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Transport infrastructure and the environment: Sustainable mobility and urbanism

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Working Paper 2013-03



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**Transport Infrastructure and the
Environment:
Sustainable Mobility and Urbanism**

Robert Cervero
October 2013

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Abstract

The urban transportation sector's environmental, economic, and social footprint is immense and expanding. Many of the world's most vexing and pressing problems – fossil fuel dependency, global warming, poverty, and social exclusion – are inextricably tied to the transportation sector. Much of the blame for the transportation sector's inordinate environmental footprint lies in the increasing automobile-dependency of cities. Rapid motorization unavoidably shifts future travel from the most sustainable modes – public transport and non-motorized ones (walking and cycling) – to private vehicles. Despite growing concerns over energy futures, climate change, and access for the poor, public transport's market share of trips is expected to erode over the next decade in all world regions if past trends (in how ownership and usage of the private car is priced and public financial resources are spent on transport infrastructure) continue. A paradigm shift is needed in how we think about transportation and its relationship to the city. The integration of transport infrastructure and urban development must be elevated in importance. In many cities of the Global South, recent Bus Rapid Transit (BRT) investments provide an unprecedented opportunity to do just that. To date, however, BRT systems have failed to leverage compact, mixed-use development due not only to little strategic station-area planning but also factors like siting lines and stations in stagnant urban districts and busy roadway medians. BRT systems are being conceived and designed as mobility investments rather than city-shaping ones. Given that the majority of future urban growth worldwide will be in intermediate-size cities well-suited for BRT investments, the opportunities for making these not only mobility investments but city-shaping investments as well should not be squandered. Transit-oriented development is but one of a number of built forms that hold considerable promise toward placing cities of the Global South on more sustainable mobility and urbanization pathways.

Keywords

Public Transport, Bus Rapid Transit, Land Use, Sustainability, Transit Oriented Development

1. Introduction

Urban areas, home to more than half of the world's population, face unprecedented transport and mobility challenges. With rapid population and economic growth, demands for urban mobility are steadily rising. Globally, some 8 billion trips are made every day in cities of which nearly half (47%) are by private motorized modes, almost all of which are propelled by fossil fuels (Pourbaix, 2011). In 2050, there may be 3 to 4 times as many passenger-kilometers travelled as half a century earlier, infrastructure and energy prices permitting (International Transportation Forum, 2011).

Concurrent to rapid rates of motorization, more sustainable forms of transport like public and non-motorized transport face mounting challenges, especially in developing countries. Public transport and non-motorized modes, despite being the chief way many poor people get around, are fast losing customers to private cars in much of the world (Gakenheimer and Dimitriou, 2011). In 2005, walking and cycling accounted for only 37 percent and public transport 16 percent globally (Pourbaix, 2011). At the same time, informal modes of transport are proliferating to fill the gaps left by inadequate or non-existent public transport services.

The transportation sector is also inextricably linked to the climate-change challenge since it is currently responsible for 13 percent of Greenhouse Gas (GHG) emissions worldwide and 23 percent of total energy-related GHG emissions (UN Habitat, 2011). If recent trends hold, the sector's share of global GHG emissions could reach 40 percent by 2050 (International Energy Agency, 2011). Fueling this increase is the growing demand for urban mobility. In the hundred-plus years of motor vehicles relying on gasoline as a fuel, the world has used approximately 1 trillion barrels of petroleum to move people, materials, and goods (Black, 2010). The transport sector's share of global oil demand grew from 33 percent in 1971 to 47 percent in 2002 and by one account could reach 54 percent by 2030 if past trends hold (IFP Energy Nouvelles, 2012). With increasing motorization and investments in roads and highways, cities find themselves in a vicious cycle – reliance on the private car unleashes more sprawl and road building further increases reliance on the private car.

It is widely accepted that cities of the future must become more sustainable, and that the transportation sector has a major role to play in this regard. The idea of a paradigm shift in urban transport is gaining currency in many parts of the world, not only to de-carbonize its fuel supply but also to create cleaner, economically viable, and socially just cities of the future. In particular, a shift towards the design of more compact cities based on the inter-mixing of land uses that prioritize sustainable forms of mobility such as public transport and non-motorized movement is broadly advocated. The post-oil city of tomorrow will need to be one that allows people to easily get around by foot, two-wheelers, buses, and trains. It is also recognized that urban transportation systems needs to be inclusive, providing mobility opportunities for all. In a car-dependent city, those without access to a private vehicle – often the poor, physically disabled, youth, elderly, or those forsaking car ownership out of choice – are unable to access opportunities and services. It will also be essential to enhance the pivotal role of transportation in the shaping the economic future of cities, in recognition that it is the transport sector that connects workers to jobs, raw materials to plants, produce and goods to markets, and people to retail shops and places of

entertainment and recreation.

This paper discusses key challenges in advancing sustainable urban mobility in the 21st century, particularly in a developing cities context. Issues facing different modal options discussed, particularly with regard to public transport. Reforms needed to achieve sustainable urban mobility on multiple fronts – environmentally but also socially and economically – are also reviewed. The paper then shifts to a particularly important transport-infrastructure challenge: investment in BRT systems that not only enhance mobility but also promote more efficient, sustainable, and socially just urban forms. Experiences in three global cities are reviewed in this regard. The paper closes with commentary on the institutional challenges and social equity considerations of advancing the sustainable mobility agenda.

2. Urbanization and Motorization

Since the mid-half of the last century, rapid urbanization has been accompanied by urban sprawl. Spread-out patterns of growth carry high costs. It not only increase automobile dependence but also consume farmland and open space, threaten estuaries and natural habitats, and burden municipal treasuries with the high costs of expanding urban infrastructure and services.

From 1995 to 2005, 85 percent of the 78 largest cities in the developed world experienced a faster growth in their suburban belts than their urban cores (UN Habitat, 2011). In Bangkok and Jakarta, 53 and 77 percent of urban growth by 2025, respectively, is expected to be in peri-urban regions (Angel, 2011). In Greater Cairo and Mexico City, sprawl is fueled mostly by informal housing settlements while on the outskirts of Mumbai and Delhi new towns and employment sub-centers have been the largest consumers of once exurban land. Sprawl in China is partly induced by local government policy wherein municipalities buy agriculture land at low prices, add infrastructure and services, and then lease to developers at much higher prices – effectively practicing value capture as a revenue generating tool.

Urbanization has both encouraged and been shaped by the growth in motorized movements in cities. The global count of motorized vehicles has been increasing at unprecedented rates. In 2010, there were nearly 1.2 billion passenger vehicles worldwide (UN Habitat, 2011; Wright and Fulton, 2005). Based on data from five years earlier, nearly half of all urban trips were by private motorized modes, a figure that continues to climb (Pourbaix, 2011). A key factor contributing to rising motorization in both developed and developing countries is the availability of fairly cheap oil, which has literally and figuratively fueled low-density development. In China, urban growth is occurring as far as 150km to 300km from the core of cities. A recent study of Shanghai residents who were relocated from the compact, mixed-use, highly walkable urban core to isolated residential towers on the periphery found dramatic shifts from non-motorized to motorized modes, accompanied by substantial increases in travel duration and vehicle-kilometers-traveled (VKT) (Cervero and Day, 2008). Economic growth and rising incomes have also triggered motorization. From 2002 to 2007, China's per capita incomes almost doubled and car ownership nearly tripled. Societal values also play a role given that for many who join the ranks of the middle class in rapidly emerging economies, owning a car is a rite of passage.

Rapid motorization unavoidably shifts future travel from the most sustainable modes – public

transport and non-motorized ones (walking and cycling) – to private vehicles. Daily trips in urban areas by private cars are projected to jump from 3.5 billion in 2005 to 6.2 billion in 2025, an 80 percent rise (Pourbaix, 2011). Much of this growth will be in developing countries. If past trends continue, petroleum consumption and greenhouse gas emissions are projected to increase by 30 percent, matched by a similar growth in traffic fatalities. While they provide tremendous mobility benefits to those who cannot afford a car, motorcycles, which are the dominant mode of transport in many Asian countries, come at a high cost. Besides congesting city streets, they can be exceedingly loud, contribute to traffic accidents, and when powered by two-stroke engines, spew dirty tailpipe emissions. A poorly tuned two-stroke engine, for example, can emit 10 times as many hydro-carbons and particulate matter as a four-stroke engine or private car (Badami, 1998; World Bank, 2002).

Motorization is also marked by environmental justice concerns given the growing international trade of old second-hand vehicles from high-income to low-income countries. Over 80 percent of the vehicle stock in Peru was originally imported as used vehicles from the United States or Japan (Davis and Kahn, 2011). In many African countries, import liberalization policies from the 1990s made it easier and cheaper for households to buy second-hand vehicles shipped across the Mediterranean Sea from Europe.

3. Mobility and Modality

Challenges faced by the two most resourceful forms of mobility – public transport and non-motorized transport – are reviewed in this section. Being pro-transit, pro-walking, and pro-cycling means not only enhancing the service quality of these options but also removing the many built-in subsidies and incentives that promote auto-mobility.

3.1 Public Transport

In 2005, 16 percent of the roughly 7.5 billion trips made in urban areas worldwide were by some form of public transport (i.e., formal, institutionally recognized services, such as local buses and rail transit) (Pourbaix, 2011). Public transport's mobility role varies widely, accounting for 45 percent of urban trips in Eastern Europe and Asia, 10 to 20 percent in much of Western Europe and Latin America, and less than 5 percent in North America and Sub-Saharan Africa (where informal services dominate the mass transit sector) (UITP, 2006).

In cities of the developing world, the mobility role of public transport also varies markedly, particularly among African cities. Only a handful of Sub-Saharan Africa cities, such as Addis Ababa, Abidjan, and Ouagadougou, have reasonably well-developed, institutionalized forms of local bus services that are of a high enough quality to capture 25 to 35 percent of motorized trips. In most other parts of Sub-Saharan Africa, private paratransit and informal operators dominate, with local buses serving but a small fraction of trips, if any. In Sub-Saharan Africa as well as poorer parts of South and Southeast Asia, government-sponsored transit is either inadequate or non-existent, mainly because governments are too cash-strapped and under-staffed to mount and sustain effective and reliable mass transit services.

In Southeast Asia, conventional 50-passenger buses are the workhorse of the public transport

networks of most cities. In Bangkok, 50 percent of passenger trips are by bus, rising to 75 percent during peak hours. In East Asia, buses serve slightly larger shares of mechanized trips than metrorail in Taipei (14.4 versus 12.9 percent) and Shanghai (12.9 percent versus 5.7 percent) whereas metrorail is more dominant in Hong Kong (35.5 percent of mechanized trips), Seoul (34.8 percent), and greater Tokyo (57 percent). Buses similarly predominate throughout Latin America, even in rail-served cities like São Paulo, Santiago, and Buenos Aires. When buses operate on exclusive dedicated lanes, they tend to gain even more popularity by mimicking the speed advantages of metros, however, usually at a fraction of the construction cost. As discussed later, the most extensive Bus Rapid Transit (BRT) networks are today found in Latin America.

In many parts of Asia, Africa, and Latin America, the informal transport sector serves the mobility needs of most people. The lack of affordable and accessible public transport systems in developing countries has led to the proliferation of informal operators, such as private microbus and minibuses services. These modes help fill service gaps but can also worsen traffic congestion and air quality. In some settings, informal carriers are the only forms of mass transport available. In India, for example, only about 100 of the more than 5,000 cities and towns have formal public transport. Everything from hand-pushed rickshaws to private minibuses have stepped in to fill the gap.

3.2 Non-Motorized Transport

Walking and bicycling are the healthiest, least intrusive, and most affordable forms of movement. In 2005, 37 percent of urban trips worldwide were made by foot or bicycle, the two predominant forms of non-motorized transport (NMT). In African cities, 30 to 35 percent of all trips are by walking but in some cities, like Dakar and Douala, the share is much higher, over 60 percent (Montgomery and Roberts, 2008). In general, the poorer and smaller the city, the more important NMT becomes, capturing as many as 90 percent of total person trips. In densely packed urban cores, NMT provides access to places that motorized modes cannot reach and are often the fastest means of getting around. Among South Asia's densest, most congested cities, more than half of all passenger and goods trips are by foot, bicycles, and rickshaw.

Walking is often the only form of transport for the very poor. Many people from the developing world are "captive walkers", meaning that they cannot afford an alternative. For them, having a well-connected and safe pedestrian environment is critical to meeting their daily needs. As the least expensive form of mobility, walking allows the very poor to allocate income for other purposes, thus helping to reduce poverty. It also promotes physical fitness, provides feeder access to bus and rail stops, and enhances security by providing "eyes on the street".

Cycling's mobility role contrasts sharply among the world cities. In general, the lower the per capita income, the bigger the mobility role played by bicycles however when high-quality cycling infrastructure is provided, bicycles can be a prevalent mode in even well-to-do cities. Today, bicycles are used for more than 40 percent of trips in some Dutch and Danish cities. Historically bicycles have also played a prominent mobility role in Chinese cities but today their use is in rapid decline, partly due to motorization but also government policies. In Beijing, for example, it is still illegal to park bicycles in front of many modern office buildings yet cars can

be parked nearby. Bicycle lanes have been taken away in cities like Guangzhou and Shenzhen to make way for motorists. Shanghai and Nanjing officials recently announced the goal of cutting bicycle trips in half.

In some of the poorest cities of the world, bicycles serve as “mass transport”, in the form of rickshaws. Cycle rickshaws are found all over Bangladesh, India, Pakistan, and Sri Lanka. They are particularly important modes for women and children. In Dhaka, around 40 percent of school trips are by rickshaw (Jain, 2011). Rickshaw pulling is often the first job for many rural migrants in cities of South Asia. In Dhaka, 20 percent of the population, or 2.5 million people, rely on rickshaw pulling for their livelihood, directly or indirectly (Jain, 2011). Still, the vehicles are being banned for slowing motorized traffic and a belief that they detract from the city’s image as a modern metropolis.

4. Immobility: Traffic Congestion

Traffic congestion is an unwanted by-product of widespread, or what some might call “excess”, mobility in cities around the world. A recent study in 20 cities across six continents revealed that traffic congestion levels markedly worsened during the 2007-2010 period (IBM, 2010). Moscow motorists reported the worst commute, with an average daily delay of two and a half hours. With a 24 percent annual growth rate in registered vehicles, traffic conditions are deteriorating most rapidly in Beijing according to 95 percent of surveyed residents.

Congestion has widespread impacts on urban quality of life, consumption of fossil fuels, air pollution and economic growth and prosperity. World Bank (1994) studies from the 1990s estimated that traffic congestion lowered GDP of cities in the range of 3 to 6 percent, with the higher value applying mostly to rapidly growing cities (e.g., places with busy port traffic, reliance on just-in-time inventorying and manufacturing, and other time-sensitive activities). Time losses from traffic congestion are estimated to comprise 2 percent of GDP in Europe and 2 to 5 percent in Asia. The hidden external costs of traffic congestion in Metro Manila, Dakar, and Abidjan have been pegged at nearly 5 percent of those cities’ GDPs (Chin, 2011). Such costs not only exact a burden on the present generation but also commit future generations to long-term debts, which can eventually slow global growth.

Limited road capacity in the face of growing demand for motorized mobility partly explains deteriorating traffic conditions. The nature of the problem, however, varies markedly across the globe. Less than 10 percent of land area is devoted to roads in many developing country cities (e.g., Kolkata, Jakarta, Nairobi) (Vasconcellos, 1999). This contrasts with 15 to 20 percent in many rapidly emerging economies (e.g., Seoul, São Paulo), 20 to 25 percent in much of continental Europe (e.g., London, Paris), and 35 percent or more in America’s largest automobile-oriented cities (e.g., Houston, Atlanta) (Vasconcellos, 2001). In India, the annual growth rate in traffic during the 1990s was around 5 percent in Mumbai, 7 percent in Chennai, and 10 percent in Delhi. However none of these cities have expanded their road supply by even one percent annually (Pucher et al., 2005).

In the developing world, buses are most vulnerable to the speed-eroding effects of traffic congestion. Because many are long, lumbering vehicles with slow acceleration and deceleration,

restricted turning radii, and limited maneuverability to switch lanes, buses move the slowest in highly congested conditions. Average peak-period bus speeds in Bangkok are 11 km/hr, for example, compared to 20 km/hr in Curitiba, Brazil, one of the first cities to provide exclusive bus-lanes (Cervero, 2000). Stop-and-go traffic causes buses to over-heat and break down. Unreliable services in turn chase away choice consumers who have the option of driving a car instead.

5. Toward Sustainable Transport

It is increasingly recognized that sustainability in the urban transportation realm must be pursued and achieved on multiple fronts – environmentally, socially, and economically. This section addresses these challenges.

5.1 Environmental Sustainability

The urban transport sector's ecological footprint is enormous and expanding. Many environmental problems in the urban transport sector are rooted in its reliance on petroleum, the automotive fuel source of choice, to propel motor vehicles, increasingly ones that are privately owned and used. The share of the world's oil consumption accounted for by transportation rose from 45.2 percent in 1973 to 61.7 percent in 2009, and the sector is expected to continue to drive the growth in oil demand (IEA, 2011). World reserves of conventional oil exceed what has been used to date, but with rapid motorization and thus increasing demands for oil, many observe believe it is unlikely that this energy source will last beyond the mid-century mark. Rising GHG emissions and global temperatures as well as levels of photochemical smog and particulates in urban air basins further underscore the urgency of weaning the sector from its dependency on oil and more generally auto-mobility. A combination of technological advances, demand management, and externality-based pricing will be critical in charting an environmentally sustainable future in the urban transport sector. On the technological front, clean-fuel vehicles and information systems that enable innovations like dynamic ridesharing and carsharing, will have pivotal roles to play. Reducing the demand for indiscriminant auto-mobility, such as by designing compact, mixed-use cities that shorten trips and encourage NMT, will also be important. Setting price signals so that polluters and those driving in rush hours internalize costs are similarly part of the environmental sustainability equation.

Environmental sustainability will depend on good economics (e.g., congestion pricing) but also the presence of the other two pillars of sustainability – institutional capacities and social equality. Setting maximum air and noise pollution standards will be useless unless there is the political will and regulatory resources in place to enforce them. Nor will the premature introduction of costly low-carbon fuel alternatives aid the poor if bus fares increase as a consequence.

5.2 Social Sustainability

Urban transport is socially sustainable when mobility benefits are equally and fairly distributed, with few if any inequalities in access to transport infrastructure and services based on income, social, and physical differences (including gender, ethnicity, age, or disabilities). Social sustainability is rooted in the principle of accessibility wherein equality exists among groups in

accessing opportunities for employment, housing, retail markets, and other essential urban services. It recognizes mobility and accessibility as human rights, not privileges. Cities that ensure accessibility for all are socially inclusive and ones that do not are socially exclusive.

One important aspect of accessibility is the affordability of transport modes. By affordability is meant the financial capacity to pay for the ability to reach destinations for everyday needs, such as work, education, and shopping, without undue economic hardships. For many urban dwellers in developing countries, the availability of reliable and affordable bus and rail services can be the difference between being integrated into the economic and social life of a city or not. The share of marginalized city-dwellers with poor access to essential facilities and services, including public transport but also clean water and sanitation, is increasing worldwide. In the poor informal housing settlements on the outskirts of Mexico City, beyond the service jurisdiction of the city's 201-km metro, residents sometimes must take 2 to 3 separate colectivos (shared-ride taxis and minibuses) to reach a metro terminal which provides low-cost connections to the core city and job opportunities (Cervero, 1998). Travel can consume 25 percent or more of daily wages. Time costs can also be exorbitant: 20 percent of workers in Mexico City spend more than 3 hours traveling to and from work each day. Studies show that taking a series of informal minibuses and motorized tricycles to and from work can cost 20 to 25 percent of daily wages in rapidly growing cities like Delhi, Buenos Aires, and Manila and as high as 30 percent in Nairobi, Pretoria and Dar Es Salaam (Vasconcellos, 2001; Kaltheier, 2002; Ferrarazzo and Arauz, 2000; Carruthers, et al., 2000).

5.3 Economic Sustainability

The urban transport sector is economically sustainable when resources are efficiently used and distributed to maximize the benefits and minimize the external costs of mobility, and investments in and maintenance of transport infrastructure and assets can be sustained. The translation of investments in walkways, bikeways, transitways, and roadways into jobs, business expansion, and increased economic output means that the urban transport sector is on an economically sustainable pathway. Increasingly, the litmus test of cost-effective transport infrastructure is whether the project is “bankable” – capable of attracting loans and private investors.

Urban transport infrastructure is expensive. It can consume a large share of the public largesse in emerging economies. In Ho Chi Minh City, a US\$5 billion subway is currently under construction and in Jakarta a new ring road is expected to cost about the same amount. Crafting reliable and equitable funding programs for transport infrastructure that reward efficient and sustainable behavior remains a formidable challenge.

6. Sustainable Mobility and Urbanism

Coordinating and integrating urban transport and land development is imperative to creating sustainable urban futures. Successfully linking the two is a signature feature of “smart growth”.

This section probes the challenges of linking transport-infrastructure investments and urban development in what is an increasingly important mobility platform: Bus Rapid Transit (BRT). BRT systems have gained popularity worldwide because they are a cost-effective alternative to far more expensive urban rail investments. High-quality bus-based systems also better serve the

low-density settlement patterns of many suburban markets and small-to-medium size cities due to the inherent flexibility advantages of rubber-tire systems – the same vehicle that provides speedy line-haul services on a dedicated bus lane or busway can morph into a feeder vehicle, collecting and distributing customers on local streets. To date, more than 150 cities have implemented some form of BRT system worldwide, carrying around estimated 28 million passengers each weekday (BRTDATA.ORG).

6.1 Bus Rapid Transit and Urban Development

New kilometers of BRT lines are today being added at a rapid-fire pace, gaining particular favor in the developing world, following on the heels of widely publicized BRT successes in Curitiba, Bogotá, Mexico City, Istanbul, Ahmedabad, and Guangzhou. These developing cities show that high-performance BRT systems that yield appreciable mobility and environmental benefits can be built at an affordable price. Metrorail systems, studies show, can cost 10 times as much a BRT system of similar length (Suzuki et al., 2013). Light Rail Transit (LRT) can be more than four times as expensive. Besides cost-savings, highly congested mega-cities of the world, like Jakarta, Delhi, Sao Paulo, and Lagos have been drawn to BRT because high-capacity transit can be built and expanded quickly during periods of rapid motorization and ever-worsening traffic congestion. The ability to open segments before an entire system is in place is particularly attractive to politicians and taxpayers who want quick results. Politicians are also drawn to the economic development potential of BRT. In its Liveanomics series, the Economist Intelligence Unit (2011) found that 61 percent of surveyed mayors reported that “improving public transport/roads” was the most important thing that could be done to make their city more competitive for business on the global stage. This was nearly twice the share that felt investing in schooling and education was the key to being economically competitive.

BRT will no doubt play an increasingly prominent role in the global campaign to achieve more sustainable urban and mobility futures. This is partly because the bulk of future population growth will be in intermediate-size cities, the very places where BRT is often more cost-effective than its pricier alternative, metrorail transit (UN Habitat, 2011). Future growth of not only population but also economic outputs is also projected for intermediate-size cities (Glaeser and Joshi-Ghani, 2012).

Figure 1 rank-orders countries or regions based on the number of cities with BRT systems as of mid-2013. The vast majority of these systems have been built in the last 15 years. Brazil has emerged as the global leader in building BRT systems, extending the success of Curitiba’s pioneering system to 30 other cities. Other Latin American countries, notably Colombia and Mexico but also Chile, Peru, and Ecuador, have since followed Brazil’s lead. Latin America is today the epicenter of the global BRT movement. A third of BRT route kilometers and nearly two thirds (63%) of ridership are in Latin America (BRTDATA.ORG, 2013). Among 38 Latin American BRT cities with reliable data from BRTDATA.ORG, average weekday ridership is more 10 times greater than averages for BRT cities of the U.S. and Europe. Latin American BRT systems are also considerably more productive than systems elsewhere. Figure 2 shows that they averaged more than 2 ½ times as many weekday riders per BRT kilometer as Asian

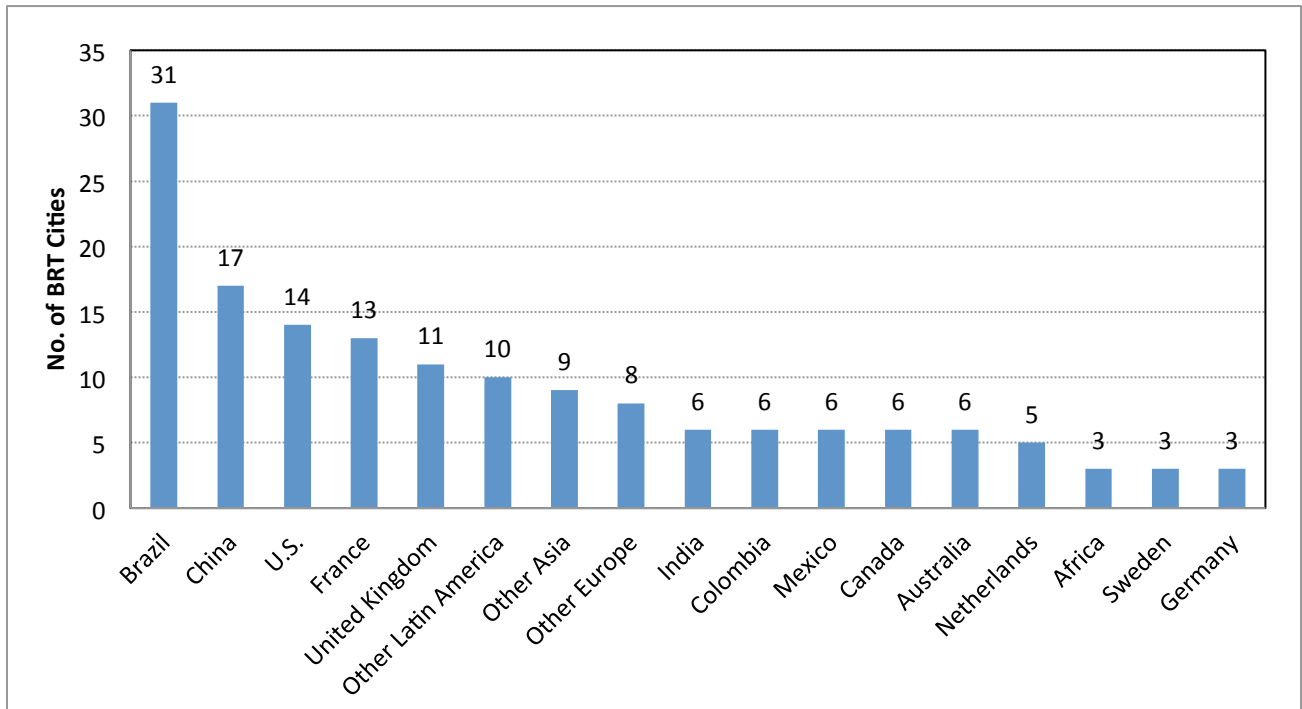


Figure 1. Number of Cities with BRT Systems, by National and Regional Settings, 2013.
Source: BRTDATA.ORG.

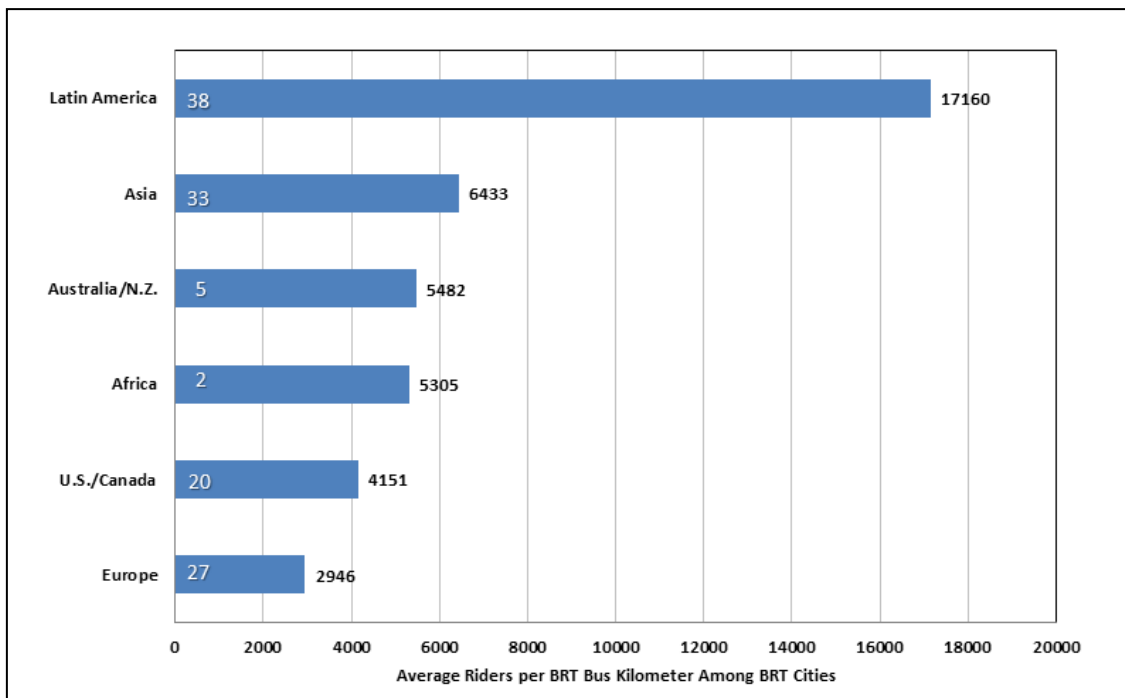


Figure 2. Average Weekday Riders per BRT Kilometer Among BRT Cities, by Continent-Region. Numbers in bars denote number of BRT cities in region that are included in the analysis.
Source: BRTDATA.ORG.

It is widely accepted that for public transit systems to be successful, they must be accompanied by high densities (Pushkarev and Zupan, 1977; Cervero, 1998; Newman and Kenworthy, 1999). Mass transit, as the saying goes, needs “mass”. For 105 BRT cities for which reliable data could be obtained, Figure 3 suggests a moderately positive relationship between BRT ridership and urban density. The presence of outliers weakens the simple correlation (.225) and as the scatterplot reveals, the number of riders per BRT kilometer tends to vary more as urban densities increase. Regardless, the positive association between urban densities and ridership productivity argues in favor of BRTOD – Bus Rapid Transit-Oriented Development.

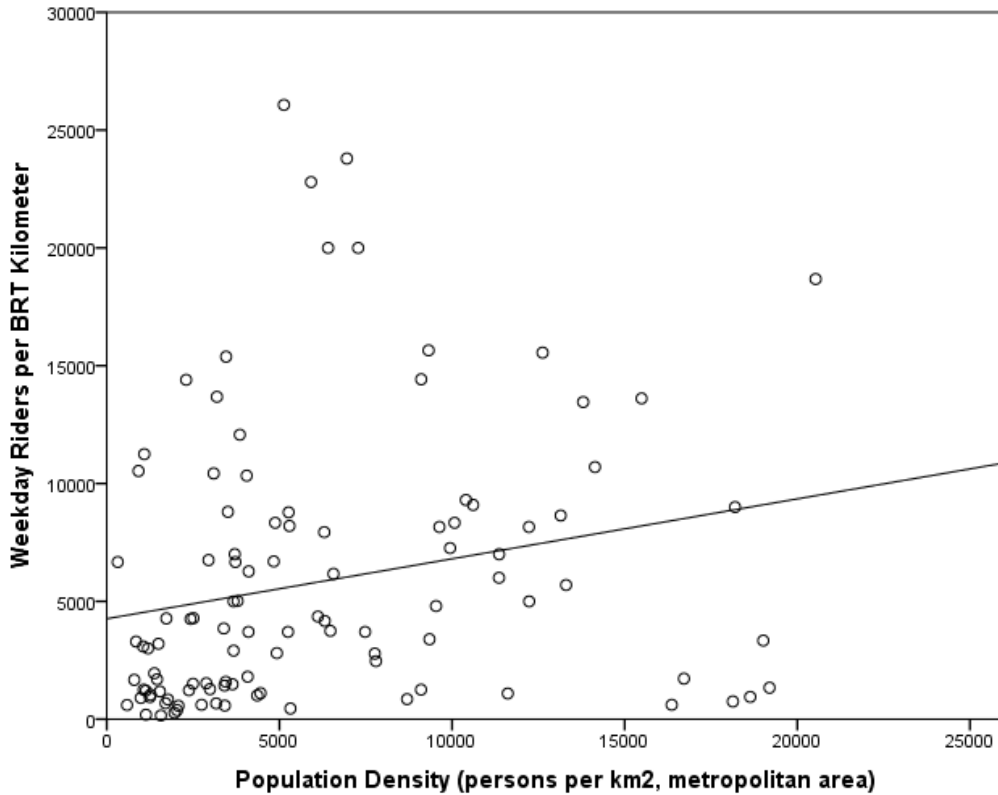


Figure 3. Scatterplot of Riders per BRT Kilometer and Population Density Among 105 BRT Cities. Sources: BRTDATA.ORG and UN Habitat (2012).

The challenges of leveraging TOD with BRT investment is probed in the next three subsections. The struggles faced by two of the world’s most extensive and highly regarded BRT cities – Bogotá and Ahmedabad – are contrasted with what remains the world’s best-case example of BRT-land-use integration – Curitiba, Brazil.

6.2 The Challenges of Leveraging TOD in Bogotá

Bogotá, the capital of Colombia and home to 7.6 million inhabitants, has gained a reputation as one of the world's most progressive cities, underscored by the 2000 opening of what has been called the gold standard of BRT, the 110-km TransMilenio system. Delegations of officials and dignitaries from around the world visit Bogotá to marvel at the system. Operating on a two-lane dedicated carriageway, TransMilenio carries upwards of 40,000 passengers per hour per direction, which matches the passenger-throughputs of most metros. The system also boasts enhanced stations (accessible by networks of skyways), smart card-based fare collection, advanced control systems, distinctive images, and affordable fares. TransMilenio's patronage is growing at a healthy pace of around 10 percent annually, from 800,000 daily riders when it opened in 2001 to around 1.7 million today, accounting for 74 percent of public transit trips in the city. Finance policy has played a role in TransMilenio's success. In 2000, a 20 percent surcharge was tacked onto all gasoline sales in Bogotá, with half the revenues earmarked for TransMilenio infrastructure. As a cross-subsidy from the 19 percent of Bogotá's population that owned cars to transit-dependents, the policy promoted social as well as environmental sustainability.

While Bogotá's TransMilenio is a substantial, widely celebrated BRT investment, able to carry some 45,000 passengers per direction per hour, reshaping urban form and land-use patterns was not a primary objective in its design. Building the system quickly and enhancing affordable transport for the poor was. Placement of BRT lines in mostly economically stagnant zones that were largely built out has suppressed land development. So has the siting of BRT stations in busy roadway medians, which limits joint development opportunities and creates unattractive pedestrian environs around stations. Minimal pro-active station-area planning and a dearth of incentives for private property-owners to redevelop parcels have also tempered TOD activities.

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

Cadastral data obtained from the city of Bogotá reveals the degree to which urban growth turned its back on TransMilineo. Between 2004 and 2010, the mean floor-area ratio (FAR) of residential and commercial development increased by 7 percent throughout the city of Bogotá versus 5 percent within 1000 meters of stations along the initial 42-kilometer system (Suzuki, Cervero, and Iuchi, 2013). In fact, more densification occurred along surface bus routes that feed into suburban TransMilineo stations than around BRT stops. Matched pair comparisons of changes in building footprints between 1998 and 2011 for 1-km radii around BRT stations and otherwise similar control areas further revealed weak effects on urban growth. For all but end-of-line stations, more new construction occurred beyond than within 1000 meters of stations.

Figure 4 shows one paired comparison for an intermediate station on a Phase II line toward the southwest of the city, near the low-income neighborhood of Kennedy. Far less new development occurred within 1000 meters of the BRT station than the control area off the line. For terminal stations, however, there tended to be relatively more new building activities than in control areas, as revealed by one of the matched-pair comparisons shown in Figure 5, for the Americas terminal station. Other researchers have similarly found more land-use densification near TransMilenio's terminal stations than control areas (Bocharejo, Portilla, and Perez, 2013). This higher degree of station-area activities was largely due to the commercial opportunities at terminals, representing busy transfer points between feeder buses and trunkline BRT services.



Figure 4. Footprints of new developments in Station Area and Control Area for an Intermediate Station, 1998 to 2011. Source: Suzuki, Cervero, and Iuchi, 2013.



Figure 5. Footprints of new developments in Station Area and Control Area for an End-of-the-Line Station, 1998 to 2011. Source: Suzuki, Cervero, and Iuchi, 2013.

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

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

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

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

have improved access to jobs, shops, and services while reducing the joint costs of what often consumes two-thirds of the poor's income: housing and transport. Whether Metrovivienda makes a serious dent in the city's housing shortages and traffic woes remains to be seen, however most observers agree that it is a significant and positive step forward.

6.3 The Challenges of Leverage TOD in Ahmedabad

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

As in Bogotá, Janmarg was envisaged and design as a mobility investment, not a city-shaping one. Janmarg lines were and are being selected to serve the city's fastest growing areas, more so than in the case of Bogotá, however little attention has been given to the physical integration of BRT stops with surrounding neighborhoods or increasing the share of future populations and workers near BRT. Janmarg, slated to span some 220 kilometers at build-out, which would make it one of the most extensive BRT systems anywhere, was designed mainly to keep costs low. Little thought was given to urban development possibilities. So far, no land-use or TOD plans have been prepared for any Janmarg stations. What land development is occurring has been left solely to private market forces.

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

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

6.4 BRT and Urbanism in Curitiba

A counterpoint to failures in coordinating BRT and urban development is the well-chronicled experiences of Curitiba, Brazil. Guided by a cogent long-term vision of the future city, the municipal government mandated that all medium- and large-scale urban development be sited along a BRT corridor. Orchestrating regional growth has been the Institute for Research and Urban Planning (IPPUC), an independent entity charged with ensuring integration of all elements of urban growth.

A design element used to enhance transit accessibility in Curitiba is the “trinary”—three parallel roadways with compatible land uses and building heights that taper with distance from the BRT corridor. The first two floors of the busway, which do not count against permissible plot ratios (building height/land area), are slated for retail uses. Above the second floor, buildings must be set back at least five meters from the property line, to allow sun to cast on the transitway. The inclusion of upper-level housing entitles property owners to density bonuses, which has led to vertical mixing of uses within buildings. An important benefit of mixed land uses and transit service levels along these corridors, in addition to extraordinarily high ridership rates, has been balanced bidirectional flows, ensuring efficient use of bus capacity. The higher densities produced by the trinary design have translated directly into higher ridership. Concentrated commercial development has also channeled trips from residences beyond BRT terminuses to the trinary corridors. In 2009, for example, 78.4 percent of trips boarding at the terminus of Curitiba’s north-south trinary corridor were destined to a bus stop on the same corridor (Duarte and Ultramari 2012). Today, Curitiba’s share of motorized trips by transit (45 percent) is the highest in Latin America (Santos, 2011). High transit use has appreciably shrunk the city’s environmental footprint. Curitiba’s annual congestion cost per capita of \$0.67 (in US\$2008) is a fraction of São Paulo’s (Suzuki et al., 2010). The city also boasts the cleanest air of any Brazilian city with more than 1 million inhabitants, despite having a sizable industrial sector. The strong, workable nexus that exists between Curitiba’s bus-based transit system and its mixed-use linear settlement pattern deserves most of the credit.

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

One area where Curitiba’s BRT investment has fallen short is the provision of housing for the poor. Most social housing built in the last 40 years for Curitiba’s poor has been far from main transit axes and transport corridors (Duarte and Ultramari, 2012). The availability of cheaper land and laxer environmental regulations on floodplain development prompted Curitiba’s authorities to put the most disadvantaged households in the least transit-accessible locations.

7. Close

The best ideas for advancing sustainable urbanism and mobility will go nowhere unless there is the political will and institutional capacity to embrace and move forward with them. The ability to manage and respond to escalating demands for urban travel is often limited in developing cities. Institutional shortcomings – such as an insufficiently trained and educated civil-service talent pool or absence of a transparent and corruption-free procurement process for providing transport infrastructure – abound. Limited experience with urban management, budgeting and accounting, urban planning, finance, and project supervision have thwarted Indonesia's decentralization of infrastructure programs from the central to local governments over the past decade.

Sustainable mobility futures will depend upon a re-ordering of priorities, a paradigm shift if you will, that promotes inherently resourceful forms of mobility, frames investments in more holistic (and less mobility-focused) terms, and importantly seizes opportunities to integrate transport infrastructure and urban development when and where they avail themselves. As more and more growth shifts to cities of the Global South, opportunities for linking land development and transport infrastructure should not be squandered. Given that a large share of future urban growth is projected for small-to-medium size cities, bus-based forms of smaller scale transit-oriented development interlaced by high-quality infrastructure for pedestrians and cyclists holds promise in many global settings. Many developing cities have the kinds of pre-requisites needed if BRT investments are to trigger meaningful land-use changes, including rapid growth, rising real incomes, and increased motorization and congestion levels. This, of course, assumes there is supportive planning and zoning, public-sector leveraging and risk-sharing, a commitment to travel demand management to remove many built-in incentives to car use, and the capacity to manage the land-use shifts that are put into motion by transportation infrastructure investments.

While integrated transport and land development can relieve congestion, cleanse the air, and conserve energy, its potential to reduce what remains the gravest problem facing the Global South – extreme and persistent poverty – is every bit if not more important. All that is done in the developing world must pass the litmus test of helping to alleviate poverty. Designing cities and transport systems to enhance accessibility and affordability is pro-poor. So are initiatives that strengthen non-motorized and public transport, keep fares affordable, and protect vulnerable populations from the hazards of motorized travel. Mass transit needs to be pro-poor across the board. In many developing countries, this means investing in busways over metros to keep fares affordable and targeting affordable housing to transit-served corridors. In Brazil, transit is kept affordable via national legislation, called Vale Transport, that requires employers to provide bus passes for commuting expenses that exceed 6 percent of workers' earnings. In Cairo and Bogotá, tens of thousands of low-income households have been relocated to more transit-accessible sites.

Being pro-poor also means designing high-quality and safe walking and cycling environments. Mixed land-use patterns and walking/cycling friendly environments allow the very poor to allocate income for other urgent purposes and thus helps reduce poverty. In the very poorest cities, small interventions – e.g. siting basic services such as schools, health centres, markets, and water standpipes to reduce travel distances – can make a big difference in the amount of time and energy devoted to transport. The time freed up allows women to achieve gainful employment

and children to attend schools. What are cardinal features of integrated and sustainable transport and urbanism everywhere -- accessible urban activities and safe, attractive walking and cycling environs – are particularly vital to the welfare of the neediest members of the world's poorest countries.

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