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The relationship between urban form and station boardings for Bogotá's BRT

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Abstract

Despite emerging evidence about the association between the built environment and travel behavior, the relationship between bus transit demand and urban form remains largely unexplored. By relying on primary and secondary data analyzed with a geographic information system, this paper examines the built environment characteristics related to stop-level ridership for Bogotá's successful bus rapid transit system. After accounting experimentally and statistically for the simultaneity between transit supply, transit demand, and the built environment, we find evidence of the importance of the built environment in BRT station boardings. Specifically, environmental supports for walking and personal and environmental barriers to car use were related to higher BRT boardings. Our results underscore the importance of urban environmental interventions to support transit use.

Keywords: Bus rapid transit; Built environment; Environmental audit; Bogotá; Simultaneous model; Factor analysis; Ridership

1. Introduction

Recent research has studied the relationship between the built environment and travel behavior with the aim of identifying environmental characteristics that support decreased auto use. Common outcomes examined include distance traveled, travel mode choice, trip frequency and use of transit. Although there is an emerging understanding of the relevance of the built environment in supporting transit use, studies have focused almost exclusively on the relationship between rail transit and residential and employment density. The focus on density seems to follow calls to examine the role of density, diversity and design in affecting travel behavior (Cervero and Kockelmann, 1997; Lee and Moudon, 2006; Cervero, 2002). However, there is a

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paucity of research examining the role of diversity and design on transit use, generally, and bus transit use specifically.

This paucity has an added sense of urgency given the increasing importance of bus rapid transit (BRT) as a cost-effective mobility solution for cities worldwide. Rodríguez and Targa (2004) define BRT as a variety of bus-based applications involving coordinated improvements in operations, technology, infrastructure and equipment to improve the level of service of bus-based mass transit options. Only in Latin-America, currently there are five BRT systems that include segregated right-of-way and integrated ticketing, with 11 more under implementation (Menckhoff, 2005). Although BRT has been integral to land development in Curitiba (Smith and Raemaekers, 1998), and rent gradients to BRT have been shown for Bogotá (Rodríguez and Targa, 2004), little is known about the built environment around stations and its relationship to ridership. Understanding this relationship can help planners determine whether coordinating BRT implementation with a strategy that enhances the built environment and stimulates development is worthwhile. Thus, our focus on BRT has important practical and policy-making considerations.

In this paper we examine the relationship between the built environment and BRT demand. We build on prior research in several ways. First, we rely on primary and secondary data to characterize the built environment around transit stops, developing measures of design and diversity not tested in the context on bus transit demand. Second, we account for the simultaneity of transit supply and transit demand. Third, we take advantage of fortuitous timing in changes to the bus system to control experimentally for the effect of transit demand and supply on the built environment. And fourth, we focus our analysis in one of the most successful bus systems in the world: Bogota's BRT.

The paper is organized in five remaining sections. In the next section we review the existing literature relevant to understanding bus transit demand. The following section describes the study area and the data collection process. The analytical strategy is described in Section 4 followed by Section 5 where results are provided. Finally Section 6 contains our main conclusions and implications.

2. Review of the literature

Accumulating evidence suggests that certain characteristics of the built environment are related to people's travel behaviors. Behaviors such as trip-making frequency, distance and time traveled have been studied for a variety of land use patterns, street networks, and streetscape design features. In particular, walking and using transit has been related to the presence of mixed uses of land (Cervero, 1996; Cervero and Kockelmann, 1997; Moudon et al., 1997; Crane, 2000), improved street connectivity (Boarnet and Crane, 1998, 2001; Greenwald and Boarnet, 2000; Kitamura et al., 1997) and higher employment and population density at the origin and/or the destination (Cervero and Kockelmann, 1997; Cervero, 1996; Messenger and Ewing, 1996; Frank and Pivo, 1994). For traveling to work, evidence suggests that the location and regional connectivity of the neighborhood with respect to other activity centers in the area is critical in explaining observed travel patterns (Cervero and Kockelmann, 1997; Ewing, 1995; Ewing and Cervero, 2001; Kasturi et al., 1998). The ways on which the landscape and the urban form affect particularly non-motorized modes has been also documented emphasizing the importance of short blocks, topography, and perceptions of safety, drawing evidence from San Francisco (Cervero and Duncan, 2003; Handy, 1996; Kitamura et al., 1997). Neighborhood studies have also shown that the share of pedestrian and transit trips is higher in non-auto neighborhoods and that auto trips are shorter (Cervero and Gorham, 1995; Cervero and Radisch, 1996; Friedman et al., 1994; Handy, 1996; Kitamura et al., 1997; Niemeier et al., 1996; Dill, 2004; Khattak and Rodriguez, 2005; Rodríguez et al., 2006).

Despite the fairly consistent evidence supporting the relationship between built environment and travel patterns, some limitations remain to be addressed. First, a preponderance of studies relied on research designs that limit researchers' ability to make causal claims. Cross-sectional correlational designs, and quasi-experimental designs prevail. Second, concerns about the endogeneity of neighborhood selection by individuals and about the simultaneity between travel patterns and urban form raise further questions about the evidence presented. And third, built environment measures have relied mostly on secondary data taken at an aggregate scale. It is likely that micro-level characteristics of the built environment such as the presence and quality of sidewalks, the sense of safety, and the presence of litter, among others, also influence people's propensity to leave their car behind and walk or use transit.

Although the relationship between urban form and rail transit patronage received significant attention in the late 1990s (Parsons Brinckerhoff Quade & Douglas, et al., 1996a; Frank and Pivo, 1994; Cambridge Systematics Inc., 1998), the same relationship for bus systems has received less consideration. Models of bus use at the route-level rose in popularity in the 1970s. Linear regression models (Strathman et al., 1997; Chu, 2004) simultaneous equation models (Gaudry, 1975; Peng et al., 1997; Kimpel et al., 2000) and count regression models (Lerman and Gonzalez, 1979) to forecast route or station use were tested with varying degrees of success. Independent variables were service supply or some proxy for level of service, population density and land use mixture, and more recently some pedestrian amenities, after controlling for socio-demographic characteristics.

Coinciding with the popularization of geographic information systems, models of bus transit use gained renewed interest in the last decade. Stopher (1992) used socio-demographic information of census tracts around bus served areas to explain observed ridership and particularly the effects of small changes in service provision over ridership. He estimated econometric models of boardings and alightings after service changes for weekday peak, weekday day, and weekday night. Peng et al. (1997) used a segment-level model to examine ridership presenting a simultaneous model, using routes as the level of analysis. They modeled transit demand and supply, finding that both are strongly related and that they provide significant feedback to each other. Although they included some built environment variables such as land use mix, population and employment density, they acknowledge that data at a smaller level of analysis would be more desirable, given that their model assumes that the built environment is constant throughout each route. They found that ridership depends partly on the mix of land uses and density, as well as service supply.

Finally, Chu (2004) estimated a ridership model at the stop level for a bus system in Florida, including several measures of the built environment as pedestrian facilities, land use mixture and some socio-demographic characteristics of surrounding areas. He found that the pedestrian environment, accessibility measures to population and employment, as well as interactions with other modes are statistically significant when modeling ridership for mass transit systems.

With two exceptions (Chu, 2004 and Peng et al., 1997) a limitation that applies to studies of bus transit demand is the assumption that explanatory variables are exogenous to transit demand. Transit supply and some built environment characteristics are likely to be simultaneously determined with transit demand. For transit supply, agencies are likely to adjust their service level to existing demand levels; if transit demand increases unexpectedly, transit supply will follow, albeit with a lag. A similar argument applies to the characteristics of the built environment around transit stops. For example, high demand at a stop is likely to stimulate development and environmental changes.

A second limitation common among studies of bus transit demand is the use of routes or route segments as the unit of analysis. Peng et al. (1997, 169) lament this: "Because of this limitation, a stop level model may be more appropriate. A stop level model, however, requires more detailed data than presently available. Perhaps the next generation of transit demand models will be at the stop level." Furthermore, a lesson from the emerging evidence of studies on the built environment and travel behavior is the importance of accessibility to the stop. Although neighborhood or zonal characteristics such as density and employment have been relevant in explaining bus use, it is plausible to expect that conditions of micro-level environments described previously also will affect bus use at the stop level. As with rail systems, bus patronage may depend not only on the economies of density afforded by certain built environments (like residential and employment densities) but also on how those environments are physically linked to transit stops.

In this context, this paper responds to needs and emerging implications identified in prior research by examining the relationship between bus transit use and the built environment at the stop level. Although we employ neighborhood environmental and socio-demographic information, we also use primary data collected for this study on micro-features of the built environment. To account for the simultaneity between transit supply and transit demand, we estimate a system of simultaneous equations.

3. Study area and data

Following Curitiba, Bogotá's bus rapid transit system (BRT) has won accolades for embodying a low cost mass transit relative to rail investments while producing impressive ridership figures (Sandoval and

Hidalgo, 2002) and accessibility benefits (Rodríguez and Targa, 2004). The system comprises specialized infrastructure, including exclusive lanes for high service capacity and articulated buses with off-board fare collection system. As of January 2006, the BRT system included 69 km of exclusive right-of-way, 94 stations, 747 buses, averaging a speed of 26.17 km per hour. The uniqueness of Bogotá's case hinges on the transformation of a busway corridor with severe pollution, safety problems, and aesthetically displeasing into a new BRT system with significantly lower travel times, lower noise, and fewer greenhouse gas emissions.

The data collection process for this study began by considering all (79) BRT stations in service as of summer 2005. Of these stations, five are located at the end of the routes, serving as transfer stations for feeder buses and long-distance buses carrying riders living in adjacent municipalities. As such, they are larger and functionally different than all the other stations. In addition, three stations were fully closed for maintenance, two stations were partially closed, and one station could not be visited due to staff safety concerns. The remaining 68 stations are the focus of our study (Fig. 1).

We define the local accessibility of a stop as the circular buffer of 250 m around each stop. Although stops are expected to have a larger area of influence, particularly for a high capacity mode like Bogotá's BRT, we focus on an area close to the stop since the quality of access to the stop is partly determined by the quality of the area immediately surrounding the stop. Given the nature of Bogotá, its density and social construction, the buffer defined includes a wide variety of land uses, types of residences (usually attached single family and multifamily), retail establishments, and offices.

To characterize the socio-demographic, built and natural environment around each stop we use secondary and primary data. Secondary data include contemporaneous information on various demographic, social, land use, housing, education, crime, transportation service and environmental characteristics at different geographic levels, as available from the local planning department (DAPD). Measures include proportion of the population with unsatisfied basic needs (NBI), average educational attainment (years of schooling), income inequality (Gini coefficient), gross population density in thousands of persons per square kilometer, prevailing socio-economic status (SES) of neighborhood (1–6, 6 being highest SES), number of murders per 1000 inhabitants as a surrogate for personal safety, number of fatal vehicle-involved accidents per 1000 inhabitants, and total number of thefts per 1000 inhabitants, all for the year 2005. To assign the values of these measures to the smaller buffer areas we used population weights.

The collection of primary data around each stop consisted of auditing five major road segments that provided access to each station. Key segments around each stop were identified using GIS. Audits are an increasingly popular means of collecting micro-level environmental attributes (for a review see Vernez and Lee, 2003). The audit used was an adaptation of the pedestrian environment data scan (PEDS), available at http://www.activelivingresearch.org/node/10641. PEDS is a built environment audit applied at the segment or path level that has been tested in various environments, showing high reliability (Clifton et al., 2007). The audit was used to collect data on environment variables along each path audited such as dominant land uses, pedestrian facilities such as width and material of sidewalks, obstructions, building setback, and buffers between facility and road and bicycle paths; pedestrian amenities such as benches, crossing aids, and public illumination; and auditor's perceptions of friendliness, criminal activity, and cleanliness. Auditors were also asked to identify a landmark on each segment and count the number of pedestrians passing that point during 10 min. These counts served as weights for aggregating data from the segment-level to the station-level. Hired auditors participated in a two-day training to ensure the high reliability of the data collected. Each audited street segment was between 250 and 300 m in length.

Table 1 provides a detailed description of the data collected. Segment-level audit data was aggregated to the station-level by weighting each segment by the number of pedestrians using it. Bike path presence was measured as the percentage of segments audited around each station with a bike path. Land use diversity was measured with an index created by dividing the number of land uses present in each buffer by the total number of possible uses (7), multiplied by one hundred. Sidewalk obstacles were measured as the inverse of the number of obstructions observed in the segment plus one (to avoid having zero as a denominator). A lower number indicates more obstacles than a higher number. The traffic control devices index measures the percentage of all possible traffic control and pedestrian aid devices (traffic signal, pedestrian signal, stop sign, crosswalk, overpass) available at each station. Finally, an amenities index was created by identifying the percentage of

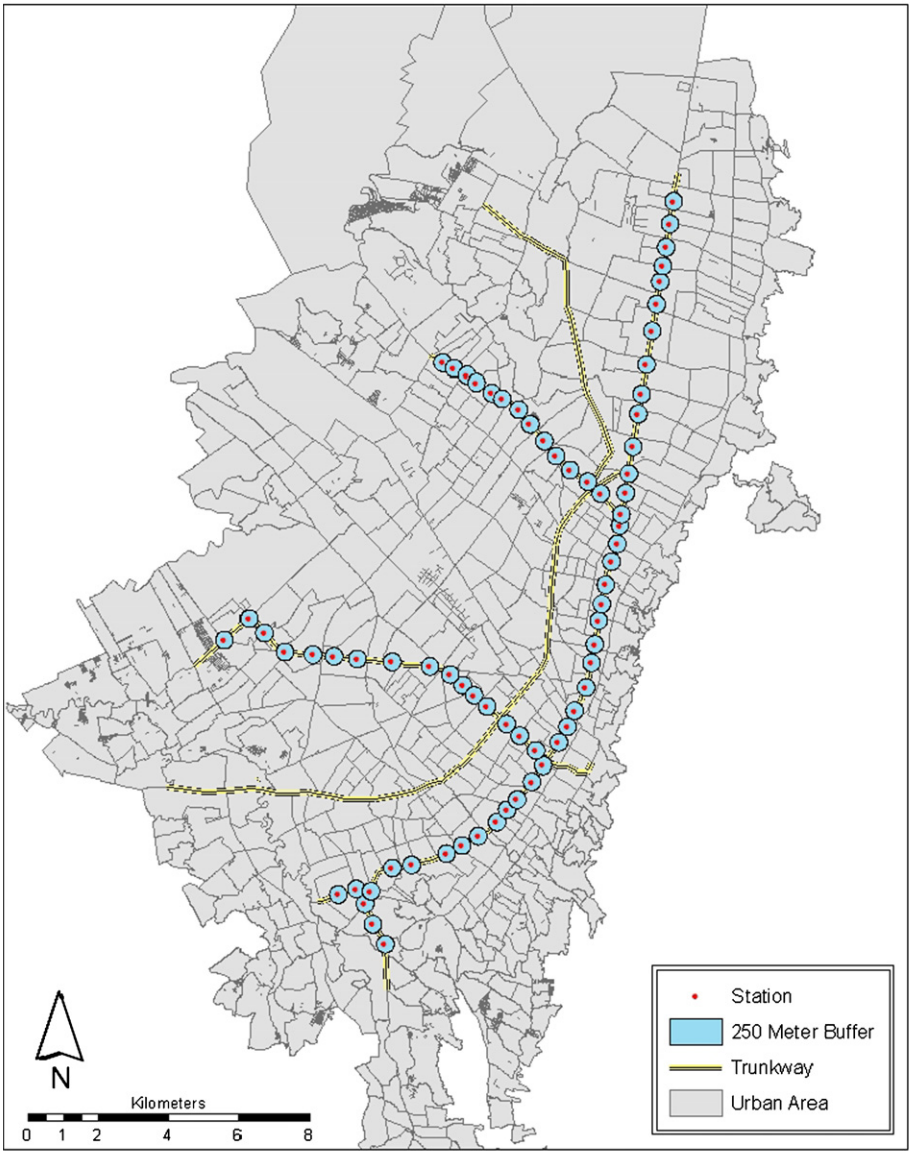

Fig. 1. Bogotá's TransMilenio BRT stations audited.

all possible amenities (benches, garbage cans, bicycle racks, public lighting, and appropriate signage) that were present in the buffer around each station.

4. Analytical strategy

We rely on a two-equation simultaneous model to account for the interaction between transit supply and demand:

$$R_i = f(\vec{F}_i, S_i) \tag{1}$$

$$S_i = f(R_i, R_{i,t-1}, \mathrm{Fed}_i, \mathrm{Alt}_i, \mathrm{Type}_i, \mathrm{Pop\_d}_i, \mathrm{Strat}_i) \tag{2}$$

Table 1
Description of variables and descriptive statistics ($N = 68$)

Variable	Definition	Mean	Std. dev.	Min	Max	Spatial level	Source
Dependent							
Boardings_2005	Number of daily boardings per station for 2005	9818	7623.38	1418	42,779	Station	TransMilenio
Boardings_2006	Number of daily boardings per station for 2006	10,531	7798.82	1498	33,136	Station	TransMilenio
Station characteristics							
Alternative	Number of bus transit alternatives available different from BRT (from 1 to 3)	1.88	0.95	1	3	Station	PEDS
Feeder	Presence of a bus feeder service (0 or 1)	0.03	0.17	0	1	Station	TransMilenio
Num_routes	Number of routes served by a station (from 2 to 27)	10.77	7.23	2	27	Station	TransMilenio
Type	Type of station defined by size (from 1 to 5)	2.25	0.79	1	5	Station	TransMilenio
Transit supply	Number of vehicles per day per station (in both directions)	1709	1057.46	356	3881	Station	TransMilenio
Physical Attributes							
Bikepath	Presence of bike path (0–1)	0.19	0.25	0	0.8	Segment	PEDS
LU-mix	Land use index (0–100)	33.89	10.82	0	62.63	Segment	PEDS
Side_buffer	Buffer width between sidewalk and road (0 to 3)	0.58	0.34	0	1.39	Segment	PEDS
Traffic_control	Traffic control index (0–100)	0.38	0.14	0.13	0.67	Segment	PEDS
Side_cont	Sidewalk continuity (0–3)	0.67	0.15	0	0.41	Segment	PEDS
Side_width	Sidewalk width (0–3)	1.88	0.38	1.03	2.64	Segment	PEDS
Side_quality	Sidewalk quality (0–1)	2.42	0.40	1.47	3	Segment	PEDS
Amenities	Index of amenities (0–100)	40.31	13.89	20	73.82	Segment	PEDS
Perceived characteristics							
Safety	Perception of safety (crime) (0–3)	2.36	0.46	1	3	Segment	PEDS
Clean	Perception of cleanliness (0–3)	2.38	0.45	1.23	3	Segment	PEDS
Ped_friendly	Perception of pedestrian friendliness (0–3)	2.33	0.39	1.41	3	Segment	PEDS
Bike_friendly	Perception of bike friendliness (0–3)	1.53	0.57	0.56	2.87	Segment	PEDS
Overall_perceptions	Overall perception (0–3)	2.25	0.44	1.06	3	Segment	PEDS
Neighborhood Attributes							
Density	Density (persons per hectare)	183.74	60.40	96.07	302	Station	DAPD
Stratum	Socio-economic stratum of neighborhood (from 1 to 6)	2.96	0.47	2.24	3.98	Station	DAPD
Road_density	Road density (linear kilometers in buffer)	9.59	2.28	4.87	16.32	Station	GIS
Sum_intersections	Sum of three way and four way intersections (sum in buffer)	60.35	29.12	14	173	Station	GIS
NBI	Unsatisfied Basic Needs Index (from 0 to 1)	0.06	0.04	0.01	0.17	Station	DAPD
Schooling	Average years of schooling (from 0 to 17)	11.82	1.37	9.30	14.65	Station	DAPD
Violent_deaths	Number of violent deaths (per 1000 inhabitants)	0.41	0.33	0.15	1.30	Station	DAPD
Crashes	Number of vehicle accidents (per 1000 inhabitants)	0.11	0.05	0.03	0.19	Station	DAPD
Thefts	Number of thefts (per 1000 inhabitants)	1.25	0.99	0.18	2.90	Station	DAPD
Unemployment	Unemployment rate (%)	11.69	2.40	8.12	16.33	Station	DAPD

where R_i and S_i are transit ridership and transit supply for station i, respectively, $\vec{F}_i$ is a vector of built environment domains regarding station i identified through exploratory factor analysis. The variables Fed (presence feeder buses), Alt (presence of other transit alternatives to access the station), Pop_d (population density around each station) and Strat (social stratum of neighborhoods around station) are used as instruments to characterize the supply and $R_{i,t-1}$ is the ridership recorded eight months before. From the supply side, this system assumes that current and past demand, density and socio-economic characteristics, in addition to the competition and complementarity from other transportation modes, determines service supply.

From the demand side, it assumes that transit supply and environmental factors determine transit use. Including the built environment domains in the demand equation presumes their exogeneity. Indeed, we feel that most built environment characteristics are exogenous to current transit use for two reasons: First, the environmental characteristics were related to the upgrading brought by the BRT system investments. Lighting, sidewalk quality and continuity, were all included as a part of the BRT package and were not related to expectations about station-specific demand. Second, the BRT had been operating for less than five years when the data was collected. Thus, environmental changes that do not occur in a short time frame, such as changes in density and land use mix, are unlikely to be significant. In summary, our research design takes advantage of fortuitous timing in changes to Bogotá's bus system to control experimentally for the effect of transit demand and supply on the built environment.

The exploratory factor analysis is justified by the high number of built environment variables available per station. The procedure will result in a lower number of factors capturing the core influences in a multidimensional way. With a higher number of stations, the use of factor analysis could have been avoided and the statistical model directly estimated. Once the factors have been extracted, factor scores are used in the statistical model. For the purposes of this exploratory factor analysis all variables were treated as continuous.

5. Results

We first provide the results of the factor analysis. Measures of sampling adequacy indicated that the correlation matrix of the 23 audit questions was suitable for factor analysis.[2] The scree test and eigenvalue >1.0 criteria (Cattell, 1978) agreed on the relative suitability of four factors for rotation. On the basis of these results, the entire sample was factor analyzed, and fours factors were rotated to a varimax (orthogonal) solution. All items (but two) loaded 0.4 or more on at least one factor, with 4 items having double loadings (Table 2). The four factors account for 83.4% of the variance of the 23 questions. The stability of the scale for each factor, or its reliability, is demonstrated by estimating Cronbach's alpha. Typically a scale is considered as reliable if its Cronbach's alpha is 0.70 or higher, although Nunnally and Bernstein (1994) claim that values greater than 0.80 are highly desirable. The factors have average standardized Cronbach's alpha of 0.884 (range from 0.80 to 0.94).

The first factor, composed by several measures of the built environment as sidewalk quality, amenities index, presence of bicycle path and perceptions, all with positive and high loadings, is interpreted as environmental supports for walkability. The second factor includes density, land use mix, bicycle supports and unemployment with positive loadings, and socio-economic stratum and education, car accidents and thefts with negative loadings, which we broadly interpret as environmental, safety, and socio-demographic barriers or deterrents to car use. The third factor has positive and high loadings for perceived and actual pedestrian safety and security variables, poverty, and a high presence of traffic control devices. Finally, we interpret the fourth factor as a connectivity measure, composed by measures of road density and number of intersections.

Factor scores and other related variables in Eqs. (1) and (2) were used in a two-stage least square regression to estimate the model of simultaneous equations presented previously (Table 3). The transit demand variable is log-transformed. Coefficients were calculated using the generalized method of moments (GMM) estimator, which generates efficient estimates of the coefficients in presence of arbitrary heteroskedasticity as well as consistent estimates of the standard errors (Hayashi, 2000, 206–227). They are jointly significant, with a centered R^2 of 0.495. A test for the endogeneity of transit supply provides support for our use of instrumental variables (Davidson and MacKinnon, 1993), while a Hansen J-test for over identifying restrictions suggests jointly that the equations are properly specified and the instruments are valid (Davidson and MacKinnon, 1993, p. 236; Woolridge, 2002, p. 123).

Results for walking supports (factor 1, $p < 0.01$), barriers to car use (factor 2, $p < 0.1$), and transit service supply ($p < 0.01$) are largely consistent with our expectations. Better walking supports and more personal or environmental barriers to car use are positively related to transit use. While connectivity (factor 4) does not appear related to transit use, lack of safety and insecurity (factor 3, $p < 0.01$) unexpectedly is related to transit

[2] Bartlett's test of sphericity $\chi^2 = 1589.708$, $P < 0.000$; Kaiser–Meyer–Olkin measure of sampling adequacy = 0.642.

Table 2
Rotated factor loadings

	Subjective factor interpretation			
	Walking supports	Barriers to car use	Low safety and insecurity	Connectivity
Perception and quality of facilities				
Side_quality	0.763			
Side_cont				
Side_width				
Amenities	0.742			
Safety	0.635		−0.524	
Clean	0.744			
Ped_friendly	0.894			
Bike_friendly	0.772	0.429		
Overall _perceptions	0.853			
Bikepath	0.685			
Road and land uses interaction				
Traffic_control			0.531	
Road_density				0.906
LU-mix		0.41		
Sum_intersections				0.883
Side_buffer	0.584			
Neighborhood socio-demographic characteristics				
NBI			0.481	
Density		0.903		
Stratum		−0.949		
Unemployment		0.925		
Schooling		−0.889		
Neighborhood safety				
Violent_deaths			0.812	
Crashes per 1000 inhabitants		−0.402	0.763	
Thefts per 1000 inhabitants		−0.677	0.512	
Eigenvalue	6.262	5.002	2.311	1.812
Cronbach's Alpha	0.915	0.882	0.800	0.940

Note: factor loadings <0.40 are left blank.

Table 3
2SLS regression model of station boardings

Variables	Coefficient	Std error	*P*-value
Transit supply	0.00097***	0.000	0.000
Walking supports	0.1421***	0.658	0.001
Barriers to car use	0.1438**	0.074	0.021
Safety and security	0.1382**	0.055	0.049
Connectivity	0.0304	0.549	0.440
Constant	7.3483***	0.153	0.000
N	68		
Centered R^2	0.45		
F statistic (5,62)	55.16		

Hansen J statistic over identification test $\chi^2 = 8.866$, P-value = 0.1813.
** and *** denote statistical significance at the 95% and 99% level of confidence, respectively.

use, with high insecurity and low safety associated with higher transit use. In the context of density, diversity and design (the 3 Ds), the environmental items of the barriers to car use factor are consistent with density and diversity. By contrast, walking supports (factor 1) do not appear to measure the 3 Ds directly. Rather, the factor is a slight departure from traditional urban form measurements based on the 3 Ds. It may be that walking supports come with density or design; however, our results show that they independently contribute to explaining boardings. Together, our results underscore the importance enhancing ways to measure the built environment, including additional environmental characteristics in analyses, and associating them with changes in transit use.

Our results are similar to those from Peng (1997) and Chu (2004) where population density-related attributes play important roles, although a direct comparison is not possible due to the data reduction techniques used here. Other control variables have similar effects to Chu (2004): social stratum, a surrogate for income, proved to be inversely related with ridership. One unexpected result is that our connectivity factor was not statistically significant. This is counter to several studies suggesting that connectivity may be critical for supporting walking activity (Frank et al., 2006; Ming, 2006; Saelens et al., 2003; Lee and Moudon, 2006). One explanation for this finding may be little variation in our connectivity variable, since Bogotá has high street connectivity.

Finally, a limitation of our approach is ignoring potential competition among stations. For example, when levels of service improve in certain stations, riders may modify their behavior accordingly and use neighboring stations less. However, with stops located almost 0.5 km from each other, this behavior is unlikely in our case. Only major transfer stations like Cll 76 or Av. Jiménez (Fig. 1) have significantly different levels of service from neighboring stations. Thus, the effect of competition among stations is not likely to alter our results significantly. Another concern is the limited sample size. With a larger sample size we would have more certitude regarding the magnitude of the coefficients and relationships at play. Furthermore, more observations may also allow us to estimate the models without using factor analysis as a data reduction technique. This would allow us to more finely identify built environment attributes related to higher transit use.

6. Conclusions

Previous research has examined relationships between the built environment and various travel behaviors. Absent from this research are studies focusing on environmental factors related to bus use generally, and BRT in particular. This absence is critical given the heightening interest from planners and policy-makers on BRT investments as mobility solutions for developed and developing cities. Relying on secondary and primary data, this study fills gaps in the empirical literature by examining the relationships between the built environment and station-level boardings in Bogotá's BRT. Study results suggest environmental supports for walking and deterrents or barriers to car use were related to higher BRT use. Furthermore, the factors measuring environmental supports for walking and barriers to car use had the strongest predictive power of the factors analyzed.

For policy-makers, our results confirm the importance of the built environment in supporting non-automobile ways of traveling generally, and bus transit in particular. Our research identified environmental features, subjectively interpreted as walking supports, which successfully predict transit use, while controlling for other attributes. These results suggest an appropriate expansion of the 3 Ds to include such walking supports. Although walking supports are likely to be spatially correlated with high density or walking transit – friendly design, our results show that they independently contribute to explaining transit use. For some of our control variables, socio-demographic characteristics (such as low income socio-economic stratum, high rate of unemployment in neighborhood and low educational attainment) and areas with high presence of traffic control devices were related to higher transit use. Finally, the importance of personal safety (from automobiles, motorcycles and other sources of conflict with pedestrians) and security, showed a relationship contrary to what we expected, although they may be the result of omitted variable bias. The latter results should be understood in the context of the study location.

Taken together, we find that the built environment is important in explaining boardings for Bogotá's BRT. For some built environment attributes, like crosswalks and sidewalks, such attributes were the result of deliberate interventions to support the BRT system. For other attributes like the high density and the high degree of land use mixing, although less deliberate they remained supportive of BRT use. Considering that many less developed cities are dense and have high degrees of land use mixing, planners and policy-makers can focus on providing institutional supports to foster walkable, safe environments.

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