment center, residential center, commuter center, and enhanced bus corridor (Steer Davies Gleave 2009). Reconnecting America developed a typology for the San Francisco Bay Area that included regional center, city center, suburban center, transit town center, urban neighborhood, transit neighborhood, and mixed-

Bus rapid transit in Curitiba, Brazil, has stimulated development along bus corridors.

use corridor (Metropolitan Planning Commission 2007). In Denver, Colorado, the Center for Transit Oriented Development (CTOD 2008) developed a guide for station area planning that included the addition of a special use/employment district type.

An alternative approach to developing typologies a priori is to use data-grouping techniques to examine existing evidence. For example, a typology of development around 25 rail stations that had integrated development in Hong Kong revealed five types: high-rise office, high-rise residential, large-scale residential, large mixed use, and mid-rise residential (Cervero and Murakami 2009). Another study used cluster analysis to develop a spatial-functional definition of station area types around Phoenix's light rail lines (Atkinson-Palombo and Kuby 2011). Employment centers, middle-income mixed-use areas, park and ride nodes, high population/rental areas, and areas of urban poverty were the types identified.

A final set of emerging typologies led by CTOD embodies the built environment with an implementation or performance dimension. These typologies often become a two-dimensional matrix, with built environment types in one axis and measures of implementation readiness in the other. Such typologies developed for Portland, Oregon, and Baltimore, Maryland, are used to guide investments and promote policy change and are particularly helpful in raising awareness about the travel benefits of TOD (Deng and Nelson 2012).

Study Cities and Data Collection

To understand the status of BRT-oriented development in Latin America we examined the built environment around BRT stops in seven cities (table 1). We looked for large cities that had BRTs in operation for five years or more and identified the following places: Bogotá (Colombia); Curitiba (Brazil); Goiânia (Brazil); Guatemala City (Guatemala); Guayaquil (Ecuador); Quito (Ecuador); and the São Paulo (Brazil) metro region (ABD Corridor). Together, these cities represent 16 percent of the world's BRT ridership and 31 percent of Latin-America's BRT ridership. We considered two types of stops: regular stops, which refer to common

TABLE 1
Cities and BRTs Studied

City/Metropolitan Area	Population (millions)[1]	BRT Start Date	BRT Length (km)[2]	Passengers Per Day	Regular Stops Total	Regular Stops # Studied	Terminals Total	Terminals # Studied
Bogotá, Colombia	7.2	2000	84	1,650,000	114	5	7	5
Curitiba, Brazil	1.8	1977	81	505,000	113	9	30	7
Goiânia, Brazil	1.3	1976	27	240,000	19	6	5	5
Guatemala City, Guatemala	1.1	2006	39	210,000	18	9	3	1
Guayaquil, Ecuador	2.7	2006	33	310,000	50	8	3	3
Quito, Ecuador	1.6	1990	56	491,000	79	7	11	5
São Paulo ABD Corridor, Brazil[3]	2.2	1988	33	180,000[4]	53	7	8	5
Total	28,725,394		353	3,586,000	446	51	67	31

1 Sources: *www.brtdata.org*, Instituto Brasileiro de Geografia e Estatística (IBGE, Brazil), Departamento Administrativo Nacional de Estadistica (DANE, Colombia), and local governments.

2 Source: *www.brtdata.org*. Calculations of length of BRT stops in Quito and Guayaquil were made by adding all corridors available in the BRT database.

3 Includes the municipalities of Diadema, São Bernado do Campo, Maua, and Santo André, but not the city of São Paulo.

4 Source: Empresa Metropolitana de Transportes Urbanos de São Paulo (EMTU).

BRT stops; and terminals, which refer to stops at the end of the line or where significant transfers occur from one BRT line to another. With the help of local planners we identified particular stops that were representative of the entire system, regardless of the development orientation towards BRT. In the end, we identified 51 regular stops and 31 terminals for further examination.

The absence of common data at a high spatial resolution required that we collect data in the field with an environmental audit tool designed for use at the road segment and block levels. A segment was defined as the street between two intersections. The data collection form contained the following fields about the environment:

- pedestrians (pedestrian-only paths, pedestrian bridges, bicycle paths);
- land uses (industrial, commercial, residential multifamily, commercial-industrial, commercial-residential, institutional);
- development intensity (low, medium, high);
- the presence of public or quasi-public spaces (big-box developments, schools, hospitals, churches, libraries, markets, sports and recreational facilities);
- the presence of open spaces (green areas, parks, squares, pocket squares);
- mix of housing;
- the degree to which the area has been built out; and
- maintenance condition of the built environment and green spaces (low, medium, high).

For regular stops, we examined road segments within 250 meters (m) of the stop. For terminals, we examined the area within 500m. In some instances (seven cases in Guatemala City and one in Goiânia) we examined two stops (instead of one) because of one-way streets that influenced the location of stops along parallel streets. In these cases the area analyzed was slightly larger than 250m. In addition to the audit data, we used some secondary data obtained from local authorities, such as population within each stop area.

Overall, we audited 10,632 segments and 2,963 blocks around 82 BRT stops and terminals. Because the surface area audited among stops was similar, comparisons of segments and blocks per stop provide information about compactness and connectivity in those areas of each city. One stop in Guayaquil had the most segments (102.1), while stops in São Paulo (ABD) had the fewest (43.1). A similar pattern was detected when examining segments per block.

All data were aggregated at the stop level. Data collected at the segment level were aggregated to develop measures of the percentage of segments around a stop with or without a given feature. Data collected at the block level were aggregated to develop measures of the raw number or the density of features around a stop. In the end, we calculated 38 variables characterizing the built environment around each stop.

BRT Stop Typologies

With such a large number of variables (38) and a relatively low number of observations (82), we used exploratory factor analysis to develop a subset of variables and to estimate their factor scores. Factor analysis relies on the correlation of the data to identify groups of variables that are most alike. The 38 variables were reduced into nine factors for further study:

- pedestrian-friendly, with connected green and public spaces;
- single-family attached residential uses not centrally located;
- high-density residential multifamily;
- undeveloped land;
- well-maintained mixed-use areas ;
- well-maintained green spaces;
- BRT-oriented public facilities for institutional uses;
- large-scale commercial development; and
- consolidated nonindustrial urban fabric.

Several observations emerged from examining the factors and their descriptive statistics. First, development intensity around stops seems to be relatively low. For example, only 8 percent of segments have developments of high density, but 31 percent of segments contain low-density development. Second, in the cities studied redevelopment as a strategy to encourage BRT-oriented development seems critical. Only 8 percent of segments had low levels of consolidation and 11 percent of them had vacant lots. By contrast, almost half of the segments had development that was highly consolidated. This result suggests limited opportunities for BRT-oriented development in undeveloped greenfield sites. Third, in terms of parking, it is remarkable that 26 percent of segments had on-street parking and 30 percent had commercial and retail activity with off-street parking. This highlights the challenge of managing parking supply (and demand) and may indicate that the environment around BRT stops often is not as friendly to pedestrians and BRT users as it should.

The performance of each stop on the nine factors was combined with population density and three additional variables that did not correlate with any other variables in an agglomerative cluster analysis to determine which stops could be grouped. The resulting cluster analysis was the basis for the typology, which identified 10 development types around BRT stops (table 2).

When examining the typology by city we find that two stop types capture city-specific factors: Quito's city center and several stops unique to Guatemala City, which has the newest system among those studied. Its newness and the fact that it serves fairly consolidated parts of the city might explain why the stops cluster together. The other eight stop types represent a broad cross-section of stops across several cities.

Five attributes appear to discriminate among stops: (1) multifamily developments with and without BRT orientation; (2) single-family attached housing, in some cases built informally, and with access to some commercial activity, often away from activity nodes; (3) high population density, supportive pedestrian infrastructure, and access to parks and green spaces, often away from activity nodes; (4) institutional stops with green spaces, not necessarily open to the public; and (5) stops that are saddled with physical barriers set by the convergence of multiple high-volume roads.

The types identified embody a wide range of possible built environments around BRT. The BRT-oriented Satellite Center type, illustrated by Bogotá, contains significant commercial activities, public facilities, parks, and pedestrian amenities while mixing in multifamily residential and single-family attached housing (figure 1). Together, these characteristics come close to the ideal of an urban TOD. Similarly, the type represented by the downtown, city center Quito stop also has many attributes of urban TOD. Whether the presence of these types translates into higher transit ridership remains an empirical question to be tested.

Community Center and Neighborhood Center stops seem to align well with Calthorpe's (1993) definition of community and neighborhood TODs. Among the cases analyzed, the former type exhibits some single-family attached housing and mixed uses that include institutional uses often aimed to

TABLE 2
BRT Stop Types

Stop Type	# of Stops	Description
Mixed-use Corridor	17	Stops along a corridor with a high mixture of land uses, including institutional uses; not particularly dense or well-located.
Downtown City Center (Quito)	1	Quito's historic center, with a high concentration of government jobs, many pedestrian amenities, several public and private venues such as churches and hotels, and considerable small-lot commercial activity.
Urban Center	7	High-density multifamily developments with incipient pedestrian infrastructure and public spaces, and a weak BRT orientation.
Institutional Use Corridor	12	Corridor stops with institutional uses such as schools, hospitals, churches, libraries, and recreational facilities not oriented towards BRT.
BRT-oriented Satellite Center	2	High population density with the presence of pedestrian infrastructure, green areas, public spaces, and BRT-oriented facilities; located far from activity nodes, with a low consolidation and high availability of open space.
Nexus	11	Connections between or among BRT lines, and with other transportation services; located where avenues and roads converge, thus acting as barriers between the stop and the rest of the neighborhood.
Guatemala City Corridor	5	Low consolidation, low-quality green spaces, with some institutional uses located close to activity nodes.
Community Center	16	Noncentral single-family attached uses, with some institutional land uses oriented towards the BRT.
Neighborhood Center	5	High population density in relatively low-quality residential developments, with considerable commercial development, far from activity nodes, but with a good BRT orientation; several stops in this cluster with informal housing.
Green Area	5	Undeveloped land, high-quality green spaces, with some institutional land uses, and far from activity nodes. One of the stops (Base Naval in Guayaquil) is an institutional land use next to the airport, thereby explaining the presence of undeveloped land (large green areas). Other stops in Bogotá and Quito are located in urban expansion areas often with affordable housing.

serve proximate areas of the city. Neighborhood centers have a higher intensity of residential development, mostly focused around single-family attached housing. Our Corridor type stops seem consistent with the concept developed for enhanced bus services in Sacramento and San Francisco, although our data can clearly distinguish between corridors that are dominated by institutional uses and others that simply have a broad mix of uses.

Our typology also identified challenges and opportunities to improve the BRT orientation of development. Only the Downtown City Center and the BRT-oriented Satellite Center types provided adequate integration between the pedestrian environment and transit. The Urban Center type, such as in Curitiba, is ripe for improved integration with the BRT because it has the densities and mix of uses to support it (figure 2). The Nexus stop type, as shown in Goiânia, embodies a frequent challenge for local planners (figure 3). Such stops and terminals should be located to facilitate intermodal transfers, but this often sacrifices access by local users and the transit orientation of the stop.

Compared to other typologies, we did not find strong evidence for employment and commuter-based stops. This may be due to the relatively muted role played by mixed land uses among stops, since land uses played a significant role in other typologies. One explanation could be the typically high degree of mixed uses already present in Latin American cities, which contributes to a low degree of variation across stop areas.

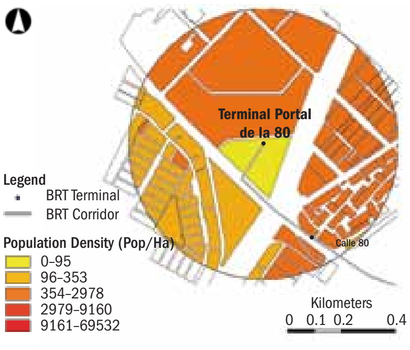
In terms of housing policy, the Neighborhood Center and Green Area types contain an interesting combination of distance to centers of activity and low-income housing. Because the stops are far from activity nodes, they are more likely to contain green spaces, affordable housing, and sometimes informal housing. Latin American cities tend to have a fairly strong land price gradient, with areas with privileged access to activity nodes having higher prices than peripheral areas. These two types raise questions over the possible consequences of BRT on exacerbating the segregation of housing and the financial burden of mobility on low-income residents.

Analysis of Stop Types and Planning Visions

Our examination of 82 BRT stops in seven Latin American cities revealed a variety of development patterns. Some types have attributes that are consistent with the principles of TOD. Others are

FIGURE 1

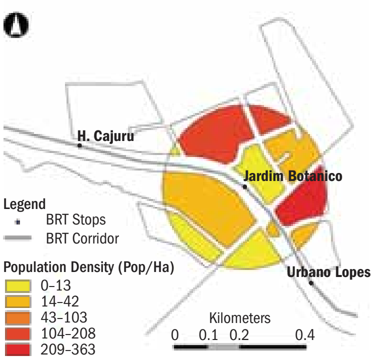
Example of a BRT-oriented Satellite Center Stop: Portal 80, Bogotá, Colombia



Score	Mean	Std Dev	Min	Max
Pedestrian-friendly with connected green and public spaces	0.23	0.73	-0.77	1.20
Single-family attached residential uses not centrally located	-0.25	0.53	-1.07	0.50
Undeveloped land	0.06	0.88	-0.97	1.47
Well-maintained mixed-use areas	-0.46	0.96	-2.40	0.27
Institutional uses	-0.46	0.34	-0.94	0.02
BRT unsupportive land uses	-0.62	0.30	-1.11	-0.24
Population density	0.73	0.80	-0.01	2.15
BRT orientation	-0.61	0.15	-0.78	-0.40
Entropy (measure of mixed use)	0.26	1.03	-1.58	1.10
Centrality	-0.87	0.40	-1.34	-0.34
Segment density	0.17	0.94	-0.55	2.23

FIGURE 2

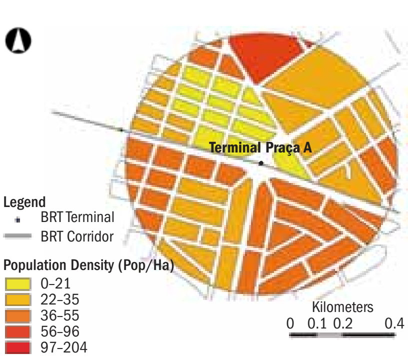
Example of an Urban Center Stop: Jardim Botanico, Curitiba, Brazil



Score	Mean	Std Dev	Min	Max
Pedestrian-friendly with connected green and public spaces	4.57	2.60	2.73	6.41
Single-family attached residential uses not centrally located	0.52	1.32	-0.42	1.45
Undeveloped land	-0.16	0.95	-0.83	0.51
Well-maintained mixed-use areas	0.33	0.62	-0.10	0.77
Institutional uses	-0.26	0.04	-0.29	-0.23
BRT unsupportive land uses	-0.48	0.74	-1.01	0.04
Population density	2.53	2.73	0.60	4.46
BRT orientation	0.92	1.72	-0.30	2.14
Entropy (measure of mixed use)	0.37	0.01	0.36	0.38
Centrality	0.21	0.92	-0.44	0.86
Segment density	3.24	3.09	1.05	5.42

FIGURE 3

Example of a Nexus Stop: Terminal Praca A, Goiânia, Brazil



Score	Mean	Std Dev	Min	Max
Pedestrian-friendly with connected green and public spaces	-0.39	0.37	-0.81	0.32
Single-family attached residential uses not centrally located	-0.55	0.54	-1.66	0.22
Undeveloped land	-0.39	0.56	-0.94	1.03
Well-maintained mixed-use areas	-0.50	0.96	-1.83	1.19
Institutional uses	-0.72	0.39	-0.94	0.30
BRT unsupportive land uses	-0.07	0.58	-0.91	0.86
Population density	-0.76	0.34	-1.16	-0.03
BRT orientation	-0.59	0.34	-0.98	0.28
Entropy (measure of mixed use)	-0.88	0.62	-1.94	0.21
Centrality	0.04	0.82	-0.84	1.87
Segment density	-0.03	0.76	-1.56	0.89

burdened by land uses, road infrastructure, and development characteristics that do not support BRT. Still other types appear to be works in progress, with significant vacant land and development that has not been fully consolidated. Finally, some stops seem to capture urban conditions that arise in many Latin American cities: informal housing distant from activity nodes; large commercial developments, frequently of the big-box type, providing private spaces for public use and commerce; and a relative absence of green spaces open to the public. This information is helpful in facilitating planning for BRT-oriented development given the rapid growth of BRT over the last two decades. Some 146 cities worldwide now have some form of a bus-based priority transit system.

Understanding the type of development that could happen around BRT stops is critical for planning station areas and for identifying how TOD fits within a regional growth strategy. Robert Cervero (1998) argues that a successful urban development vision must precede and guide transportation investments, and that planning is necessary if subcenters around transit stops are to take place. He buttresses his argument with the impressive evidence of Copenhagen, Stockholm, and Singapore, suggesting that efforts to develop regional and station-area visions are critical for the future success of TOD. In fact, the burgeoning TOD typologies in the United States are predicated in part on their ability to support long-term TOD planning. For example, the Denver typology was critical to create a land use vision for its existing and forthcoming light rail station areas.

Visions of what potential future development could take place and where it would occur are central to planning, and are frequently embodied in potential future scenarios that decision makers, the public, and planners must consider. Visionary planning is often a precondition for effective TOD station area planning. The CTOD calls for planning for the plan, involving the public, marketing the project, and creating a regional TOD strategy, all of which necessitate a vision of what development can occur. Visions are particularly powerful to engage the public because they materialize potential outcomes of the planning process and enable a better understanding of the impact of their decisions about density, the mix of uses, and access to station areas.

The next step in our research is to determine the causes of the different development patterns we have identified. In some cases, the environment has changed dramatically with BRT investments, whereas in other cases there has been little change. At play are market and regulatory forces that determine the outcome of development and revitalization. Changing land use regulations, relaxing density caps, or reducing parking requirements are ways to further leverage the development potential of parcels close to BRT or other mass transit stops. This coordinated strategy between land use and transportation is the cornerstone of TOD. LL

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