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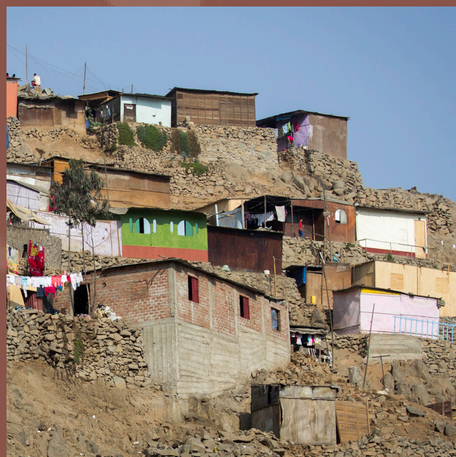

Urban Transport and Poverty: Mobility and Accessibility Effects of IDB-supported BRT Systems in Cali and Lima

IDB Inter-American Development Bank

IIC Inter-American Investment Corporation
A Member of the IDB Group

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Acronyms and Abbreviations

BRT	Bus rapid transit
COP	Colombian peso
GIS	Geographic information system
GTU	Lima Urban Transport Agency
IDB	Inter-American Development Bank
INEI	National Information Institute (Peru)
LAC	Latin America and the Caribbean
OD	Origin destination
OVE	Office of Evaluation and Oversight
PEN	Peruvian Sole
PT	Public transit
TAZ	Traffic analysis zone

Acknowledgements

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Bus rapid transit systems typically aim to increase overall mobility while also reducing negative externalities such as traffic accidents and emissions of local and global pollutants. They often also seek to improve mobility and access to jobs, goods, and services for the poor.
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Executive Summary

Bus rapid transit (BRT) systems, designed to operate at capacities at or near those of metro systems, have grown rapidly in Latin America and the Caribbean (LAC) and elsewhere as a lower-cost alternative to rail-based transit. They typically aim to increase overall mobility while also reducing negative externalities such as traffic accidents and emissions of local and global pollutants. They often also seek to improve mobility and access to jobs, goods, and services for the poor. BRT systems represented roughly half of all Inter-American Development Bank (IDB) urban transport projects, which in turn represented 36% of the IDB transport portfolio, from 2005 to 2012.

A recent OVE evaluation (RE-454-1) of BRT systems presented lessons learned from three IDB-funded BRT projects in Lima, Cali, and Montevideo. Although the projects in Cali and Lima achieved considerable in-vehicle travel time savings and environmental benefits (in the form of reduced vehicle emissions), the use of the systems by the poor living in the area of influence of the systems was lower than expected. This evaluation assesses the effects of Cali's and Lima's BRT systems on mobility and accessibility of the poor, with a specific focus on the integration of feeder lines in the poor areas of the cities, taking into account pre-existing public transit operations. In addition, it identifies determinants of and barriers to BRT use among the poor in Lima and Cali, the degree of system coverage, affordability, and accessibility, and the relative roles of access times, in-vehicle time, and monetary costs in explaining mobility preferences. Finally, it offers suggestions to improve the design and operation of future BRT systems with pro-poor objectives.

Promoting access and mobility for low-income populations is an important and increasingly a stated objective of many public transport system investments. Low-income populations often bear the highest burdens related to negative transport externalities in cities, including longer travel times and higher exposure to pollution and risk of traffic accidents. Lack of access to affordable and efficient transport generates social exclusion, impeding access to employment opportunities, services, and markets. As poor populations often live on the periphery of LAC cities, they must travel long distances to reach jobs and services in the center; thus they tend to have the longest travel times and to incur more transfers. Spatial segregation of the poor from skill-appropriate job centers decreases the affordability of job search and access and increases unemployment. Thus, for inclusive economic development, it is critical to develop integrated programs that improve both access to affordable housing in areas closer to job centers and other economic opportunities, and transportation infrastructure and services in low-income areas.

The BRT systems in Lima and Cali were designed to reconfigure the traditional and often highly informal services that tended to transport passengers from door to door along often long and oversupplied routes to a trunk-and-feeder configuration. The BRT corridor alignments pass through or reach into low-income or poor neighborhoods, and in both cities the designs include feeders that reach into poor areas to provide connections to the main BRT trunk lines.

In Lima, although the BRT system serves numerous middle-class and poor neighborhoods, it does not reach many people classified as extreme poor. Poor and very poor populations also tend to have longer walking times to access the system. One barrier to providing service in extreme poor areas is the prevalence of low-quality road infrastructure; often characterized by narrow dirt roads that wind along hillsides, moto-taxis provide most public transit in these areas. Although there are inequalities in coverage and service frequencies, some of the largest network-level travel time savings are among low-income populations in the north-western and southern areas of the city. However, usage by poor and very poor (43%) groups is lower than that of the middle class (57%), partly because of lower coverage in poor areas.

The poor have highly positive perceptions of the Lima BRT system speeds, particularly in the segregated trunk line. The integrated fare that allows a free transfer between the BRT and feeders is also generally perceived as affordable and as a positive feature of the system; however the very poor (35%) find the fare inaccessible. Additionally, many perceive the feeder service as slow and unreliable. Users complain that the buses in the trunk and feeder areas are often too full to board in peak hours, and bus overcrowding makes conditions highly uncomfortable on board.

Lima's system appears to provide the most benefits for the poor needing to take longer trips and trips to access school or jobs. Indeed, the largest travel time savings for the system would be expected to occur for trips utilizing the BRT trunk services, where buses operate in their own segregated right of way and often offer express and super express services. The statistical analysis, undertaken by the Office of Evaluation and Oversight (OVE), shows that *longer* wait times and *more* transfers are all statistically correlated with trips using the BRT system. Given that most of the poor live further from the trunk line, these trips mostly cover long distances and involve more than one mode, such as a BRT feeder or other public transit service to connect to a trunk station.

OVE's analysis also finds that being poor or very poor is associated with a statistically significant decrease in the probability of using Lima's BRT, indicating that there are significant barriers to use by the poor, who otherwise have mostly positive perceptions of trunk services. A lack of routes serving their destinations, long lines to charge cards and enter buses, and bus delays are among the top reasons cited for not using the BRT systems.[1] Affordability is in fact a barrier for the poor in using the BRT system for a large share of their trips. Given the integrated and flat fare pricing structure, the poor tend to use the BRT for longer trips for which the price becomes competitive with traditional transit modes. Nevertheless, daily trips from the periphery to the center, whether on the BRT or other transit modes, are unaffordable, suggesting that the very poor in particular may be circumscribed in the radius of opportunities that they can reach.

Cali's system provides wide coverage to the city for the poor and non-poor alike. It was designed to serve nearly 100% of the city's demand and was placed in the highest-demand corridors (north-south, east-west), connected radially through the city center. Poor neighborhoods have BRT feeder coverage in the eastern portions of the city, although several areas on the western side of the city do not receive adequate connections and service, especially in steep and hilly zones that lack sidewalks and stairs. Hilly areas, as well as low-income neighborhoods in the eastern side of the city, are now served by informal jeeps, which the transit agency is working to integrate into the BRT system. While the overall coverage of routes is fairly equal across socioeconomic strata in Cali, areas with a higher concentration of low-income populations tend to have a slightly lower supply of mass transit routes. OVE's accessibility analysis finds that on foot, 92% of the extreme poor could reach a route of the MIO in 15 minutes or less, and 90% could reach one in fewer than 10 minutes.

OVE's survey of poor public transport users in Cali finds that a greater portion of trips (58%) are via alternative public transit rather than the BRT. In contrast to Lima, poor public transit users in Cali tend to rate both feeder and trunk services as slow and unreliable. Although most respondents see the price of the system as economical, regular public transit users cite poor quality and slow service, bus delays, and long lines as the main reasons for not using the system. As in Lima, the poor in Cali tend to favor the BRT for longer trips requiring transfers, and trips to attend work or school. The system generally benefits areas that are farther from the center and in specific peripheries, irrespective of socioeconomic strata. Although the BRT system is perceived as slower than other public transit modes, the integrated fare provides a significant cost advantage over the traditional modes, for which users pay the full fare at each transfer. Users of the MIO tend to pay less than users of other public transit modes, even taking into account the tendency to use the MIO for longer trips.

OVE makes several suggestions for the IDB and its clients to consider when designing and implementing BRT systems that seek to improve access and mobility for the poor.

1. Increase spatial coverage and improve the integration of the BRT system. Integration strategies include improving the reach and frequency of feeder service and extending segregated trunk line services in poor and low-income areas, integrating the BRT system with existing informal or traditional modes, and improving connectivity and integration between the BRT and the metro and other public transit to increase access to other high-speed transit in the city.

2. Consider policy alternatives and strategies for targeting subsidies to low-income BRT users and systems. On the supply side, subsidies targeted towards BRT agencies, conditioned on service quality measures, could be considered and piloted. On the demand side, subsidies targeted to the poor could also be considered—for example, a means-based targeting scheme that discounts fares for users under a certain income threshold. When evaluating subsidies and increased coverage of BRT systems, governments should take into account positive externalities from increased usage, such as reductions in congestion, pollution, and accidents.

3. Explore mechanisms to facilitate dialogue and increase coordination among stakeholders and transport planning institutions, such as (i) improving coordination between transport authorities in the cities, (ii) supporting dialogue and coordination with current traditional and informal services to reach agreements that can boost the coverage, integration, and accessibility benefits of the system; and (iii) supporting higher user participation and representation in planning and decision-making processes related to the system's future development and operation.

4. Support mechanisms that strengthen the technical capacity of BRT authorities to increase the effectiveness of the bus operations. In this regard, the Bank should consider providing increased technical support during the initial operational stages to foster service quality through improved technical programming and route planning.

[1] Respondents to this question were poor regular public transit users living in the area of influence ofthe BRT system, who did not use the BRT at least once a week.

1

Urban transport projects at the IDB often seek to improve mobility and access to jobs, goods, and services for the poor.
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1 Introduction

Bus rapid transit (BRT) systems have become an increasingly popular approach to addressing mobility and environmental problems in urban areas in Latin America and around the world. In line with this trend, the Inter-American Development Bank (IDB) support for BRT projects as well as other urban transport in Latin America and the Caribbean (LAC) has grown rapidly in recent years: the annual lending volume for the urban transport sector grew by 36% from 2005 to 2012, to account for more than 20% of the transport sector lending portfolio. BRT systems represented roughly half of all IDB urban transport projects. These projects typically aim to increase overall mobility while also reducing negative externalities such as traffic accidents and emissions of local and global pollutants; in addition, they often seek to improve mobility and access to jobs, goods, and services for the poor.

A recent evaluation (RE-454-1) of BRT systems by the Office of Evaluation and Oversight (OVE) presented lessons learned from three IDB-funded BRT projects in Lima, Cali, and Montevideo. Although the projects in Cali and Lima achieved considerable in-vehicle travel time savings and environmental benefits (in the form of reduced vehicle emissions), the usage of the systems by the poor living in the area of influence of the systems was lower than expected.

This evaluation expands the aforementioned evaluation of the BRT project results with respect to their objectives of improving mobility and access for the poor. It assesses the effects of Cali's and Lima's BRT systems on mobility and accessibility of the poor, with a specific focus on the integration of feeder lines in the poor areas of the cities, taking into account pre-existing public transit (PT) operations. In addition, OVE identifies determinants of and barriers to BRT use among the poor in Lima and Cali. In particular, the analysis assesses the systems' coverage, affordability, and accessibility and the relative roles of access times, in-vehicle time, and monetary costs in explaining mobility preferences, in order to improve the design and operation of future BRT systems with pro-poor objectives.

2

Low-income populations often bear the highest burdens related to negative transport externalities in cities, including longer travel times and higher exposure to pollution and risk of traffic accidents.
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2 Background

Disparities in the costs of and access to transportation systems contribute to and reinforce the already high levels of inequality in LAC. Low-income populations often bear the highest burdens related to negative transport externalities in cities, including longer travel times and higher exposure to pollution and risk of traffic accidents. Lack of access to affordable and efficient transport generates social exclusion, impeding access to employment opportunities, services, and markets. Poor populations often live on the periphery of cities and must travel long distances to reach jobs and services in the center; thus they tend to have the longest travel times and incur more transfers (Ardila-Gomez 2012). While they incur long travel times to the central business districts, many also take trips to more dispersed locations.

The impacts of rapid urbanization on public transportation hold particular salience for Latin America, the world's most urbanized region. From 1950 to 2014, the share of the population in Latin America living in urban areas increased from 40% to around 80%, and is expected to increase to 90% by 2050 (Atlantic Council 2014). The increased demand for housing associated with rapid urban growth commonly leads to increases in the value of centrally located city land, pushing lower-income groups outward to the periphery of urban areas. This, in combination with budget constraints, leads to a lower capacity for travel and to an increase in social, spatial, and economic inequalities (Ferrarazzo and Arauz 2000; Kaltheier 2002; Salon and Gulyani 2010; Vasconcellos 2001).

Spatial segregation of the poor from skill-appropriate job centers decreases the affordability of job search and access, and thus increases unemployment (Kain 1992). A majority of the poor in the cities of developing countries make on average between one-fifth and one-third fewer trips per capita than the non-poor (Gakenheimer 1999).

Rapid urbanization, rising housing costs associated with economic growth, and urban sprawl lead the poor to seek lower-cost housing in peripheral zones that lack the necessary infrastructure and population density to create viable routes for transit operators.
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Their travel patterns differ widely from those of the non-poor in terms of modal selection and expenditure; either becoming captive users of public transport or relying on non-motorized travel as a result of affordability barriers. In addition, informality in the public transit sector has led to a decrease in the quality of public transportation for many of these urban spaces and has decreased access to jobs and other economic opportunities among the poor, who depend on public transit for a large share of their trips (Box 2.1 and Carruthers, Dick, and Saurkar 2005). Travel expenditures can consume 30% or more of daily wages, adding to the already-high travel time costs, which in some cases can exceed two hours (Kaltheier 2002; Vasconcellos 2001).

Access to affordable housing closer to jobs and opportunities goes hand in hand with public transport system design. Transport accessibility for the poor and non-poor alike is both a land use and a transport issue. Rapid urbanization, rising housing costs associated with economic growth, and urban sprawl lead the poor to seek lower-cost housing in peripheral zones that lack the necessary infrastructure and population density to create viable routes for transit operators. Establishing policies that improve access to affordable housing in areas closer to job centers and other economic opportunities, and improving transportation infrastructure in areas already settled, are complementary. Successful public transport systems should be a part of urban growth plans developed in response to fast urbanization and influxes of migrants from the rural zones.

Box 2.1. Informal andparatransit services

Broadly defined, informal transportation is transport that operates "without official endorsement" (Cervero and Golub 2007). Cervero (2000) defines it as transport that operates "informally and illicitly, somewhat in the background, and outside the officially sanctioned public transport sector." Shri BK Chaturvedi, on the other hand, defines it as, "Public transport that is mainly unregulated/unlicensed"(UN-Habitat 2012). Thus, it is not necessary illegal, but rather lacking partial or full regulation. Low barriers to entry in the market contribute to frequent over-competition. Most workers are self-employed, and sometimes they organize themselves into cooperatives or route associations (Cervero 2000). Whereas formal transportation is often characterized by flat fares, informal transport fare pricing tends to be distance-dependent (Cervero 2000).

Paratransit is a cross between a private auto and a public bus, emulating characteristics of the private auto by providing point-to-point, flexible routing and demand-responsive service, and those of a bus by offering a shared service carrying multiple passengers at a time and serving both short and long trips (Cervero 1997). It can operate in a range of regulatory environments, from completely unregulated free-wheeling services often seen in developing countries to highly-regulated such as in airport shuttles found in many developed countries.

Informal and paratransit operators typically use small-scale, owner-operated vehiclesthat vary widely in capacity and type—small mototaxis, motorcycles, vans, shared taxis, and up to 25-passenger mini-buses—and run unscheduled services along fixed or semi-fixed routes. Operators typically serve narrowlydefined markets, seeking to fill gaps left by the formal transport sector.Operating often without legal recognition, they often compete with the formal transit system and may serve neglected markets such as very-low-income neighborhoods where bus service is underprovided.

Potential benefits of the informal/paratransit sector include (i) service provision in areas where formal transportation would not operate, (ii) employment to unskilled workers, (iii) provision of complementary services to high-capacity fixed-route services, (iv)competitive or negotiable pricing, and (v) flexible, demand-responsive service (Cervero 2000; Schalekamp et al. 2009).

Key disadvantages include (i) high levels of accidents, traffic congestion, emissions, and air pollution associated with erratic driving from operators competing for passengers, a lack of proper driver training, driver fatigue from working long hours, overcrowding of vehicles, oversupply of vehicles, and poor vehicle quality; (ii) operators serving only the higher-volume routes and ignoring the less profitable ones; and (iii) poor working conditions for operators (Schalekamp et al. 2009; Cervero 2000).

A. Urban Transport Context and BRT System Investments in Lima and Cali

The cities of Lima and Cali are characterized by a high degree of urban socioeconomic segregation and inequality. Their low-income populations tend to live in peripheral zones and have longer journeys to main activities, which reduces overall affordability and access.

Lima, the capital of Peru, is one of the fastest growing urban areas in the LAC region. Lima's population of slightly above 9.9 million[1] represents about one-third of the population of the country.[2] Between 2007 and 2012 Lima's population increased by 11%. General trends of economic growth in Lima and Peru have led to a relatively stable increase in individual income since 2007. According to the National Information Institute (INEI), poverty rates have fallen, from 44% in 2004 to 14.3% in 2015. In 2012, national income inequality as measured by the Gini coefficient had reached 0.41—a marked decline from the rate of 0.5 in 2005.

The poor in Lima tend to live in the periphery of the city, in the northern and southern cones, while high-income populations are concentrated in the central and south-central areas of the city. Forty-two percent of the extreme poor (Stratum E) and 19% of the poor population (Stratum D) live in peripheral areas of Lima, defined as all areas at least 9 km from the city center.[3] In many cases, low-income neighborhoods are outside the immediate area of coverage of the mass transit lines in the north and west of the city.[4] The extreme poor often reside in informal settlements characterized by a general lack of infrastructure and public services (Calderón 2013). Although Lima has engaged in several long-range planning initiatives, highly fragmented institutions, poor collaboration among government agencies, and weak enforcement of zoning laws have rendered most planning efforts ineffective. [5]

The public transit system in Lima is highly chaotic and informal because of the liberalization policies of the early 1990s, when the government deregulated the public transport system, eliminating fare regulations and barriers to entry. The government allowed the import of foreign used vehicles and allowed any person or company to provide public transport service. Between 1990 and 2000, the number of public transit vehicles exploded, increasing from 10,500 to 47,000, and the number of licensed transport lines in Lima grew from 150 to 411 (DESCO 2004). Although this expansion increased services to remote and new settlements and created a form of employment, it resulted in an oversupply of aging minibuses whose drivers aggressively competed for passengers and whose services were characterized by low productivity and duplication of services along many routes. Approximately 30% of the services were considered informal (or unregulated). This oversupply and informality in the public transit sector have led to poor service quality as well as high levels of traffic accidents and air pollution (Bielich 2009).

Lower-income groups in Lima tend to have longer travel times, reflecting both longer distances and higher rates of public transit use. They have lower per capita vehicle ownership rates and make the largest share of their daily trips on foot—28% of trips by the poor (Stratum D) and 35% of trips among the extreme poor (Stratum E)—followed by trips by traditional buses (such as Combis, Colectivos, Omnibus and Microbus[6]) (analysis of JICA 2013).

Cali is the third-largest city in Colombia, with an estimated population of 2.35 million in 2014 (Department of Statistics and Census 2014). It has one of the highest poverty rates among the country's large urban areas. In 2010 approximately 586,000 individuals (26.1% of the population) in Cali lived in poverty, and around 38,000 (6.4% of the population) lived in conditions of extreme poverty; by 2015 poverty rates fell to 16.5% and extreme poverty rates to 3.4%.[7] Income in Cali is also unequally distributed (with a Gini coefficient of 0.48 in 2015). Because of the internal Colombian conflict, Cali has become an attractive destination for low-income migrants from rural areas.

Poor populations in Cali tend to concentrate in the western hills and even more predominantly in the eastern area of the city. In contrast, the middle class (in the city center) and the richest populations (in the south) reside along a north-south axis around which the city's infrastructure developed.[8] As in Lima, the poor tend to walk for a higher proportion of trips and also rely more on conventional and informal transport systems in comparison with wealthier strata (Analysis of Municipality of Cali OD Survey 2010).

In Cali, as in Lima, public transport has been characterized by high levels of congestion, informality in the public transport sector, accidents and air contamination, a weakly enforced regulatory framework, and a deteriorated road infrastructure. Motorization rates have been rising in Cali in the past decade. While most of the absolute growth has been in the form of private cars, motorbike ownership has skyrocketed because of rising incomes and increased access to financing mechanisms (Cali Como Vamos 2011). Motorcycle ownership rates do not differ significantly by stratum, indicating a strong role for the motorcycle in the mobility of lower-income groups.[9]

Lima and Cali are part of a growing number of Latin American cities that have invested in BRT systems in order to improve the quality of public transport. The BRT systems in both cities were supported by loans from the IDB and aimed at improving efficiency of local mobility, decreasing environmental impacts and reducing transport-related social inequalities.

In 2003 the IDB approved the Metropolitan Lima Urban Transportation Program (PE-0187) as part of the financing package required to build and operate the first stage of Lima's public transport system. The total public investment was originally estimated at US$134.4 million, of which US$90 million was jointly financed by loans of the IDB and the World Bank (US$45 million each), and the rest by the Municipality of Metropolitan Lima. The main objective of the project was:

> … to improve mobility conditions for the population of Metropolitan Lima, particularly among lower-income groups, and to reduce the private and social costs of providing and using mass public transportation. For this purpose, the program will establish a transportation system that is efficient, modern, reliable and safe, based on large-capacity buses circulating on dedicated bus lanes. This will make places of employment and economic and social services more accessible, mainly for the poorest population groups; it will also shorten travel time, reduce the number of accidents involving public transportation, and lessen environmental pollution (IDB, Loan Document PE187 2003).

The BRT project is part of Lima's larger Urban Transportation Program. The loan supported the first line of this program, "El Metropolitano," which is also the first mass public transit system in Lima. The corridor comprises 28.6 km of segregated busway connecting the northern and southern areas of Lima with the financial district, major universities, and the historic downtown. The system also has feeder routes that connect the two terminals with the surrounding and primarily low-income neighborhoods in the north and south cones. The project sought to formalize the informal transport sector in the area of influence of the system by scrapping old vehicles and hiring the drivers into the new system. According to the project description, the system would carry over 900,000 passengers per day, of whom 550,000 (60%) were expected to be poor or low income.

In 2002, the Colombian Government developed a National Program for Urban Transport to develop integrated public transport systems in several cities, and sought financial support from the multilateral development banks. Following the experience of Bogotá's Transmilenio, it decided to implement BRT-oriented integrated mass transit systems in the country's seven largest cities after Bogotá: Barranquilla, Bucaramanga, Cartagena, Pereira, Santiago de Cali, Medellin, and Soacha. The IDB participated in the Cali BRT project through two loans, 1659/OC-CO and CO-L1101. The project was part of a national initiative aimed at providing Colombian major cities with BRT systems. The main objective of the Cali BRT project was:

> … to improve the transportation options of the population of the city of Cali, in particular low-income segments. The Cali [integrated mass transit system] has and will continue to improve service quality, reducing travel time, accidents, and pollution of the environment, and increasing service frequency and reliability. In particular, with the implementation of a modern bus transport system that will connect

> the low- and middle-income areas of Cali with the areas where job-generating activities and social services are concentrated, the [integrated mass transit system] will benefit primarily the lowest socioeconomic segments in strata 1 to 3 (low-low to medium-low), which account for 85% of the system's users, and the Afro-descendent population, which represents 26% of Cali's urban population (IDB, Loan Document CO-L1101 2005).

The BRT system, known as the MIO, was designed as an integrated mass transit system with three segregated trunk corridors totaling 49 km, and 200 km of feeders and complementary routes. It aimed to cover nearly 100% of the public transport demand in the city. The ambitious project sought to replace most of the traditional public transport system.

B. Objectives and Methodology

This evaluation assesses the effects of Cali's and Lima's IDB-supported BRT systems on mobility and accessibility of the poor, with a focus on the integration of feeder lines in the poor areas of the cities. OVE utilized a combination of qualitative and quantitative methods: including (i) best practices research on BRT/informal transport integration in other urban areas globally; (ii) a literature review on policy approaches to increasing public transit tariff affordability; (iii) interviews with a wide range of stakeholders, including the project team leaders; local and national authorities involved in planning, managing, and operating the urban transport systems; academics; the private sector; bus companies; citizen groups; and focus groups with poor and low-income populations in Lima and Cali; (iv) a geostatistical analysis of city travel and geospatial data; and (v) a statistical analysis of OVE and city survey data on travel patterns and expenditures of the poor in the area of influence of the BRT systems. The poor were defined according to the socioeconomic stratification methodologies used by each city (Colombia's SISBEN and Lima's APEIM), with the poor and very poor defined, respectively, as Strata D and E in Lima, and Strata 1 and 2 in Cali.

OVE drew on the following data sources: (i) existing city transportation (origin-destination) surveys and transportation network models; (ii) an intercept survey[10] designed and administered by OVE in 2014 in each of the cities; (iii) population by socioeconomic strata and by traffic analysis zones (TAZs); and (iv) spatial (geocoded) data on the routes and frequencies of the BRT systems and other city public transit systems. OVE surveyed approximately 800 low-income/poor public transit users in the area of influence of the BRT trunk and/or feeder lines.[11] In addition to questions aimed at measuring socioeconomic status, the survey asked about the frequency of public transport use (BRT versus other public transit modes), perceptions of the BRT systems, and the trips taken the day before the survey.[12] Non-BRT users, defined as those who used the BRT once a week or less, were asked to state their reasons for not using the system. Finally, the survey also included a stated preference mode choice exercise.

The survey datasets were utilized to analyze the travel patterns, rates of usage of the BRT versus competing public transit modes, perceptions of the BRT services among the poor, and factors influencing public transit mode choice.[13] To measure affordability, OVE compared the share of income spent on public transportation costs to an affordability benchmark (discussed below) and the cost of a fixed basket of trips at rates taken by the non-poor, to estimate the degree to which the poor may forgo trips because of affordability issues. The affordability indices were calculated and compared among BRT and non-BRT users using expenditure data in the surveys. To control for trip distances, OVE also compared trip costs as a percent of income between the BRT and traditional modes for common origin-destination pairs among low-income travelers. Finally, the spatial analysis assessed the degree of coverage of poor areas, walking access to the system, and changes in travel time and public transit supply by socioeconomic strata. OVE combined the city transportation demand models and TAZs, defined in the models, with data on population by socioeconomic strata. A TAZ is defined as predominantly from a given stratum when the highest share of population in that zone comes from that stratum (see Annex II).[14]

C. Measuring Accessibility and Affordability of Urban Transport

Accessible and affordable transport systems offer a means to reach essential life-shaping opportunities such as jobs, education, shops, and social activities (Ohnmacht, Maksim, and Bergman 2009; Lucas 2012). Transport system accessibility can generally be defined as the potential for opportunities of interaction (Hansen 1959), the ease of reaching any area of activity using a given transport system (Dalvi and Martin 1976), and the overall benefits provided by the system (Ben-Akiva and Lerman 1979). Definitions of accessibility rely on indicators of the ease of reaching specific destinations inside the city, given a number of available opportunities and the travel-related costs to reach those opportunities within a time and budget constraint (Bocarejo and Oviedo 2012). Finally, activity-related definitions link land uses and location of economic or other opportunities, giving particular attention to the number of activities that can be reached within a given range of travel costs such as travel time, distance, and monetary costs.[15]

Transport system affordability measures the burden of trip costs on households' budgets. Affordability measures include observed and potential affordability. Observed affordability focuses on actual travel behaviors. The traditional observed affordability index calculates household expenditure on transportation or public transportation as a share of disposable income (Falavigna and Hernandez 2016).[16] Other affordability measures utilize monthly household expenditure instead of income (Blumenberg 2003) given that, especially among low-income populations, income might be relatively unstable from month to month, whereas expenditure is more stable and a better measure of a family's economic well-being since households tend to smooth consumption (Diaz-Olvera, Plat, and Pochet 2008). Because of the high degree of interconnectedness between housing and transportation, some experts use a combined housing and transportation affordability index. Such an index accounts for the fact that, for example, some individuals choose to live in a particular location that offers lower housing costs and tolerate higher associated transportation costs (Litman 2015).

A key limitation of *observed* affordability measures is that they may exclude trips forgone because of budget limitations. Therefore, affordability can be particularly inaccurate for the lowest-income populations, who may not take trips because of financial constraints (Falavigna and Hernandez 2016). To address this limitation, some experts suggest the use of a *potential affordability* measure, or *fixed-basket-trips* measure. This estimates the number of public transit trips a household would take if they were not sacrificing any necessary trips (Falavigna and Hernandez 2016), and divides this value by some measurement of income or expenditure. For example, Carruthers, Dick, and Saurkar (2005) compute affordability based on the assumption of 60 trips per month, which includes commuting to work plus a number of additional trips, multiplied by the public transit fare per trip.[17]

The literature is inconclusive regarding how much of a household's income or expenditure should go toward transportation for it to be considered "affordable." The most common figure among experts and governments is 10%—that is, transportation is unaffordable for households whose transportation expenditures comprise more than 10% of their household income or total expenditure (Mitric and Carruthers 2005; Armstrong and Thiriez 1987). However, other experts and governments have used figures of 6% (Mitric and Carruthers 2005) and 20% (Litman 2015). Studies on transport expenditures in LAC find that the poor often spend a significantly higher share of their income on transport than the non-poor. For example, in 2002 in Buenos Aires, the average public transport expenditure to commute to work as a share of income was 31.6% for the bottom income quintile compared to 12.8% for the general population (Carruthers et al. 2005). In São Paulo, the lowest-income group spent over 30% of their income while the highest-income group spent 7% (Carruthers, Dick, and Saurkar 2005).[18]

In efforts to enhance public transit affordability, governments have utilized both supply-side and demand-side subsidies.[19] Accurate targeting is a key challenge for transportation subsidies (Box 2.2 and Estupiñan et al. 2007). Demand-side subsidy targeting mechanisms include (i) means-tested targeting, in which some measurement of a household's socioeconomic level is used to determine eligibility for the subsidy; (ii) categorical targeting, in which individuals receive a subsidy because they belong to a certain group, such as students or elderly people; (iii) self-selection, in which characteristics of the benefit discourage those who do not need the subsidy from utilizing it (through free or discounted service at lower quality than full-cost service, for example); and (iv) geographical targeting, in which subsidies are directed toward entire neighborhoods that have large shares of low-income households. In order to maximize benefits to the poor, supply-side subsidies might be conditional on certain pro-poor services, such as covering financially unviable routes to more remote areas where the poor live (Estupiñan et al. 2007) (see Annex I for an extended literature review).

Box 2.2. Public transit subsidies and targeting in Santiago, Chile

From 2003 to 2006, bus fares in Santiago increased by 31% as a result of rising fuel prices (Estupiñan et al. 2007). From 2004 to 2006, the Government provided direct money transfers to low-income households to offset rising transportation costs. A study by Gómez-Lobo (2007) found that this transfer policy provided better targeting than other subsidy strategies, including subsidies on prices of fuel or bus fares. Beyond more effective targeting, another benefit of this policy was that it avoided some of the distortionary consumption and production effects associated with subsidizing fares or altering fuel prices.

D. Integration of the Informal Transit Sector in BRT Systems

BRT system implementation can exacerbate affordability and accessibility issues by eliminating the traditional informal systems that are tailored to the needs of poor households. The implementation of BRT systems is often accompanied by regulation of pre-existing (often informal or paratransit[20]) systems to improve the efficiency and quality of services. Integration of informal providers into modern mass transit modes can improve public transit quality for many people, particularly the poor, by improving safety conditions and streamlining fares, among other benefits. However, the reduction of informal transit services may stifle flexible and often less expensive paratransit services that a high-capacity trunk and feeder system may not be designed to provide, thereby reducing services the poor rely on in outlying areas. No standard, successful strategy exists to guide transitions from the point-to-point services associated with an informal system and the trunk-feeder services associated with a modern BRT system (Hernandez, Cochran, and Chatman 2015). In addition, regulators can find it difficult to make integration-oriented reforms because of the resulting political backlash from economic stakeholders such as route and bus owners, and bus operators (Schalekamp et al. 2009; Hernandez, Cochran, and Chatman 2015).

One integration scheme is to provide financial incentives such as tax cuts on vehicle registration and other fees to motivate private operators to fill needs where public buses, for example, would be very expensive to run (Cervero 2000). Such an approach can be particularly advantageous in some poor communities where narrow streets inhibit passage of large buses, or where low passenger volume would make a particular route financially unviable. Another intervention to better integrate the formal and informal sectors is to make strategic investments in infrastructure for the informal sector. Traditionally, governments have invested large amounts in infrastructure that improves road conditions for private vehicles. However, investments in infrastructure that are targeted toward informal operators may have a larger benefit for the poor, who are more likely to use informal transportation. One example of such an investment is off-street parking for informal operators.[21] Regulation of the informal sector should focus on promoting safety standards and providing liability insurance for operators (Cervero 2000). Other regulatory dimensions that should be considered include entry into the market, coverage, and vehicle emissions standards.

An evaluation of various potential regulatory schemes for Rio de Janeiro, Brazil, found that a multipronged regulatory approach to informal transportation would result in the greatest benefits to public transportation users (Golub et al. 2009). A combination of regulating the informal sector through entry regulations for vehicles, eliminating monopolistic power in the formal sector by establishing competitive bidding processes, and improving mass transit levels of service would work to reduce flooding of the market by informal operators, while creating a profitable environment for both formal and informal operators (Cervero and Golub 2007) (see Annex I for more information on integration strategies).

3

Lima's BRT system was designed to connect travelers from the northeast and south to downtown, in one of the highest-demand corridors in the city.
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3 Findings

The evaluation findings for each city are structured along five evaluation dimensions: (i) BRT coverage and accessibility; (ii) system use and perceptions; (iii) affordability, tariff policies, and subsidies; (iv) determinants of BRT use; and (v) BRT system integration. They are preceded by a brief description of the systems' planning and design

A. Lima

Lima's BRT system was designed to connect travelers from the northeast and south to downtown, in one of the highest-demand corridors in the city. The planning of Lima's BRT system took into account several criteria and objectives: (i) construction capacity, (ii) total passenger demand for PT, (iii) speed or cost of execution (because the Via Expresa already had a busway, execution was less costly and faster since it required fewer changes to street configurations and infrastructure), and (iv) attention to poor populations.

The system was also planned to reach the poorest areas of the city in the northern and southern cones with feeder routes. A study on low-income beneficiaries at project inception found that the main transport issues among the poor included long travel times and the discomfort of the services, most of which were highly informal, and poor quality of service (DESCO 2012). Despite serious concerns with safety, the combi was the preferred mode because it was faster than other available public transport modes. Users reported a willingness to pay 30% more for improved services.[22]

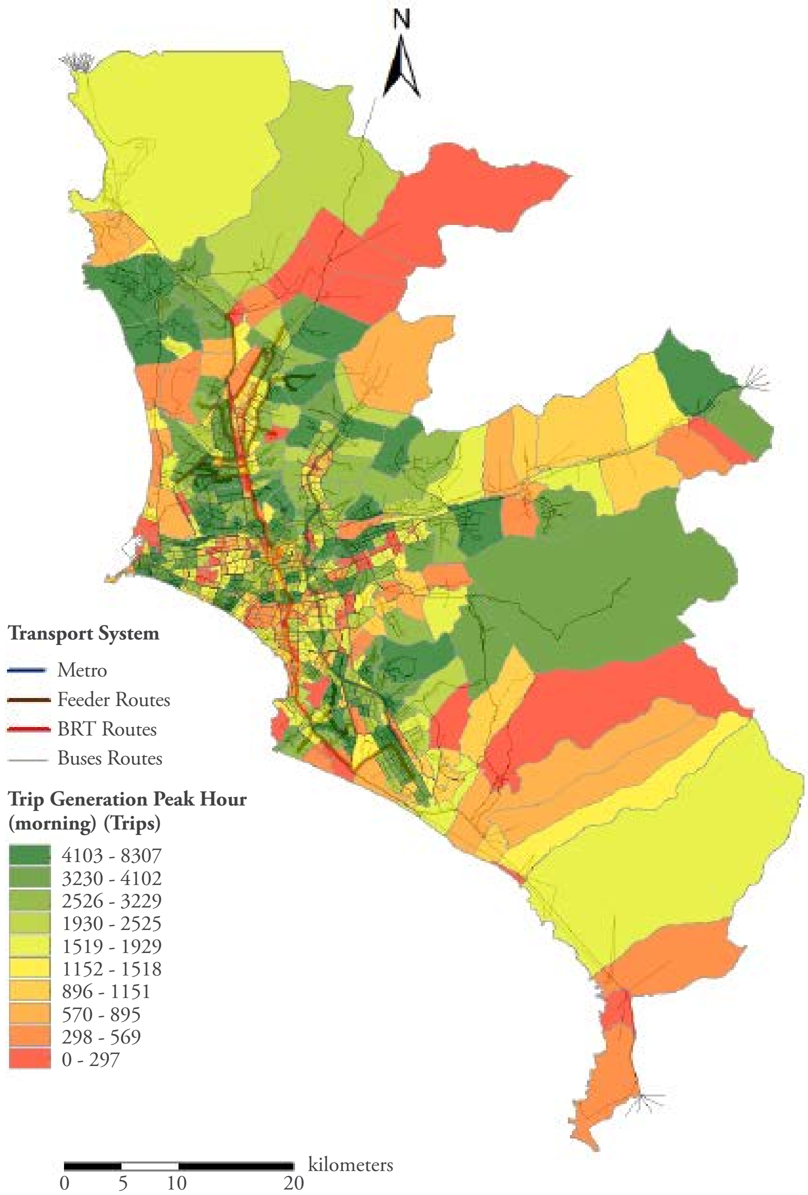
Analysis of Lima's origin-destination survey reveals a predominantly periphery-to-center morning commute pattern. A high share of morning trips originate from outlying areas, where lower-income residents are concentrated, and terminate in the center of the city; however, there are also a considerable number of trip destinations in the far north, eastern, and western portions of the city (Figure 3.1). For example, TAZs in the outskirts of the city and primarily composed of Stratum E generate 61,000 trips during the morning peak, but attract only 31,000 trips in the same period. Similarly, Stratum D and peri-urban zones generate 361,000 trips in the peak hour, 32% of daily public transport demand in the morning peak.

Figure 3.1a

Low-income zones in Lima generate 42% of transport demand in the morning peak, while they attract only 25% of trips in the same period

Lima: Spatial distribution of generation (left) and attraction (right) of trips in public transport

Source: OVE, based on data from INEI (2007), GTU, Protransporte, and JICA (2013).



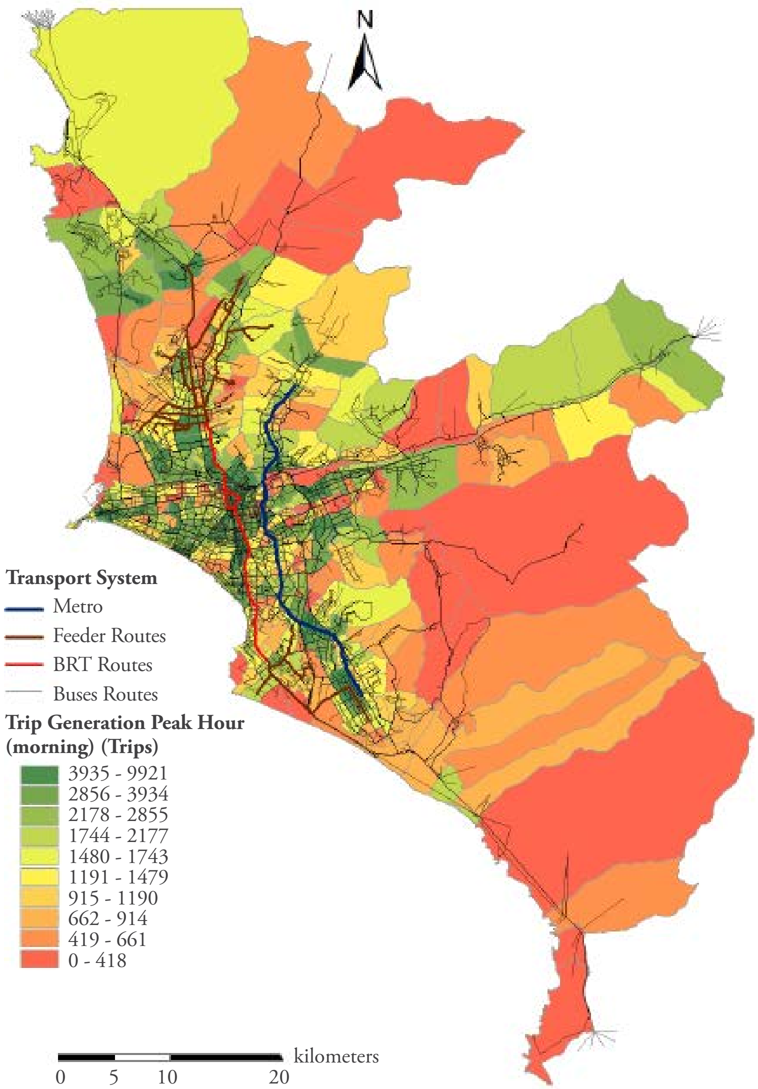


Figure 3.1b

Low-income zones in Lima generate 42% of transport demand in the morning peak, while they attract only 25% of trips in the same period

Lima: Spatial distribution of generation (left) and attraction (right) of trips in public transport

Source: OVE, based on data from INEI (2007), GTU, Protransporte, and JICA (2013).

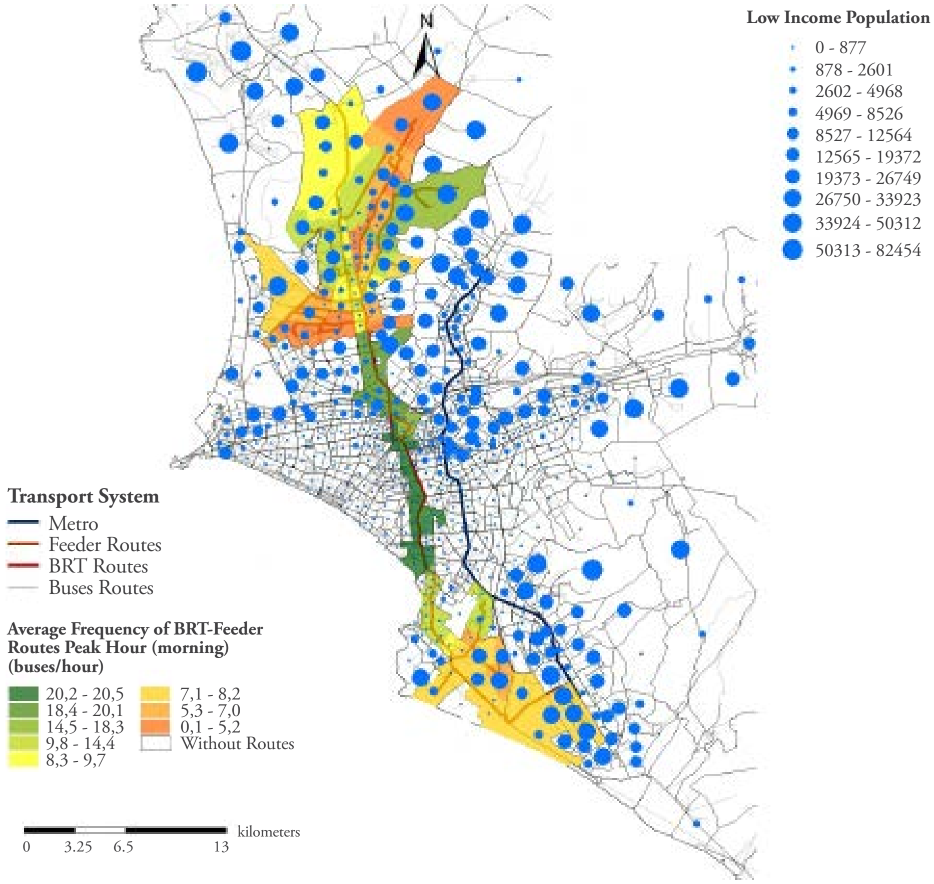
1. BRT coverage and accessibility for the poor

The Metropolitano north-south trunk line is supplemented by 19 feeder routes in the north and 5 feeder routes in the south. The feeder system increases the reach of the BRT system and has improved the mobility of people who live very far in the outskirts of the city (Figure 3.2). For example, for some individuals it might decrease their travel time from three or four hours to two hours. However, overall, the BRT reaches middle- and low-income areas (Strata C and D), but does not reach many extreme poor (Stratum E) areas, in part because there are often no roads where they live (settlements tend to be irregular and informal). Roads that do exist in these neighborhoods are often narrow, unpaved, and wind along hillsides. Stratum E travelers primarily rely on mototaxis in the absence of other options. Interviewees noted that people in Stratum E generally do not travel much because they lack income or jobs.

FIGURE 3.2

Spatial coverage of the Metropolitano

Source: OVE, using data from INEI and Protransporte.



OVE's quantitative analysis of the coverage of the system finds that middle- to lower-income areas receive the highest coverage of the BRT system, with trunk lines providing service in predominantly upper-income areas and feeders concentrated in predominantly low-income zones. The analysis finds that the zones that are primarily composed of extreme poor (Stratum E) receive very little service: only 3% of such zones enjoy feeder service. No Stratum E areas are near the trunk line (Table 3.1).[23] By contrast, 31% of the zones served by the Metropolitano are in Stratum C. Middle- and lower-income zones within the system's area of influence are covered by an average of 9 to 10 BRT routes, while Stratum E zones within the area of influence have only one route on average.

OVE's analysis of walking accessibility to the system by strata finds that poor populations tend to have longer average walking times to access the system compared to other income groups. Figure 3.3 shows the percent of the population (vertical axis) that can reach the BRT system within a given number of minutes (horizontal axis) by stratum. Nearly 35% of the population of Stratum C and 25% of D lives within 15 minutes' walking distance of the Metropolitano, while only 12% of the population in Stratum E can reach the system by foot in this time.[24]

Table 3.1. Travel zones within the area of influence of the Metropolitano, by strata

Stratum	# of zones in the city	# of zones covered by trunk	% of zones w/ trunk service	Avg trunk routes per zone	Avg feeder routes per zone	# of zones with a feeder	% of zones with a feeder	Total zones with a BRT	% zones in city with a BRT
Extreme poor (E)	29	0	0%	0	1	1	3%	1	3%
Poor (D)	150	3	2%	6	2.5	35	23%	38	25%
Low-middle income (C)	197	21	11%	4	4.2	41	21%	62	31%
Upper-middle income	100	16	16%	4	2.2	5	5%	21	21%
High income	52	9	17%	5	0	0	0%	9	17%

Source: OVE analysis, using data from INEI (2007) and Protransporte (2016).

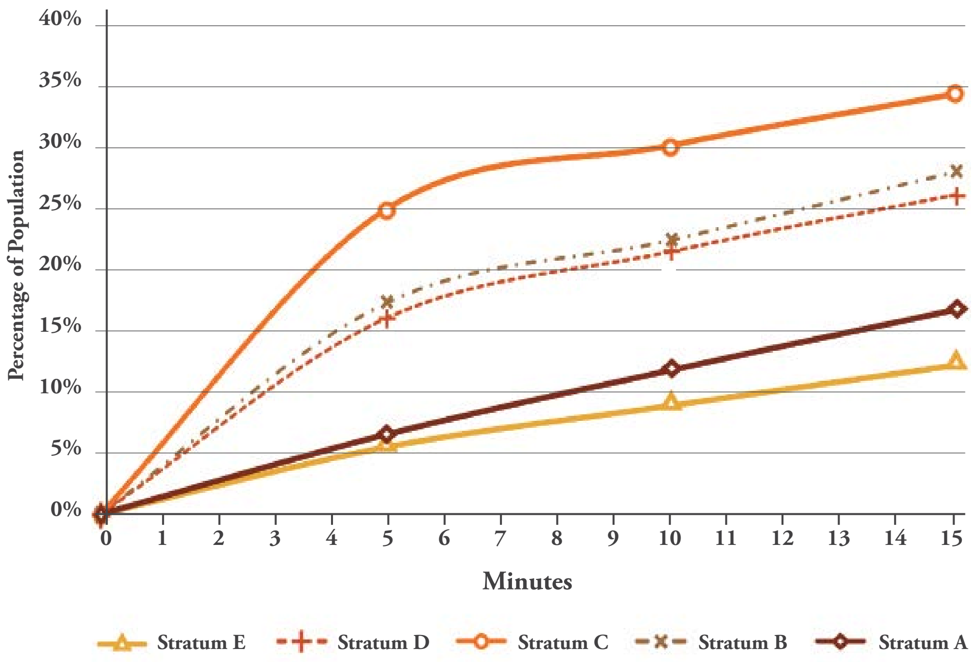


Figure 3.3

Walking distance to the BRT by socioeconomic strata

Lima: Cumulative distribution

Source: OVE analysis, based on data from INEI (2007) and Protransporte (2016).

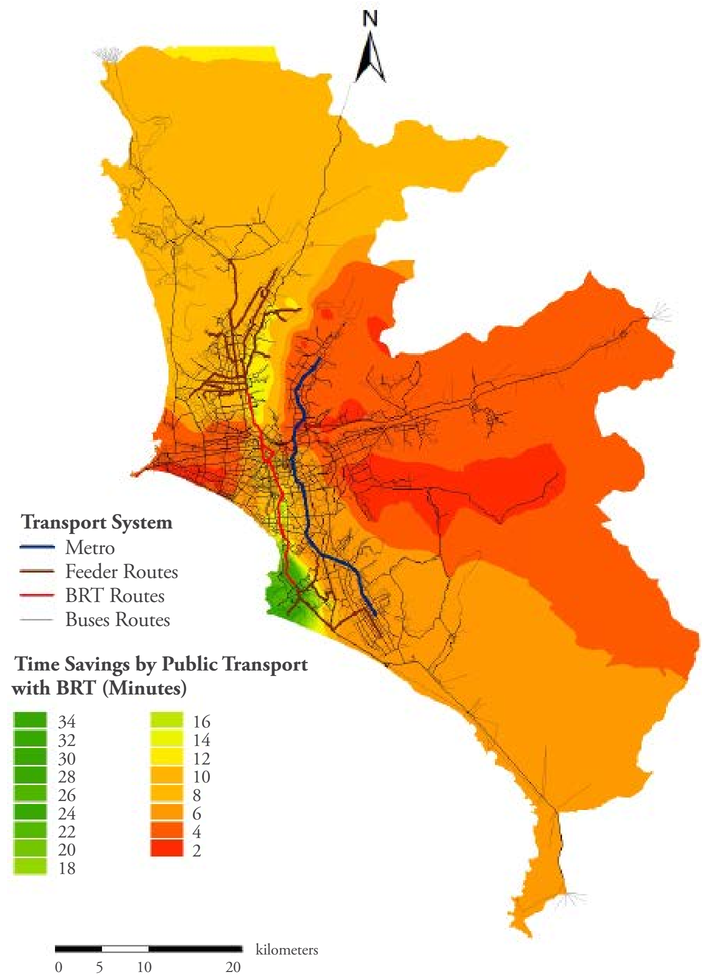
OVE's analysis also estimated the distributional impacts of the BRT on the supply and frequency of public transport services, measured in terms of available seats during the morning peak. The BRT scenario assumes a degree of substitution of the traditional public transport in the corridors where the Metropolitano trunk and feeder lines operate, according to available information for the public transport network in Lima. The largest increase in public transport supply is observed along the trunk line and north-west side of the feeder system.

Despite inequalities in coverage and service frequencies, OVE's network analysis[25] finds some of the largest network-level travel-time savings among low-income populations in the north-western and southern areas of the city (Figure 3.4). Although average network time savings in travel zones for all strata are around 7 minutes,[26] time savings in the city can be up to 34 minutes in some zones of Stratum C, while maximum savings in Strata D and E can be up to 32 and 28 minutes, respectively (Figure 3.5 and Annex III).

Figure 3.4

Network travel-time savings in Lima with the BRT system

Source: OVE, using data from Protransporte and Municipality of Lima Urban Transport Agency (GTU).



2. Usage and perceptions of the BRT system

The system has attained its goal of having 60% of its riders from socioeconomic Strata C, D, and E; however, the share of ridership by poor and very poor (43%) people is lower than that from the middle class (57%).[27] Many interviewees attribute lower rates of ridership among the poor to the fact that the BRT often does not reach where they live and work. A focus group conducted in San Juan de Miraflores in the south of Lima revealed that many of the poor there do not use the BRT because it does not reach where they live. It also does not reach the factory areas (many located in Callao), where many of the poor work.

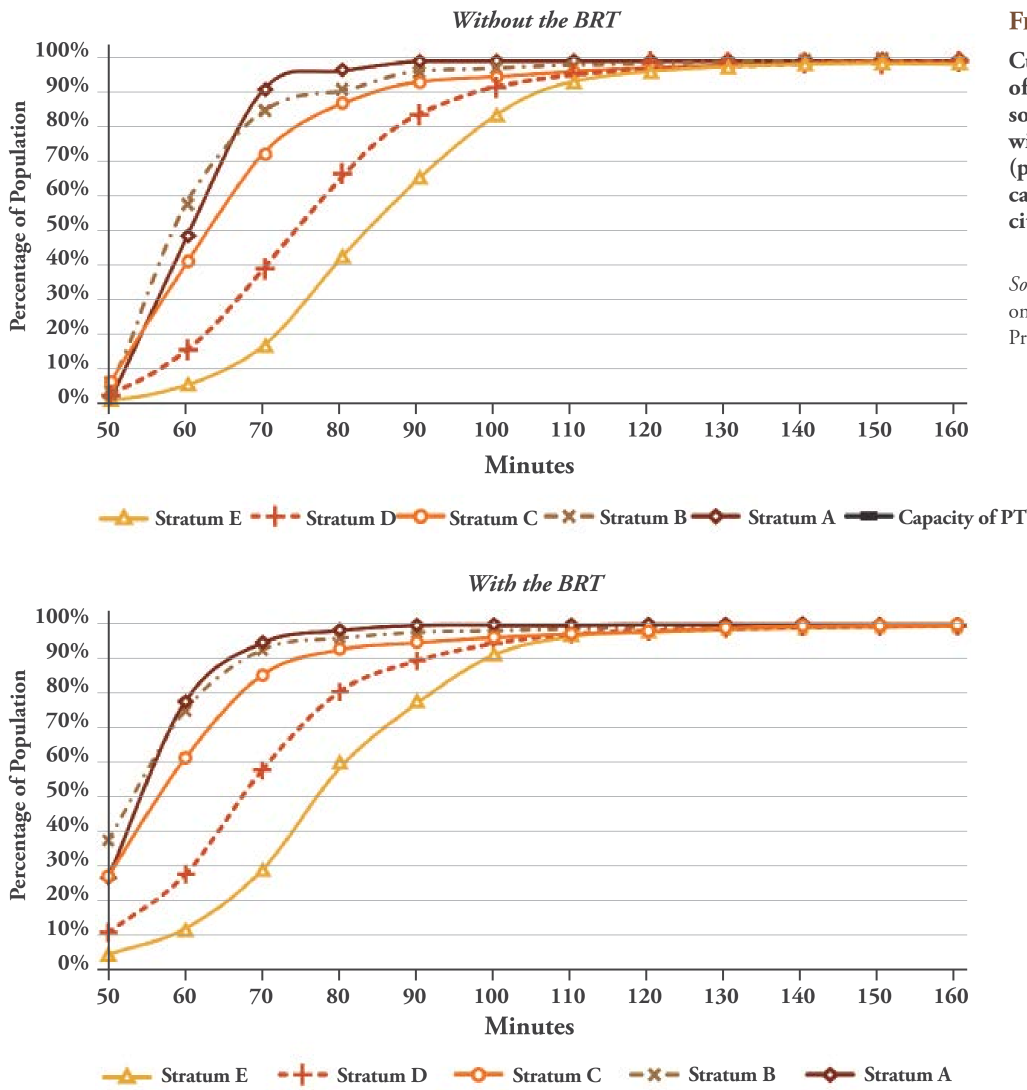


Figure 3.5

Cumulative distribution of accessibility by socioeconomic strata without and with BRT (percent of population that can reach all points in the city network within a given

Source: This evaluation based on data from INEI (2007) and Protransporte (2016).

OVE's survey shows that among trips taken on the BRT, the majority of trips (60%) involved both the trunk line and the feeder line, while a smaller portion involved just the trunk line (21%) or just the feeder line (19%). While these trends are consistent among the poor (Strata D and E) and low-middle-income (Stratum C) populations, BRT ridership in all forms was higher among Stratum C in the sample than it was among the poor. Table 3.2 shows the breakdown of trips including at least one BRT stage as a percent of all trips in the sample. Specifically, more than half (56%) of survey respondents from Strata C, D, and E were regular users, defined as those who use the BRT more than once a week; however, a majority of the respondents who used the system more than once a week were in the low- to middle-income strata, and just 19% of regular users were poor or extreme poor (Figure 3.6). In comparison, while 57% of the extreme poor had used the BRT at least once in the previous week,[28] 97% had used other public transit modes more than once a week. Informal modes (combis, custers, and buses[29]) play an important role as a feeder service to the BRT trunk, with 30% of all BRT trunk line trips involving such modes to access either the BRT or the final destination from the BRT trunk line (Table 3.3).

Figure 3.6.

Use of the BRT and other public transit among populations living within 1 km of system, by socioeconomic strata (%)

Source: OVE analysis of OVE's survey.

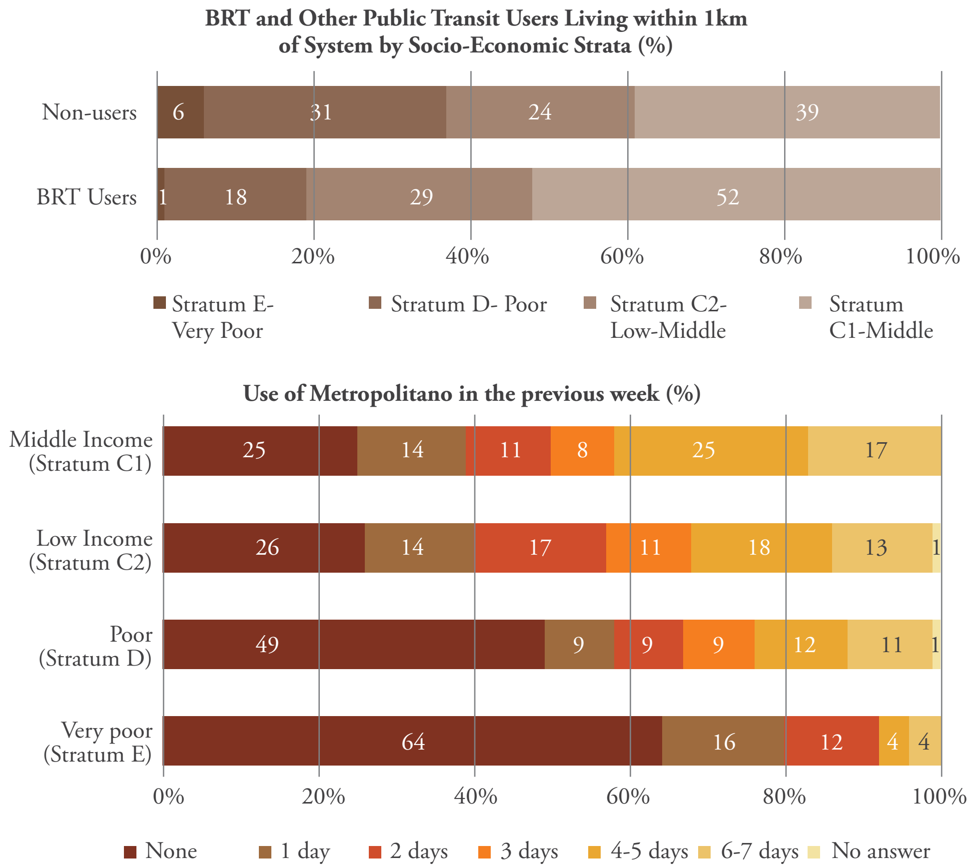


Table 3.2. Lima share of BRT trips by BRT components

Poverty status	Trunk only (% of BRT trips)	Feeder only (% of BRT trips)	Trunk & feeder (% of BRT trips)	BRT usage rate by poverty status (% of all trips)
Low-middle income (Stratum C)	20%	21%	59%	40%
Poor (Strata D & E)	15%	24%	60%	25%
All (Strata C, D, & E)	19%	21%	60%	36%

Source: OVE utilizing OVE's survey data.

OVE's survey asked low-income public transit users living near the BRT system to rate various aspects of the BRT system, including speed, reliability (or wait time), and affordability. Notably, the speed of the BRT trunk services (where buses operate in dedicated lanes and receive signal priority at intersections) received high marks: 80% of BRT users rated the express services (which operate skip-stop services in dedicated lanes to and from high-demand stations) as fast or very fast,[30] and 48% rated the local BRT trunk line service that stops at each stop in the dedicated corridor as fast or very fast. However, feeder services in poor neighborhoods were generally perceived as slow or very slow; only 21% of users thought that the feeders provided fast or very fast service. Perceptions were similar but slightly less favorable for non-users:[31] only 16% stated that the feeders were fast or very fast. Waiting time for feeder buses was also often considered long or very long (53% of Stratum D and 64% of Stratum E).

Table 3.3. Lima BRT trunk access mode

BRT Access Mode	Trunk only		Trunk & BRT feeder		Total		Share of BRT trips
	No. of trips	%	No. of trips	%	No. of trips	%	%
Formal mode (BRT feeder, walk, taxi)	204	43	274	57	478	100	70
Informal mode (combi, custer, bus)	73	35	133	65	206	100	30
Total	277	41	407	60	684	100	100

Source: OVE utilizing OVE's survey data.

The extreme poor were significantly more likely than any other strata to charge their transit card each time they used the system, compared to any other strata (48% of E versus 33% for D and 39% for C), indicating a potential barrier for this group. Given long lines at ticket machines in peak hours, this increases the total time needed to use the system and may discourage potential users with budget limitations.[32] Among BRT non-users in Strata C, D, and E, the lack of connectivity and accessibility to specific areas of the city was the most frequent reason (67%) for not using the BRT. Long lines to charge cards and enter buses (21%) and bus delays (13%) were other common explanations for infrequent or no use.

Low-income transit users in focus groups cited one of the biggest problems with the Metropolitano as crowding of stations and feeder buses in their neighborhoods.[33] During peak hours the trunk line stations can become crowded and have long lines, both to charge cards and to get onto the buses. Especially for those who do not board at the first station, it can be difficult to get on, because all of the buses that pass might be filled with people, and there are more people trying to get on the bus than people getting off the bus. Users commented that they sometimes have to wait as long as 15 minutes to get onto a trunk line bus. To get on feeder buses, they sometimes have to wait 15 to 20 minutes. For some people in the north who live along the feeder line, the feeders are so full that they do not stop at their bus stop, because they would not be able to take on any additional passengers. Hence, some areas, even though they are technically along a BRT feeder line, remain uncovered by the BRT system.

Despite the capacity and frequency challenges of the BRT, some of the low-income focus group participants viewed it as the best transportation option, in part because of its speed. Whereas a combi might take one hour to cover a given distance in traffic, the Metropolitano covered that same distance much more quickly because of its designated lane and other operational characteristics. Even with the extra waiting time due to bus crowding and lines, they said the Metropolitano still gets them to places more quickly. Many interviewees, including local experts and focus group participants from the north and south, believed that the trunk line should be extended in the north (11 km) as was originally planned, to increase high-speed services in their neighborhood. This would not only increase the number of poor with access to faster trunk services, but would also increase the operational efficiency of the feeders, whose routes would be substantially shortened.

3. Affordability, tariff policies, and subsidies

The Metropolitano's fares are calculated to cover operating costs, because the system is required to be financially self-sustaining. Flat fares that allow free transfers may increase the affordability of longer trips involving transfers. In December 2014, Protransporte increased the trunk line fare from 2.00 soles to 2.50 soles. In March 2015, it decreased the fare for feeder lines from 0.80 soles to 0.50 soles. The fare is integrated, so using the feeder and trunk lines in one trip costs 2.50 soles. In comparison, the traditional bus system charges by distance, beginning at 0.50 soles.

The Metropolitano provides discounts or free rides to students, police, and disabled people; with around 80% of users paying full price. Police and firefighters, who make up around 3% of Metropolitano users, ride the system for free. Students, around 17% of users, pay half price to use the system. Free ridership for severely disabled people recently gained approval as well. One of the results of this pricing system is that the poor, who do not receive discounts, essentially assist in subsidizing the fare for police, firefighters, and students. Because the BRT system has a flat fare (not dependent on distance traveled), there is de facto a cross-subsidy on longer trips that experts argue benefits the poor. The poor—who tend to live in the more peripheral areas of the city and thus travel longer distances than higher-income groups when taking the trunk line to destinations in the city center—thus receive a subsidized fare in terms of distance traveled. Many of the shorter trips taken by low-income populations are more economical via the traditional system, which has distance-based pricing.

According to Lima's 2013 OD travel survey, low-income Metropolitano users spent on average 55% more than their counterparts who did not use the Metropolitano (OVE's analysis of JICA OD 2013 data). Metropolitano users also experienced travel times that were on average 47% longer than those of non-users. Given the trunk-feeder configuration, the reduced-stop spacing in segregated corridors, and the flat integrated fare, the BRT would have a comparative advantage for longer trips, a possible explanation for the longer average travel times and expenditures.

Perceptions of the price of the BRT vary by degree of poverty and rate of usage. OVE's survey of the poor found that 46% of BRT users felt that the price of using the system is either economical or very economical. However, the very poor were more likely to rate the system as not affordable (35%). Equal shares of users and non-users—24%—felt the system was either expensive or affordable (with the remainder of respondents being neutral or stating "no opinion"), indicating that price may not be the primary deterrent among non-users.

Focus group participants also felt that the price of the Metropolitano is affordable. In particular, they said that it is very affordable for long distances. Users explained that the route they travel, if taken in a combi instead, might cost 5 or 6 soles (more than double). Another benefit of the Metropolitano's pricing is that it is reliable. According to participants in focus groups in low-income communities, combis can often charge very unstable prices. For example, they often do not respect the 50% discount for students as they should. Additionally, if they are covering a route with little competition, they might take advantage of the scarcity of transportation options and raise their prices, threatening to kick out a rider who contests the higher price. However, despite the price stability benefits of the Metropolitano, a bus operator noted that the price of a Metropolitano card (4.50 soles) acts as a barrier for the poor to start using it.

OVE's affordability analysis found that low-income public transit users living within the area of influence of the BRT system spent over 20% of their income on public transport, more than double the 10% threshold that many experts define as affordable (see section C above). Transport expenditures among the entire sample average 22% of personal monthly income, and the poor to very poor (Strata D and E) pay slightly more as a percentage of their income (23%) (Table 3.4). Indices for BRT versus other public transit users in the sample vary little, with the poor paying more for non-BRT modes as a share of income.

Table 3.4. Lima: Observed affordability as a percent of income

Poverty status	BRT users	Non-BRT users	All PT	Obs
Stratum C	22%	20%	22%	542
Stratum D y E	22%	23%	23%	191
Total	22%	21%	22%	733

Source: OVE, analysis of OVE's survey data.

The fixed-basket affordability index, which accounts for potential trips forgone because of budget constraints, shows that average expenditures would rise to 35% of the personal income of the poor if they took all trips using the Metropolitano and at the daily trip rate of the non-poor (Table 3.5). In comparison, the fixed-basket index for other public transit modes would rise by only one percentage point from the observed affordability measure of 22%.[34] The average fixed-basket index is considerably higher among the poor than among middle-income groups. In a hypothetical scenario in which all trips in the fixed-basket estimate are carried out using the BRT system, travel expenditure represents 40% of the mean income of the poor (Strata D and E) and 33% of the mean income of the non-poor (Stratum C).

Table 3.5. Lima: Fixed-basket affordability index (in % of income)

Poverty status	All public transit users	BRT users	Non-BRT users
Stratum C	26%	33%	22%
Stratum D y E	32%	40%	26%
Total	28%	35%	23%

Source: OVE, analysis of OVE's survey data.
Note: Fixed basket assumes trip rate of the non-poor (2.4 trips/day * 30 days/month).

To compare the affordability of trips via the BRT versus traditional transit modes across similar distances, OVE selected the four most frequent origin-destination pairs in the dataset as case studies (Comas to Downtown ("Cercado de Lima"), Comas to Independencia, internal trips within Comas, and Independencia to Los Olivos). Indices for trips from Comas to downtown Lima (approximately 16 km) estimate the degree of affordability to reach jobs and opportunities located in the city center (Table 3.6). A fixed-basket calculation for work trips from Comas to downtown shows that the BRT is slightly more affordable than traditional modes (13% versus 14%), but accessing downtown for all trips in a month quickly becomes unaffordable *regardless* of the public transit mode taken (reaching 24-25% of income of the poor using either the BRT or traditional modes).

Notably, the BRT affordability indices for shorter-distance OD pairs in the north of Lima are higher than traditional transit. For example, expenditure on trips between Comas and Independencia, which are 8-9 km apart, would represent 19-21% of monthly income for the BRT but 11-12% using other public transit modes. Traditional public transit trips for this case are considerably less expensive, since not only are the fares for the traditional system lower and distanced based, they also entail fewer transfers.

Short trips within poor neighborhoods, such as those within Comas, are often taken using traditional modes; however, when using the BRT, trips are typically on feeder services. Feeder trips cost 1 sole at the time of the survey and are now 50 centavos, which makes the BRT as affordable on average as non-BRT trips. Medium-distance trips requiring a BRT transfer, such as Comas or Los Olivos to Independencia, are more expensive than non-BRT trips for both groups. Affordability on the BRT is similar to that of the non-BRT for long (15 km +) and short (<4 km) trips within the area of feeder service, but traditional public transit is more affordable for medium-distance trips between districts requiring the combination of a BRT feeder and trunk trip.

Table 3.6. Fixed basket monthly affordability indices for common origin-destination pairs by district among poor users in the North Cone (as % of income)

OD pairs	Poverty status	BRT	Non-BRT
Comas residents to and from:			
Downtown (work trips only*) (16 km)			
	Poor Non-poor All	14% 13% 13%	15% 13% 14%
Downtown (16 km)			
	Poor Non-poor All	24% 20% 21%	25% 21% 22%
Independencia (8-9 km)			
	Poor Non-poor All	21% 19% 19%	12% 11% 11%
Within Comas (2- 3.5 km)			
	Poor Non-poor All	11% 9% 10%	10% 9% 9%
Independencia residents to and from:			
Los Olivos (6.5 km)			
	Poor Non-poor All	13% 9% 10%	9% 6% 7%

Source: OVE, analysis of OVE's survey data.
**Note:* All refers to Strata C, D, and E, poor to Strata D and E, and non-poor to Stratum C.

The poor take shorter and more local trips using traditional transit modes, which cost comparatively less than the Metropolitano for shorter trips and tend to choose the BRT for longer trips, given the system's flat integrated fare. For example, 72% of public transit trips from Comas were by BRT (and the remainder by other PT), while 66% of trips between Comas and Independencia were made via non-BRT transit modes such as combis and moto-taxis; a majority of within-district trips are via such modes, as well (see Figure 3.7). Therefore, the analysis suggests that the poor may not limit the number of trips but their length, with implications for job and other opportunity radio.

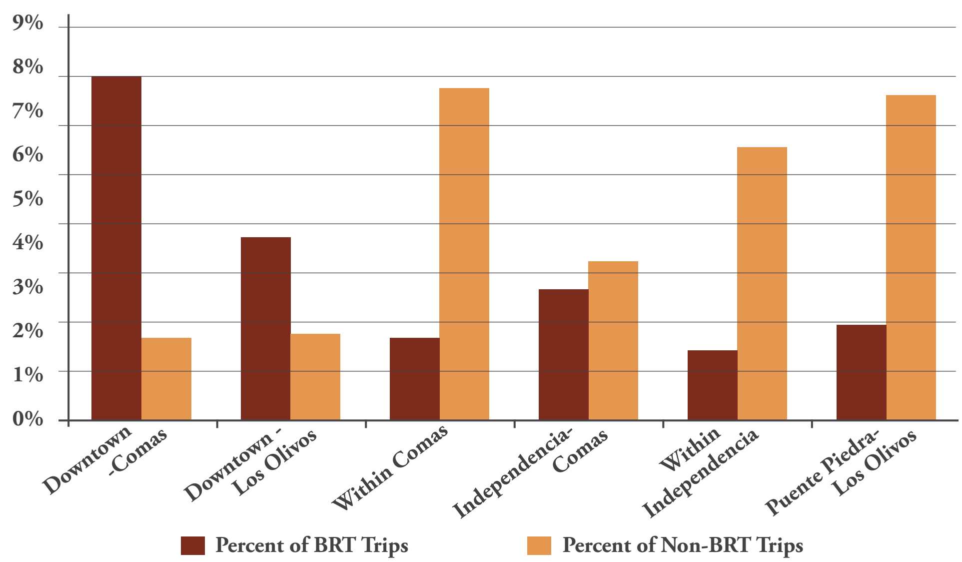
4. Determinants of BRT system and other public transit system usage

To better understand the factors influencing the usage of the Metropolitano system, OVE estimated a statistical model[35] to analyze usage as a function of trip characteristics (purpose, wait time, walking time, in-vehicle time, etc.) and demographic variables (gender, age, poverty, education). OVE finds that BRT usage is correlated with longer wait times, lower in-vehicle travel time, and more transfers. For example, a one-percentage-point increase in the probability of using the BRT is correlated with a 23-second increase in wait time among low-income groups living in the north and south cones.[36] The BRT is much more likely (12.4 percentage points more) to be used when making a trip for work or education purposes, indicating that users are willing to pay more for income- (or future income-) generating trips. Conversely, a reduction in one percentage point in the probability of BRT usage is correlated with an additional 5 minutes of in-vehicle time.[37] The results also show that a one-percentage-point increase in the probability of BRT usage is correlated with a 3.5-percentage-point increase in the probability of having an additional trip transfer.

FIGURE 3.7

Six most frequent OD pairs by transit mode

Source: OVE analysis of OVE's survey data.



This result is driven by the fact that low-income BRT users make more transfers than when they travel by other public transit modes. This is likely explained by two factors: (i) the largest travel time savings would be from trips in the trunk services, where buses operate in their own segregated lane and often offer express and super express services (skipping some or several stops) between high-demand stations during peak hours; and (ii) most of the poor live farther from the trunk line and would therefore more often need to take a feeder or other public transit service to connect to a trunk station. Thus, consistent with results found in the rest of this evaluation, transit users in the north and south cones are willing to wait longer and make additional transfers in exchange for the in-vehicle travel time savings offered by Lima's trunk services.

As compared to being in Stratum C, being poor or very poor is associated with a statistically significant 7.1 percentage point decrease in the probability of using the BRT.[38] This implies equity concerns about the viability of the BRT system as a transit option for the poor.

OVE complemented the previous statistical analysis with a stated preference analysis of public transport users in the areas of influence of the BRT system.[39] A calculation of the trade-offs between time and cost derived from the analysis suggests a value of time of 3.56 Peruvian soles per hour traveled. Results of the general model suggest that an increase in 3 minutes of travel time has the same negative effect on the perceived utility of a transport mode as 0.17 soles of extra fare. The standard value of time for the poor segment of the sample is higher than for the very poor, suggesting a greater tendency to have longer trips in exchange for lower costs in the lowest-income group.

5. BRT system and feeder integration for social inclusion

Interviewees described the coverage and frequency problems of the feeder routes as a vicious downward cycle fueled by lack of technical capacity and funding for the operation of the system. Because initially there was not enough demand on some feeder routes, Protransporte established new routes to keep the feeder buses busy. This led to decreased frequency on each route, which caused demand on each route to decrease further because of increased wait times. The frequency of the buses on the feeder routes is therefore very low. The decision to lower the price of the feeder system in March 2015 may be helping to curtail this cycle. Another problem that the feeder operations experience is bunching: because the buses operate in mixed traffic, the actual headways can deviate substantially from planned headways—buses get stuck in traffic and therefore arrive in bunches rather than arriving evenly spaced out.

According to numerous interviewees, including bus operators, various government officials, and experts, although increasing the number of buses in service could help, many of the capacity issues that the system experiences could be resolved by improved bus programming. The current bus programming is generally described as being of poor quality and not dynamic, and bus operators cited potential efficiencies to be gained from more modern programming.

Non-government and government interviewees alike said that often local government transport agencies, including the BRT agency, lack the technical skills necessary to perform their transport planning and programming work well, since the government lacks funding to hire people with strong technical expertise. Lima, as a local government, has a very small budget of 900 million PEN – much smaller than that of other metropolitan areas of similar size. One cause for the lack of funding for local public transport systems is the politicization of urban transport finance. Many interviewees cited the national government's prioritization of the Lima Metro as a key example of how Lima's political challenges compound transportation issues. With the $600-800 million that it cost to build the Lima Metro Line 1, some argued that the government could have achieved larger gains by instead allocating funds to the more cost-effective bus-based systems.

B. Cali

Cali's system was designed to serve the highest-demand corridors (north-south, east-west), connecting radially through the city center. MIO's original planning and implementation scheme was to gradually replace traditional and informal buses with integrated public transport services. The proposed route map covered most of the city, although not evenly, with a great oversupply of public transport in some areas and very limited options and routes in others (Jaramillo, Lizárraga, and Grindlay 2012). The original design, approved by CONPES (DNP 2002; IDB 2005), was adjusted in 2007 by downgrading the easternmost trunk line to a pre-trunk corridor (reflecting a variety of factors, including updated estimates of actual demand and financial considerations). However, that eastern part of the city is characterized by very high density and the highest concentration of low-income users. Although an origin-destination survey was carried out and informed the design, in practice the design of MIO's trunk lines and feeders was primarily based on the routes used by the traditional system (IDB 2005). Although one of the objectives of the project was to improve mobility for the poor, no specific analysis was conducted to inform the system's design in this regard.

Since operations began, the city has increased the coverage of integrated public transport services throughout the city, and several of these investments have been targeted to low-income areas. However, the transit agency lacks the resources to provide sufficient frequency to meet demand. Although the goal of the current government of Cali for the MIO system was to attain 100% spatial coverage in the city, the financial and technical assessments of the requirements for achieving this objective were such that Metrocali decided not to continue the geographical expansion of the system. This is mainly related to constraints to maintaining services with minimum standards, particularly in peripheral areas. Instead, additional resources have been targeted at increasing the availability of buses where frequency is very low.

1. BRT coverage and accessibility for the poor

In Cali, poor neighborhoods in the eastern portions of the city have BRT feeder coverage; however, several areas on the western side of the city do not have adequate connections and service, especially in steep and hilly zones lacking sidewalks and stairs, where many MIO buses had difficulties with the terrain. Hilly areas, as well as low-income neighborhoods in the eastern side of the city, are now served by informal jeeps (Steer Davies Gleave 2013), which the transit agency is working to integrate into the BRT bus system. In 2015 the city built a cable car to provide access to the MIO system for poor communities living in the hilly areas to the west. This system operates essentially as a feeder for the MIO trunk services and coordinates its schedule with the MIO, to allow for integration between the two systems.

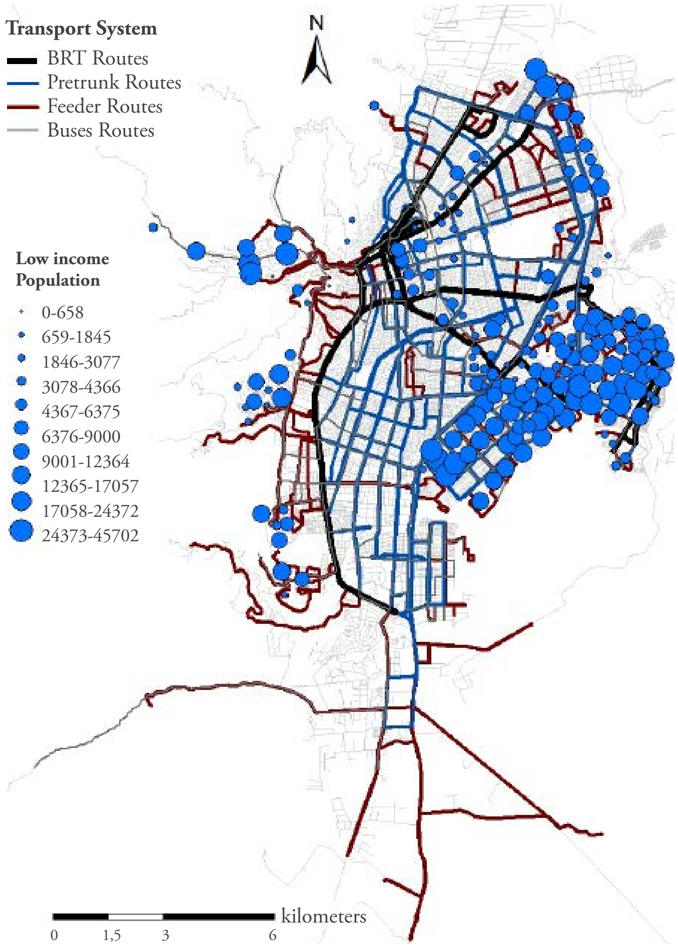


Figure 3.8

BRT coverage and location of low-income populations in Cali

Source: OVE, using data from Metrocali (2015, 2016).

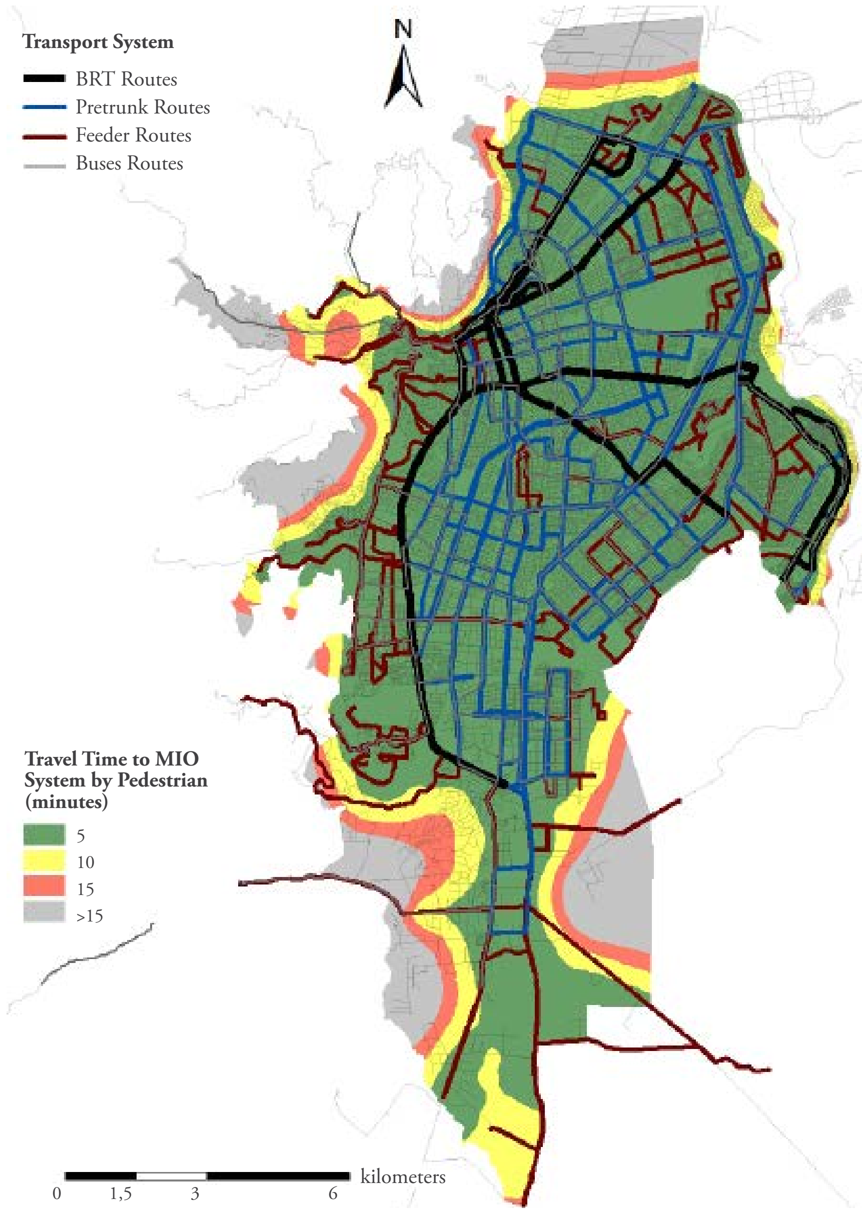
OVE's accessibility analysis finds that 92% of Cali's extreme poor can reach a MIO route in 15 minutes or less, and 90% can reach one in under 10 minutes on foot (Figures 3.9 and 3.10).[40] Although people outside of the coverage area would have to walk a maximum of 65 minutes if they wanted to reach MIO services on foot, 78% of this population could reach the system within half an hour. For Strata 2, 3, 4 and 5, 98% of people can reach a MIO route within 20 minutes walking, and maximum walks are up to 35 minutes. In Stratum 6, the highest-income group, however, the coverage is slightly lower: some of the population of this stratum lives in high-value land on the periphery of the city.

Overall coverage of routes is fairly equal across strata areas, with low-income areas receiving a slightly lower coverage of mass transit routes. Coverage of the MIO services is nearly ubiquitous, with at least one route in 96% of the city's TAZs (Table 3.7). Most strata have over 90% MIO coverage, with the least coverage in Stratum 1; an average of 87% of Stratum 1 zones have MIO coverage. The number of routes per zone (12-13) is similar for most strata; Stratum 5 has the highest zone average, at 17.

Figure 3.9a

Walking accessibility to the MIO and frequencies of buses

Source: OVE, based on data from Metrocali (2015, 2016).



Bus frequencies are slightly lower in the lowest-income neighborhoods (Figure 3.9). On average, 7.1 buses per hour traverse low-income zones, compared with 8.3 in middle-income zones, and 8.6 in high income zones. Thus while MIO has reached very good levels of spatial coverage, the frequency of buses in low-income areas, especially in Stratum 1, is considerably lower (Figures 3.8 and 3.9 and Table 2, Annex III).

Analysis of the spatial distribution of the total public transport availability finds the lowest supply of public transport, measured as available seats during the morning peak, around the far edges of the city (Figure 3.11). In particular, the southern and eastern areas of the city have the lowest baseline bus transit supply and show marginal changes in the scenario with the BRT system. As Figure 3.11 shows, the largest increase in public transport supply due to the MIO is in the northern, central, and south-central areas of the city. Compared to a non-MIO scenario, the MIO has a larger spatial coverage of services, larger vehicle capacity, and better operational conditions, particularly in trunk and pre-trunk services. The resulting increase in capacity is positive for many zones in the city compared to a scenario with only traditional public transport.[41]

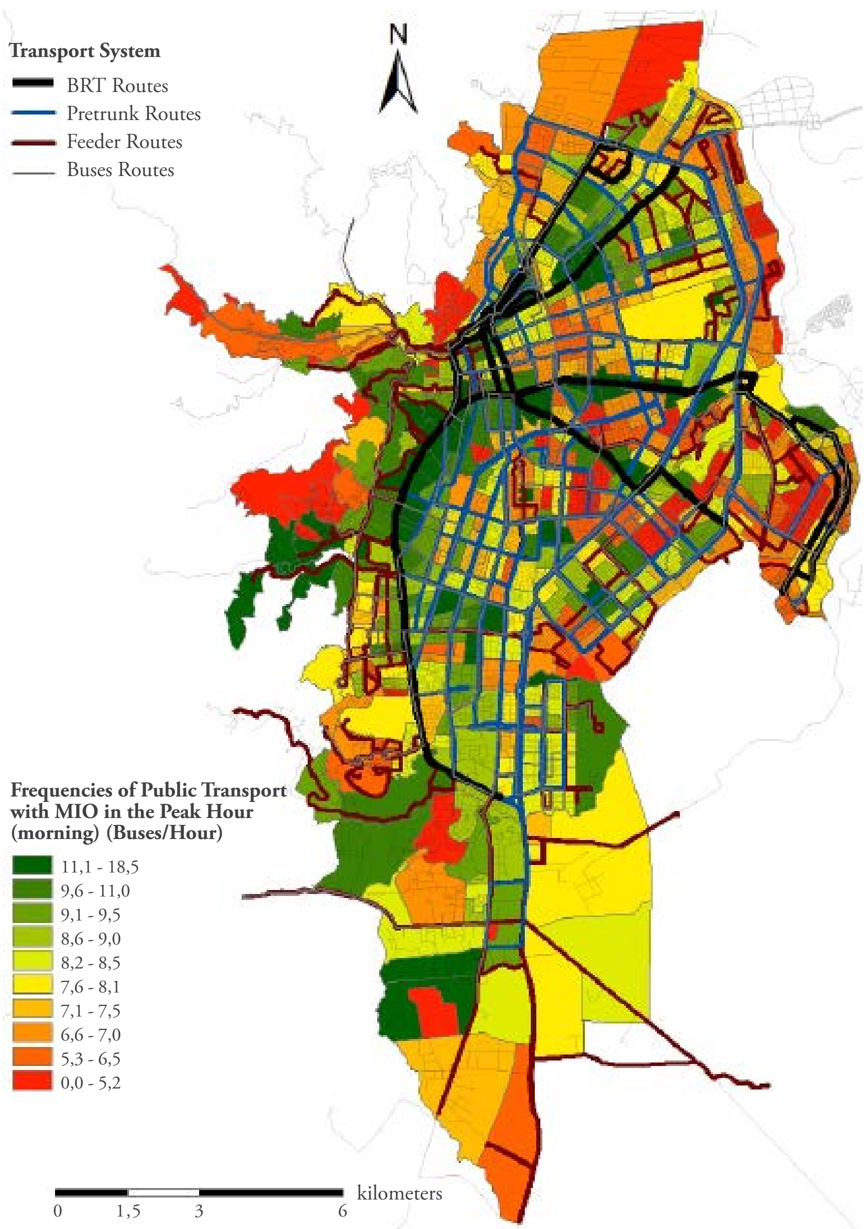


Figure 3.9b

Walking accessibility to the MIO and frequencies of buses

Source: OVE, based on data from Metrocali (2015, 2016).

FIGURE 3.10

Cali: Cumulative distribution of population with pedestrian access to BRT system by strata (percent of population within 15-minute walk to the system.)

Source: OVE, based on data from Metrocali (2015, 2016).

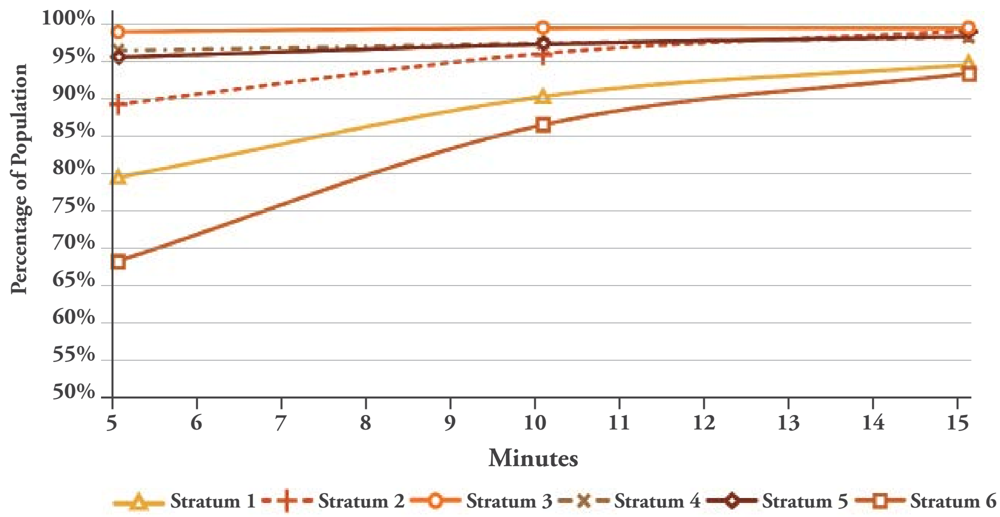


TABLE 3.7. MIO BUS ROUTE COVERAGE BY STRATA

Strata	Number of zones in Cali	Zones covered by MIO	Average MIO routes/ zone	Average frequencies/ zone	% of zones covered by MIO
1	62	54	12	6.3	87%
2	124	118	13	7.5	95%
3	156	154	13	8.3	99%
4	58	55	13	8.2	95%
5	76	75	17	8.8	99%
6	27	25	11	8.2	93%
Total	503	481	13	8	96%

Source: OVE, based on data from Metrocali (2015, 2016).

The restructuring of the public transit system is benefiting areas that are farther from the center and in specific peripheries, irrespective of stratum (Figure 3.12). Approximately 90% of the population of Stratum 1, and nearly 80% of the population in Stratum 2, experienced time savings of at least 11 minutes. Although all socio-demographic groups experienced benefits from these additional public transit services and better operational conditions, Strata 1 and 6—the lowest- and highest-income populations—receive the highest time savings with the BRT. Network time savings in the city can be up to 35 minutes in some zones of Strata 1 and 6, while maximum savings in Strata 2 and 5 can be up to 25 minutes. The middle class is better located and thus already had lower travel times compared to those living in the periphery; their travel time savings can be up to 25 minutes for Stratum 3 and 20 minutes for Stratum 4. Since the highest-income groups often settle in more remote areas of the city, they experience travel time savings benefits similar to those of the peri-urban poor.

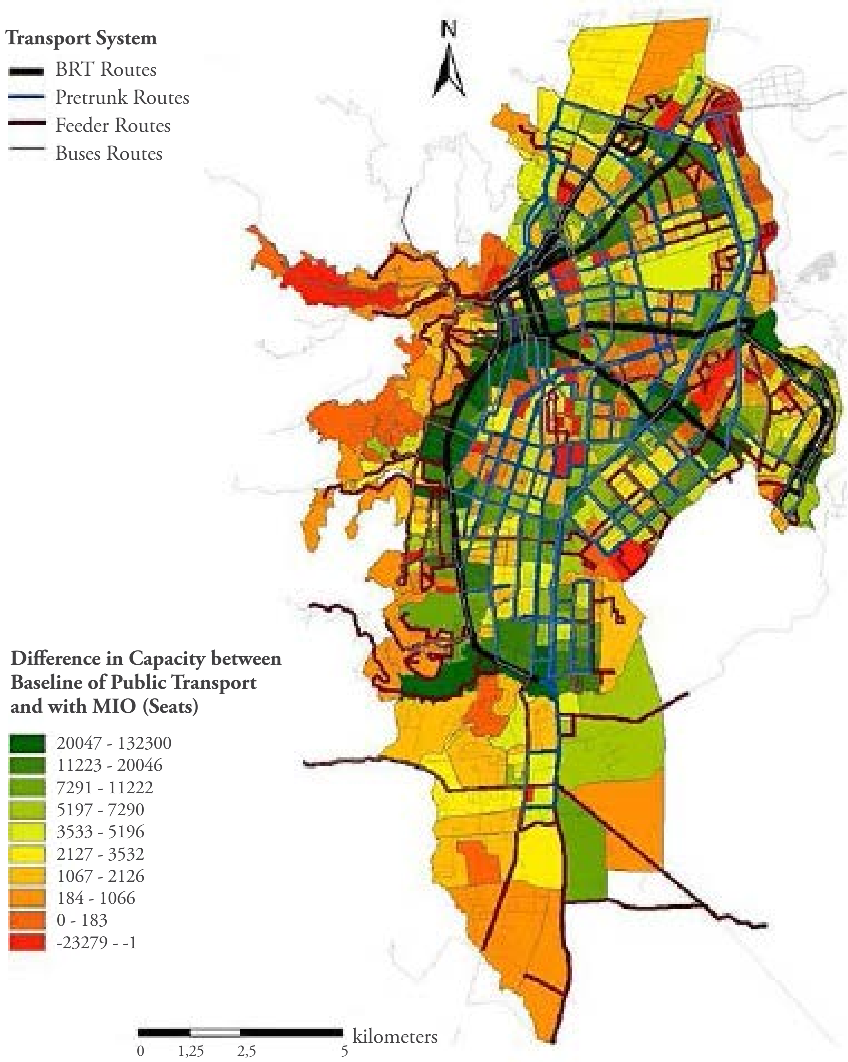


Figure 3.11

Change in bus service availability in Cali

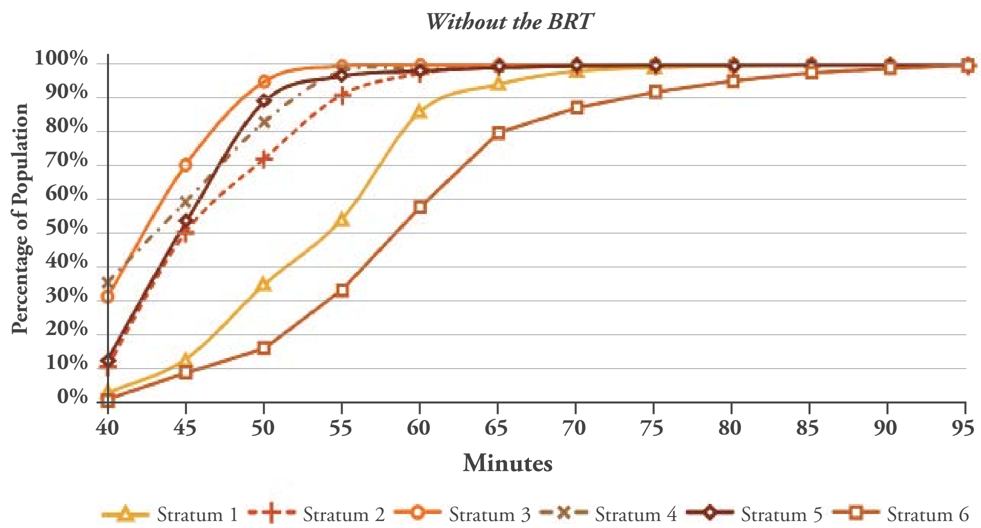
Source: OVE, based on data from Metrocali (2015, 2016).

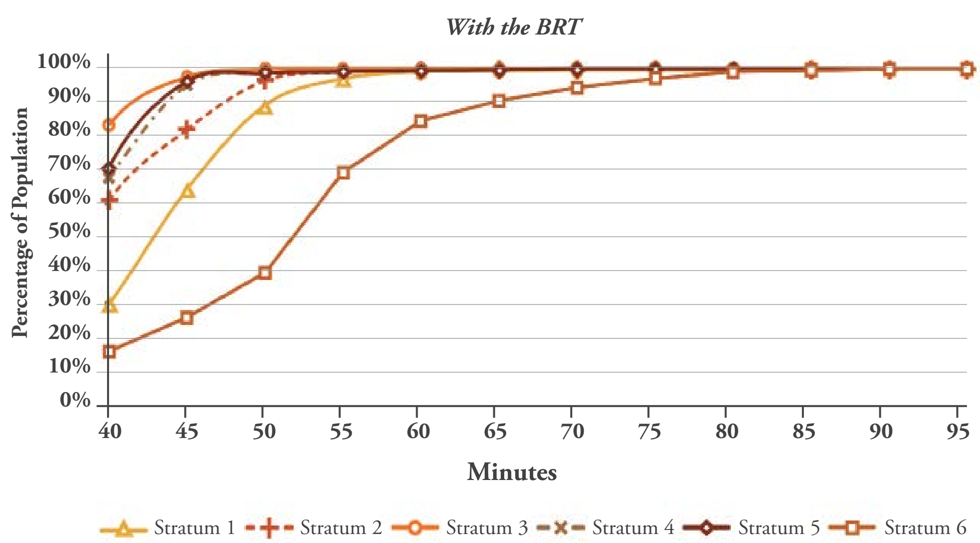
2. Usage and perceptions of the BRT system

Ridership on the MIO among the poor was initially low (about a fourth of what was expected) but has steadily increased over time. Initial use of the system by the poor was low in comparison to other public transport forms, and in comparison to rates of usage by middle-income groups. For example, analysis of Cali's 2010 origin-destination survey shows that 7% of the extreme poor (Stratum 1) and 9% of the poor (Stratum 2) used the MIO, while 43% and 29% of Strata 1 and 2, respectively, took other forms of public transit (such as conventional or informal buses). Among low- to middle-income groups, 10% of Stratum 3 and 9% of Stratum 4 used the MIO, and they took other forms of public transit 21% and 10% of the time, respectively. In later years, as the system expanded, use by the poor and very poor increased. An ex-post evaluation commissioned by Metrocali in 2013 found that the MIO is the main mode of public transport for middle- and lower-income groups. However, the MIO is still used more by Stratum 3 than by Strata 1 and 2.

Figure 3.12

Cumulative BRT system coverage (% of population) by travel time





Source: This evaluation uses data from Metrocali (2015, 2016).

OVE's survey shows that most trips on the MIO system used just the trunk line (53% of all BRT trips in sample), while a smaller portion used just the feeder line (20%) or the trunk and feeder lines combined (27%). While these trends were consistent among the poor and the extreme poor, MIO ridership in all forms was higher among the poor in the sample than it was among the extreme poor. Tables 3.8 and 3.9 show the breakdown of trips that include at least one MIO stage as a percent of all trips in the sample. In comparison to Lima, the informal and traditional transit sector plays a minor role in carrying passengers to the BRT trunk line, accounting for only 2% of BRT trunk line trips.

Table 3.8. Cali: Share of trips in sample using MIO components

Poverty status	Trunk only (% of BRT trips)	Feeder only (% of BRT trips)	Trunk and feeder (% of BRT trips)	Total use of BRT by poverty status
Poor	49%	25%	26%	39%
Extreme poor	57%	15%	28%	29%
Total	53%	20%	27%	33%

Source: OVE, using OVE survey data.

Table 3.9. Cali BRT trunk line access modes

BRT access mode	Trunk only		Trunk and feeder		Total		Share of BRT trips
	No.	%	No.	%	No.	%	%
BRT feeder or walk	282	72%	108	28%	390	100%	98%
Informal modes (Camperos)	7	88%	1	13%	8	100%	2%
Total	289	73%	109	27%	398	100%	100%

Source: OVE, using OVE survey data.

For the very poor, modes such as informal camperos (jeeps) are still important (serving close to 10% of all trips and 2% of BRT trunk trips), and for Stratum 3 the taxi has an important role (24% of daily trips). OVE's survey of poor (Strata 1-2) public transport users in Cali confirmed this trend, finding that 26% of *all* the trips taken by low-income users involve the BRT. If walking trips are excluded, the BRT serves an even greater portion of trips: 42% of trips use the BRT and 58% use non-BRT PT.

Most survey respondents characterized the services as either slow or very slow, with only slight differences between the opinions of users and non-users. In general, compared to non-users, regular users of MIO have a more positive perception of the speed of feeder services, though the poor have a less positive perception of this feature than extreme poor. Compared to non-users, regular users of the system also have a less favorable perception of the reliability of trunk services, with more respondents stating that trunk buses are unreliable or very unreliable. The share of respondents stating that the system is very unreliable is much higher among the poor than among the very poor. Adjustments to system scheduling in stations and stops in or adjacent to low-income neighborhoods may improve approval ratings and use of the MIO among the poor. The majority of the survey respondents perceived the price of the fare of MIO as fair, with some exceptions; a slightly lower proportion of MIO users than of non-users stated that it was fair (62% of non-MIO versus 55% of MIO users). The main reasons low-income public transit users cited for not using Cali's BRT were that

(i) other modes of public transit reached their destinations more quickly (32%), (ii) the MIO buses were often delayed (18%), and (iii) lines at stations were too long (18%). Notably, 10% of OVE's survey respondents among non-BRT users living near the feeder routes cited long walks to bus stops as a barrier.

3. Affordability, tariff policies, and subsidies

In Cali, as in Lima, the BRT is required to be financially self-sustaining; thus fares must cover operational and maintenance costs. As a result, the fare for MIO is 1,800 Colombian pesos (COP). In contrast, the price of traditional and informal services is not only negotiable and paid in cash, but it can also be as low as 1,200 COP. Informal service modes include motorcycle-taxis, jeeps, and collective taxis.

The 2010 Cali citywide OD survey analysis shows that travel times for BRT users were 4 minutes longer (7% difference) on average than travel times of collective transport users, and travel costs were 130 COP (11%) lower on average. Integrated fares and the introduction of feeder routes that reduce the need to transfer are factors that likely explain the lower costs for MIO users (analysis of 2010 OD survey).

The MIO's spatial coverage and integrated system is an advantage in terms of affordability, as transfers are less expensive than the traditional system. As a result, the affordability of the MIO system is similar to that of non-MIO alternatives for both the poor and the very poor. Indices are more favorable in Cali, on average, than in Lima, with mean expenditure below 20% of income for most groups (Table 3.10). Public transit trips are marginally more expensive for the poor than the extreme poor. Table 3.10 shows the similarities between monthly MIO trips and non-MIO trips. The mean expenditure per month on MIO trips as a share of income is 7% lower than that of non-MIO trips, which suggests that differences in the affordability index for both groups are related to the distribution of income of users and non-users (Stratum 2 uses more non-MIO). The trip basket analysis suggests that if all trips were conducted in the MIO, the affordability index would not be much higher than if all trips used non-MIO public transit alternatives.

Table 3.10. Cali observed affordability as a percent of income

Poverty status	MIO users	Non-MIO users	All PT
Poor	18%	20%	18%
Extreme poor	16%	17%	16%
Total	16%	18%	17%

Source: OVE analysis of OVE survey data.

The average fixed-basket affordability index for the MIO is 5 percentage points higher than the average observed affordability index (22%, compared to 17%); this difference is slightly larger for the extreme poor (Table 3.11). The affordability index for all public transport trips shows that average expenditure tends to decrease slightly with higher socioeconomic strata. There is an important effect of coverage and connectivity in the MIO system that, in combination with the integrated fare, results in improved affordability for the poor compared to alternative transit services.

Table 3.11. Cali fixed-basket affordability index (in % of income)

Poverty status	All PT	MIO users	Non-MIO users
Poor	20%	20%	20%
Extreme poor	22%	21%	26%
Total	21%	21%	24%

Source: OVE analysis of OVE survey data.

4. Determinants of BRT system and other public transit system usage

OVE's statistical analysis of the factors influencing MIO usage finds that the poor favor the MIO for longer trips. In particular, a one-percentage-point increase in the probability of MIO usage is correlated with a 1.3-percentage-point increase in the probability of having an additional transfer.[42] This may be explained by the fact that fare integration improves the affordability of trips requiring transfers, increasing the relative attractiveness of the system for trips involving a large number of interchanges and trips that cover longer distances.

OVE's analysis also finds that – as in Lima – the MIO is considerably more attractive for trips to work and education than those for other purposes. For trips with vocational or work purpose there is an increase of 13 percentage points in the probability of choosing MIO.[43] The system's extensive coverage (92% of the city) and supply of services connecting areas of high activity to the rest of the city may increase its relative value related to non-MIO alternatives for trips to the city center and other areas of highly concentrated employment.

Travel cost is negatively correlated with MIO usage. This is consistent with findings from the survey questions on perceptions and the analysis of stated preferences. Coefficients suggest that for every percentage point increase in the probability of using the MIO,[44] travel costs decrease by 100 COP. These results suggest that the poor in Cali are not willing to pay more for the MIO than for other transportation alternatives. This might be attributable to the quality-of-service issues that were documented both in other survey questions regarding perceptions of service and in focus groups; in particular, recall that the poor did not hold the speed of the feeder *or trunk* services in Cali in high regard.

Being poor, older, and a car owner are factors associated with not choosing the BRT system over alternative transportation modes. Specifically, being *very* poor is associated with a 7.1-percentage-point decrease in the probability of using the BRT as compared to not being poor. This can be correlated with variables such as price, as the very poor have lower purchasing power, as well as higher segregation and limited coverage that may require more transfers and longer walking time for accessing the MIO, which makes it very unattractive for this population. The findings also suggest that older populations may have a lower tendency to choose MIO,[45] which might be related to the larger transfer requirements and bus overcrowding that can generate more discomfort and accessibility issues for older users. Specifically, one additional year of age reduces the probability of a user's choosing MIO by 0.43 percentage points.[46] The probability of choosing MIO decreases by 15.6 percentage points for individuals who own a vehicle, suggesting a potential reduction in the demand for the MIO with increases in car ownership and motorization rates in the city.

OVE's stated preference analysis of public transport users in the areas of influence of the BRT system finds that low-income populations place the highest value on short access times, followed by shorter in-vehicle time and lower monetary costs for a public transit trip. An estimation of the trade-off between travel time and travel cost shows a value of time of 2,098 COP per hour. The high value of time suggests this variable has a relevant effect in modal choice. An additional 3 minutes in travel time reduces the utility of public transport for the low-income population as much as a fare increase of 105 COP. The value of time is higher for the very poor than for the poor. Results suggest that reducing trip duration can provide additional utility to low-income users. This analysis also indicates that a reduction of up to 5 minutes in access (walk and waiting) time may generate a 23-percentage-point increase in the usage of the MIO, from a base of 34% for the very poor and 35% for the poor, to 57% (very poor) and 58% (poor).

5. BRT system and feeder integration for social inclusion

There are three main challenges to achieving an integrated BRT system in Cali: (i) an oversupply of traditional and informal public transport that competes with the MIO; (ii) inability of the system to cover operational costs using fare revenues; and (iii) limited coordination among agencies involved in transport planning in the city. A resurgence of competition from parallel public transit systems erodes demand for the MIO and thus fare revenues. Traditional and informal forms of transport are prevalent in areas farther from the city center, where a large share of the population of Strata 1 and 2 live. Several informal providers have emerged to fill the gaps in MIO service, which is limited because of fare revenue shortfalls, aggravating financial sustainability and service quality issues.

This problem is in part rooted in the policy that the BRT systems should be financially self-sustaining through fare revenues. As a result of fare revenue shortfalls, providers have defaulted on the schedule designated by Metrocali, reducing service quality and increasing the demand for and supply of informal transport. Currently, approximately 700 of the required 800 buses are in operation. Moreover, most of the deficit in buses is concentrated in a single operator that operates routes in the eastern zone, where a large share of lower-income populations lives, to the detriment of the quality of services in this area.

Alternative operational scenarios developed by Metrocali suggest that more direct routes to reduce transfers (which are unpopular with users) would increase demand and ultimately revenue.[47] However, eliminating transfer requirements would require implementation of additional routes and fleet, and in some cases infrastructure. Even though the marginal revenue attained by the additional estimated ridership is expected to outweigh these additional costs, the city lacks the resources to make this initial investment.

Finally, fragmented and uncoordinated local governance impedes the development of policies and plans to overcome this downward low-demand/low-service-quality cycle. For example, Metrocali is the system's managing agency, but the transport and traffic authority is the Transport Secretariat; this situation creates gaps in decision-making processes and occasionally leads to limited coordination and cooperation between transport agencies. In addition, the Mayor has autonomy to make decisions that may affect the system without involving other departments, as in setting the MIO fare: the Mayor has authority to define the user fares, but Metrocali calculates the technical fare and manages fare revenues and operational costs—a situation that creates a disconnect between policy and delivery.

Coverage of poor areas is substantially wider in Cali than in Lima.
© OVE

4 Conclusions and Suggestions

The BRT systems in Lima and Cali were designed to reconfigure into a trunk-and-feeder configuration the traditional and often highly informal services that tend to transport passengers from door to door, along often long and oversupplied routes. The projects had multiple objectives, including improving mobility, particularly for the poor who are largely dependent upon PT, while reducing emissions, accidents, and congestion related to an oversupply of informal buses. The BRT corridor alignments passed through or reached into low-income or poor neighborhoods, and in both cities the designs included feeders that reached into poor areas to provide connections to the main BRT trunk lines. Both cities are characterized by high concentrations of the poor in increasingly outlying areas and often in informal settlements characterized by a lack of or low-quality transportation infrastructure, challenging the cities' ability to provide formal public transit coverage for the very poor. The evaluation also found a fragmented planning process among local governance institutions responsible for public transport and a disconnection in service provision between the formal and informal sectors.

Coverage of poor areas is substantially wider in Cali than in Lima. In Lima the system coverage and frequency tend to benefit the middle class the most, but also the poor; however, coverage for the very poor is spotty. At the same time, use by the poor, particularly the extreme poor, is lower than that of other socioeconomic groups; this is due at least in part to gaps in coverage, low service frequency in peri-urban areas where the poor are concentrated, and, in Lima, fare affordability for shorter trips. Given lower coverage and integration of the BRT system in Lima, informal modes (combis, custers, and buses) play an important role as a feeder service to and from the BRT trunk, with 30% of all BRT trunk line trips involving such modes, compared to just 2% in Cali. This decreases the affordability of Lima's system for the poor, given that informal modes charge a distance-based fare starting at the same base fare as Lima's feeders (50 cents).

Service quality is an issue in both cities. In Lima the service frequencies are more a concern for feeders, while trunk services, particularly express lines, are perceived as very fast. In Cali both feeders and trunk buses are considered much slower than alternative public transit modes. Peak-hour overcrowding is a significant concern in both cities.

While the poor rated the price of the system as affordable in both cities, the extreme poor more often cited affordability concerns. In addition, OVE found that the BRT services are not affordable for the poor at the technical tariff required to cover operational costs, particularly if they use the BRT for all trips. In particular, OVE's affordability analysis shows that the BRT system would be highly unaffordable for the peri-urban poor in Lima if used daily at the non-poor trip rates, while in Cali, daily BRT usage would only be slightly less affordable than using traditional public transit modes. Underlying this finding is the fact that fare differentials between the BRT and the traditional modes are higher in Lima than in Cali. In Lima, where the vast scale of the city implies longer trip distances to reach jobs, the poor self-select into public transit modes in a way that tends to minimize costs, maintaining a travel budget of around 22% of income and taking a higher share of shorter trips to achieve this. There is some evidence that the poor in Lima are thus limited in the radii of travel distances that are affordable, which in turn indicates a reduced number of opportunities available to them compared to the non-poor. Nevertheless, the BRT has increased affordability for longer trips, relative to the distance-based fares of the traditional system—a step in the right direction. Increasing the coverage and overall integration of Lima's system could improve its affordability.

In Lima, where in-vehicle travel time savings are large in the trunk corridor, users are willing to pay and wait more for the BRT services because of the net time savings; in Cali, the integrated fare rather than the speed is the primary advantage of the system. Both systems are predominantly used for longer trips and for work and school. In both cities, morning commute patterns indicate that jobs tend to be located in the downtown areas, except for some manufacturing jobs in Lima that are located far from the BRT lines. Focus group participants expressed the wish that BRT trunk services would be extended to more areas in their neighborhood and that feeder services would be more frequent. Similarly, a wide swath of poor neighborhoods in the eastern portion of Cali could have benefited from time-saving

BRT trunk line infrastructure and services. The stated preferences analyses in both cases show that improvements in access times (reducing walking and wait times) can significantly increase the utility of the BRT for low-income populations.

OVE makes several suggestions for the IDB and its clients to consider when designing and implementing BRT systems that seek to improve access and mobility for the poor.

1. Increase spatial coverage and improve the integration and quality of the BRT system *trunk*, *feeders*, and *complementary routes*. The evaluation found spatial disparities in the distribution of BRT services in low-income areas in both Cali and Lima. Results from Lima, in particular, suggest that increasing the spatial coverage and the integration of the BRT system with other modes can greatly improve overall accessibility and system usage. Such increased coverage and integration could be achieved through such measures as the following:

    - Improving the reach and frequency of feeder service and extending segregated trunk line services in poor and low-income areas. For example, filling gaps in feeder service in the western and eastern sides of Lima's trunk line could greatly improve accessibility to the BRT trunk corridor. In addition, extending segregated trunk corridors into areas with high concentrations of poor populations—for example, by completing the pending 11-km BRT trunk line to Lima's northern cone, or by developing a trunk line in the eastern area of Cali—could greatly improve access for the poor to higher-speed services.

    - Integrating the BRT system with existing informal or traditional modes (such as jeeps, combis, and moto-taxis) can provide cost-effective and flexible service in lower-density neighborhoods and hard-to-reach hilly areas (see Annex I for an extended literature review on integration strategies). Often operating informally and according to demand, such modes can play an important role as both feeders to BRT systems along high-demand corridors and complementary services in lower-demand corridors. Cities can examine opportunities to leverage informal operators to provide coverage in the peri-urban spaces that are financially unviable for large public system vehicles because of their limited infrastructure and low population density. Moreover, fare integration with informal transport, especially the transit used to access steep hilly zones in Lima and Cali, can also boost BRT use and affordability. However, integration schemes should be accompanied by regulatory reforms to mitigate the negative side effects associated with the informal transit sector (e.g., emissions control standards, safety and vehicle standards) while at the same time retaining the mobility benefits. Modern ITS technology (e.g., GPS, Internet, and mobile phones) could be used to prevent oversupply and monitor driving behavior. This might be implemented in collaboration with the Bank's private sector windows.

- Improving connectivity and integration between the BRT and the metro and other public transit to increase access to other high-speed transit in the city. Expanding trunk lines and feeder services and integrating them with the new metro lines (in Lima) and with job centers with high numbers of skill-appropriate jobs for the poor, as well as other activity centers (e.g., schools, marketplaces, community centers), could create an intermodal mass transit network that could improve the utility of the BRT systems in poor areas.

2. Consider policy alternatives and strategies for targeting subsidies to low-income BRT users and systems. The BRT bus companies in both cities, but particularly in Cali, are struggling financially, leading to a downward cycle of poor service quality, less ridership by all income groups, and a resurgence of competition from the informal transit sector. Integrated fares and reduction in transfer costs can improve the affordability of the systems. However, these benefits can be overshadowed by a high overall price of the BRT system (as in Lima). Low service standards and insufficient supply and frequency of buses (as in Cali), particularly in feeder areas and in non-peak hours (Lima and Cali), can also drive down demand. On the supply side, subsidies targeted toward BRT agencies, conditioned on service quality measures, could be considered and piloted. On the demand side, subsidies targeted to the poor could also be considered—and may entail, for example, a means-based targeting scheme that discounts fares specifically for users under a certain income threshold. When evaluating subsidies and increased coverage of BRT systems, governments should take into account positive externalities from increased usage, such as reductions in congestion, pollution, and accidents.

3. Explore mechanisms to facilitate dialogue and increase coordination among stakeholders and transport planning institutions. Mechanisms are needed for (i) improving coordination among transport authorities in the cities; (ii) supporting dialogue and coordination with current traditional and informal services to reach agreements that can boost the coverage, integration, and accessibility benefits of the system; and (iii) supporting higher user participation and representation in planning and decision-making processes related to the systems' future development and operation.

4. To increase the effectiveness of the bus operations generally, support mechanisms that strengthen the technical capacity of BRT and public transit authorities. Improved technical capacity could improve service quality through improved programming and route planning. Along these lines, the Bank should consider providing increased technical support during the initial operational stages, as several interviewees involved with the implementation of the systems noted that, being new to BRT, they struggled with the operational and institutional components of the systems.

Notes

1 https://www.inei.gob.pe/prensa/noticias/cerca-de-10-millones-de-personas-viven-en-lima-metropolitana-8818/

2 The city, as defined by the INEI, includes the urban population of the provinces of Lima and Callao.

3 The population of Lima is divided into five strata by socioeconomic status as estimated by the Peruvian Association of Enterprises Market Investigation (also known by its Spanish acronym, APEIM), using household survey data from Peruvian National Household Survey (also known by its Spanish acronym ENAHO). In 2013, 7.6% of the population was classified as Stratum E (roughly half the share in 2007 of 16.4%), 30.3% Stratum D (compared with 34% in 2007), 38.4% Stratum C, 18.5% Stratum B, and 5.2% Stratum A. Some of the highest concentrations of population from Strata D and E are in the districts of Puente Piedra, Comas, and Carabayllo in the north; Villa El Salvador, Villa María del Triunfo, Lurín, and Pachacamác in the south; Ate and Lurigancho to the east; and Callao to the west. See http://www.apeim.com.pe/wp-content/themes/apeim/docs/nse/APEIM-NSE-2013.pdf.

4 GIS analysis for this study using data from INE, 2007 (also see Annex II).

5 Long-range plans were approved in 1949, 1967, 1987, and 2013 (ONPU 1968; Metropolitana de Lima 1992, 2013).

6 Combis, Colectivos, Omnibus and Microbus are types of informal and traditional collective transport vehicles that range in size (e.g. a combi is an informal mini-bus, while an omnibus is a larger bus with capacity to carry 90 passengers or more.

7 National Department of Planning and DANE, National Bureau of Statistics of Colombia.

8 Colombia has a consumption-based socioeconomic classification that serves as proxy for purchasing power and income and is used primarily for allocating subsidies for public utilities to the poor. It approximates welfare through indicators such as housing characteristics and general quality of living conditions. It ranges from one to six, where one represents the lowest value in relation to consumption-based welfare measures, analogous to extreme poverty, and six the highest value for the wealthiest groups.

9 In the last four years the city has experienced rapid rates of growth in motorcycle ownership, growing from 50,000 to 150,000 registered motorbikes; see http://www.oecd-ilibrary.org/docserver/download/7514011ec013.pdf?expires=1460564008&id=id&accname=guest&checksum=8B6015AA79ED652CB2E31507BB46AD53.

10 Surveyors intercepted interviewees on the street and on the public transit systems in low-income and poor neighborhoods.

11 The sample included 837 low-income public transit users in Lima and 797 in Cali. In Lima the survey instrument included filter questions to determine socioeconomic strata (NSE) based on the APEIM methodology (APEIM 2014).

12 Respondents were asked to relate trip purposes, modes, monetary costs, and access, wait, and travel times for each trip made the previous day.

13 We use a probit model that estimates the probability of BRT use as a function of trip and demographic characteristics for all PT-related trips taken by a sample of individuals the day before their interview. The general form of the binary choice model is: $P(y=1\,|\,x)=G(\beta_1 x_1+\beta_2 x_2+\beta_3 x_3+...+\beta_k x_k)$ where y is a binary variable equal to 1 if any stage of a trip is taken on the BRT feeder system or trunk system and equal to 0 otherwise, and x includes trip purpose, travel time, access and wait and in-vehicle time, number of transfers, age, poverty status, vehicle ownership, education, and employment status.

14 The network analysis uses travel speeds of available modes in the system as provided by the city transport authority to estimate the travel times from different nodes to all other nodes in the network before and after the BRT (see Annex III).

15 See Hansen (1959), Cervero (1989, 1996), Gutiérrez (2001), Van Wee, Hagoot, and Annema (2001), Halden (2002), and Ben-Akiva et al. (2006).

Notes

16 $Aff=(E_{pt}/y)*100$, where E_{pt} is the monthly expenditure of a household on public transportation, and y is the monthly household income. Affordability can also be calculated as the share of monthly household expenditures on public transportation (Armstrong and Thiriez 1987).

17 Another method is to calculate the average number of trips taken by members of the third income quintile (the middle class), under the assumption that those individuals do not forgo any trip because of financial constraints, nor do they tend to take trips that are purely recreational as the fourth and fifth quintiles might (Falavigna and Hernandez 2016). The key limitation of most potential affordability measures is that they fail to account for differing household compositions (Falavigna and Hernandez 2016).

18 Other studies: transportation expenditures as a share of income were 6.4% for the bottom income quintile and 3.8% for the general population in Montevideo, Uruguay (Falavigna and Hernandez 2016). Similarly, the same study finds that in 2009 expenditures were 11.7% versus 6.2% in Córdoba, Argentina, for the poor and the general population, respectively.

19 Supply-side subsidies seek to reduce transport fares through direct subsidies to the transportation operators, while demand-side subsidies direct the subsidies to the transportation users.

20 See Box 2.1 for definitions of paratransit and informal.

21 For example, in Manila, Philippines, the vehicle fleet during rush hour is over twice as large as it is at other times. By creating off-street parking facilities for informal operators, the city has reduced the number of idle vehicles on the road during non-rush hours, thereby reducing congestion (Cervero 2000).

22 Source: DESCO 2002.

23 Using information from Protransporte (2016) regarding the operational scheme of the Metropolitano's feeder and trunk routes, we estimated the coverage of TAZs with access to at least one route and calculated the average number of buses in the morning peak. In this regard, using the distribution of the population, we assigned the dominant stratum to each TAZ based on the stratum of the majority of the population in the zone.

24 Therefore, of 818,448 inhabitants of Stratum E, only 99,727 people are covered by the system.

25 The network analysis uses the city's transport model and average speeds of public transit modes at nodes in the network to estimate the average travel time in peak hours from each TAZ to all other TAZs in the city. We analyze the network effects by strata, defining a TAZ's stratum as the predominant stratum within that TAZ.

26 Network travel-time savings are higher in the southern terminal as compared to the northern one because of the denser and more contiguous street network and proximity to the metro line.

27 The demand for the Lima BRT system has been growing steadily since the system opened; it currently carries approximately 550,000 passengers a day (JICA 2013).

28 For example, 33% of the poor and 37% of the extreme poor used other public transit five days a week, while daily use of the BRT among the poor was 15% and among the extreme poor was 8%. In 2013, BRT trips accounted for approximately 2.2% of all trips taken by middle-income groups, 0.6% of trips by the poor, and 0.2% of trips by the extreme poor (OVE analysis of JICA Origin Destination survey 2013).

29 A combi is a van or mini-bus seating up to 10-12 people and a custer is a larger bus usually manufactured by Toyota.

30 A large majority of non-users (57%) had positive perceptions of trunk services, as well.

31 Non-users are defined as those who use the system one time a week or less.

32 The poor are more likely to charge the cards with enough money for one or two trips, thus increasing their wait times and decreasing some of the time savings of having off-board fare collection with a smart card.

33 Focus groups were conducted in Lima in February 2016 in low-income neighborhoods in the north and the south.

34 Calculations use average trip costs for BRT versus other public transit modes observed in the sample. A BRT trip is defined as any trip for which one or more stages of the trip utilize the BRT feeder or trunk.

35 The model utilized data from OVE's travel survey in the system's area of influence on trips the sample of individuals took the day before their interview.

36 All estimates of the marginal effects are made holding all other variables constant at their mean.

37 All results reported in this paragraph were statistically significant at the 5% level, with the exception of trip cost, as reported in the footnote above.

38 This figure is statistically significant at the 95% confidence level.

39 The stated preference survey asked approximately 800 respondents to choose from hypothetical scenarios (cost, access, and travel time) for three types of public transit modes. The results suggest a higher value of access time than in-vehicle time or the cost of the service. Analysis of these data measured how transit users make trade-offs among trip cost, travel time, and access times (time to reach the station by foot).

40 Walking accessibility of the MIO was calculated building on the characteristics of the road network. The reference walking speed for this analysis is 4 km/h.

41 However, these results are limited insofar as the frequencies for MIO in the morning peak are considerably higher than other periods, and financial constraints have forced the system to operate at minimum frequencies in many cases, which could put it at a disadvantage in comparison to the traditional system.

42 Statistically significant at 99% confidence level.

43 Holding all other variables constant at their mean.

44 Relative to the mean (40% usage rate).

45 In addition, marginal coefficients for age are significant at 99%, with a value of -0.00429.

46 Significant at the 99% confidence level.

47 77% of MIO users must make at least one transfer.

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