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Urban Transport Systems in Latin America and the Caribbean:

Challenges and Lessons Learned

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Abstract

This paper discusses the transportation challenges that urban areas in Latin America and the Caribbean face and reviews the causal evidence on the impact brought by different urban transport system interventions implemented around the world. The objective is to highlight the main lessons learned and identify knowledge gaps to guide the design and evaluation of future transport investments. The review shows that causal studies have been concentrated in certain areas and that an important number have been carried out in developed countries. Empirical challenges due to the non-random placement of these interventions and their possible effects over the entire transport network might explain the reduced amount of causal evaluations. A large part of the literature has focused on the impact of transport systems on housing values, finding overall increases in prices and rents, but with results highly dependent on the quality and perceived permanency of the system. There are few studies that explore socioeconomic effects, and those available have emphasized employment access. There are almost no studies exploring displacement effects, which should be examined to better understand the social inclusion role of transport systems. New avenues of research are emerging that exploit non-traditional sources of data, such as big data. Moreover, studies looking at ways to improve the operational efficiency of systems and those seeking to promote behavioral changes in transport users.

Keywords

Urban transport systems, Latin America and the Caribbean, impact evaluation

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1. Introduction

Rapid population growth, urbanization, and widespread use of motor vehicles have generated large mobility challenges in urban areas of Latin America and the Caribbean (LAC), including high rates of congestion, traffic accidents, and pollution (CAF 2010). As a significant share (68 percent) of passenger travel in LAC cities is on public transit or shared systems (Estupiñan et al. 2018), improving urban transport systems presents opportunities to respond to these challenges. However, while investments to improve urban transport systems have increased over the past two decades, the supply of high-quality public transport has not kept pace with the growth in transport demand (IDB 2013). In combination with increased incomes and, in some cases, policies directed at encouraging purchases of new cars, this has generated a surge in motorization rates (De la Torre, Fajnzylber, and Nash 2009). This trend is expected to continue in the next decade, leading to increased pressure on urban transport infrastructure

Unplanned urban growth and high rates of poverty and inequality have prompted the poor to settle in informal housing on the periphery of large cities, often in areas with little or no road infrastructure and that are difficult to serve with traditional or formal public transit systems (Cervero 2000). As a result, the urban poor either forgo trips or endure long and costly travel times to get to their jobs or carry out other tasks, a circumstance that aggravates social inequalities (Ardila-Gomez 2012). In addition, women, particularly those from lower-income segments, are often excluded from access to public transit and have less accessibility and mobility due to personal safety concerns and high rates of harassment in crowded transit systems (Osmond and Woodcock 2015; Simicevic, Milosavljevic, and Djoric 2016). From a social inclusion perspective, the affordability of transportation is another challenge, as travel expenditures consume 30 percent or more of labor income of the poor in the region, adding to already-high travel time costs (Kaltheier 2002; Vasconcellos 2001).

In response to all of these issues, the LAC region has seen a renewed focus on urban transport interventions and an important increase in investments directed toward improving transport systems over the past two decades (Infralatam 2018). Given financing gaps and the need to improve operational and managerial efficiency in the sector, governments are increasingly engaging with the private sector, and there are several examples of successful public-private partnerships (PPPs) in transport in the region (Vassallo Magro 2015). Regarding the types of investments, following the initial success of bus rapid transit systems in Curitiba, Brazil and Bogota, Colombia, such systems have become an increasingly popular approach to cost-effectively improve urban mobility (Rodriguez and Mojica 2009). As these systems have matured, and in many cases have reached ridership saturation levels (O´Callaghan 2016), larger cities in higher-income LAC countries have begun investing in metro systems and light rail, while others have invested in cable cars. For cities that have systems that are already well established, more sophisticated interventions have emerged that aim to improve the operational efficiency of these systems and their accessibility to more vulnerable populations. These efforts include policies such as integrated tariffs or transport subsidies to maximize demand and/or increase affordability for lower-income groups.

Given that resources are scarce, a first-order question for policymakers relates to the impact that these different investments in “hard” infrastructure components are having. The expectation is that improving accessibility and mobility should promote greater access to employment, health, education, and other opportunities, as well as improved road safety and citizen security. But benefits might not be distributed equally across all groups of the population, or might not be realized at all (Scholl et al. 2018). These types of investments are also often associated with changes in land use and a rise in property values, which can have important implications for housing affordability and potential displacement of disadvantaged individuals and families. Other important questions, usually on the operation side of the system, which in several cases is performed by a private sector actor, relate to the impact of “soft” components of public transport systems that seek to increase demand (particularly off-peak demand) and access to the system. For this, behavioral theories inspired by the economics and psychology literature are increasingly being used to understand effects on passengers as well as passenger responses.

This paper presents a review of studies that provide evidence on the effectiveness of different urban transport system interventions. Although the focus is on LAC, given that there are still few studies for the region, this work includes all studies conducted worldwide that are relevant for this analysis and that rigorously estimate causal effects, exploiting experimental or quasi-experimental methods. A prior literature review related to this topic was prepared by Boarnet (2007). As this area of the literature has been moving fast in recent years, the present paper complements and updates this previous report. The present paper has two objectives. The first is to summarize the existing knowledge on the impact of urban transport systems in order to inform policymaking in the region. The second is to explore the main methods and sources of data that have been used in this literature and to highlight the main knowledge gaps, identifying potential avenues of future research. Urban transport interventions cover a wide range of transportation alternatives, so the focus here is only on passenger transportation systems such as subways, light rail, bus rapid transit systems, cable cars, and transport network companies. Driving restriction interventions are also discussed, given their potential to affect the demand for passenger transport systems. Other interventions, such as road and highway improvements and interventions related to intelligent traffic management systems, although important, fall outside the scope of this review.

There are a limited number of causal studies exploring the impact of urban transport systems. This is explained by the empirical complexities that arise when trying to distinguish between effects that can be attributed to transport investments versus those that result from the non-random placement of these investments (i.e., driven by demand considerations) and that might benefit populations that were already better connected, had higher employment rates, or had higher incomes, among other considerations. There is also an important aspect of firm and household dynamic location decisions, given that any benefits identified might not necessarily reflect the welfare gains obtained by the original population living in project-served areas, but rather might reflect the fact that new populations with distinct characteristics (i.e., compositional changes), are moving in (Cortes et al. 2017). For certain interventions that have the potential to change the entire transport network, identifying pure comparison groups (i.e., populations or areas not affected by the intervention) might be a challenge as well.

The review of the evidence shows that the literature has focused on the impact of transport systems on housing values, driven by the availability of information and the speed of price responses to changes in urban infrastructure. Those studies, in general, find increases in prices and rents, but results seem to be highly dependent on the context and on how permanent the real estate market participants perceive the transport investments to be. For example, the evidence on subways and light rail is quite conclusive, while the evidence for bus rapid transit systems is less conclusive, as these systems can be changed or reallocated over time. On the other hand, there are few studies exploring socioeconomic and displacement effects. The findings in this area seem quite heterogeneous, probably due to the complexities underlying labor market access and poverty, which suggests a need for complementary policies, such as those targeting labor market issues or directly tackling poverty. The lack of studies that examine socioeconomic outcomes could be due to data limitations, including the difficulty of following households over time and the time that these impacts might take to appear. New avenues of research are starting to emerge that exploit non-traditional sources of data, such as administrative data and big data generated by satellite images, mobile phone calls and apps, among others. Moreover, given the wide variation in the quality and reliability of transport services, much research is still needed on the impact of service quality on aspects such as ridership, employment, and pollution, among other things.

The next section of this paper presents an overview of the situation of urban mobility in the LAC region, highlighting progress and challenges. Section 3 describes the main theories guiding the modeling of the impact expected from urban transport systems. Section 4 reviews the evidence available on diverse types of urban transport system interventions, and Section 5 discusses the main findings and recommendations emerging from this work.

2. Urban transport in Latin America: progress and remaining challenges

Latin America and the Caribbean has experienced explosive urbanization in the last 40 years, with the share of its urban population increasing from 50 percent of the population in 1970 to 80 percent by 2013 (United Nations 2011). In addition, robust income growth and a sharp expansion of the middle class have spurred a rapid increase in automobile and motorcycle ownership. With an average of approximately 90 vehicles per 1,000 population, the motorization rate in LAC exceeds those of Africa, Asia, and the Middle East (De la Torre, Fajnzylber, and Nash 2009). However, there is heterogeneity across countries. For example, between 1990 and 2010, per capita car ownership more than doubled in Mexico from about 75 to 175 cars per 1,000 population, and nearly tripled in Brazil from 45 to 125 cars per 1,000 population (Fay et al. 2017). Moreover, growth in motorcycle ownership has surpassed that of autos in many LAC cities, where motorcycles make up as much as 49 percent of the vehicle fleet (UN-Habitat 2012).

While investments in infrastructure for passenger transport have increased recently, the supply of high-quality public transport and road infrastructure has not kept pace with the growth in transport demand. Weak institutions and government oversight have also exacerbated the inefficiency and informality of urban transport systems (Pazos 2016), contributing to chaotic and unsafe conditions, as well as to increased levels of congestion and pollution, particularly in lower-to-middle income LAC cities (IDB 2013). In 2010, the LAC region reported an average rate of 25.3 fatalities per 100,000 population associated with car accidents, compared to 16.1 fatalities per 100,000 population in the United States and Canada (IDB 2013). In addition, the average one-way commute time reached up to two hours in some cities, imposing considerable time and monetary costs on both freight and passenger transport (UN-Habitat 2010). According to a report by the Clean Air Institute, air pollution levels in many LAC cities exceed World Health Organization (WHO) guidelines for major pollutants, posing significant adverse costs to human health, life expectancy, and productivity (Green and Sánchez 2013).

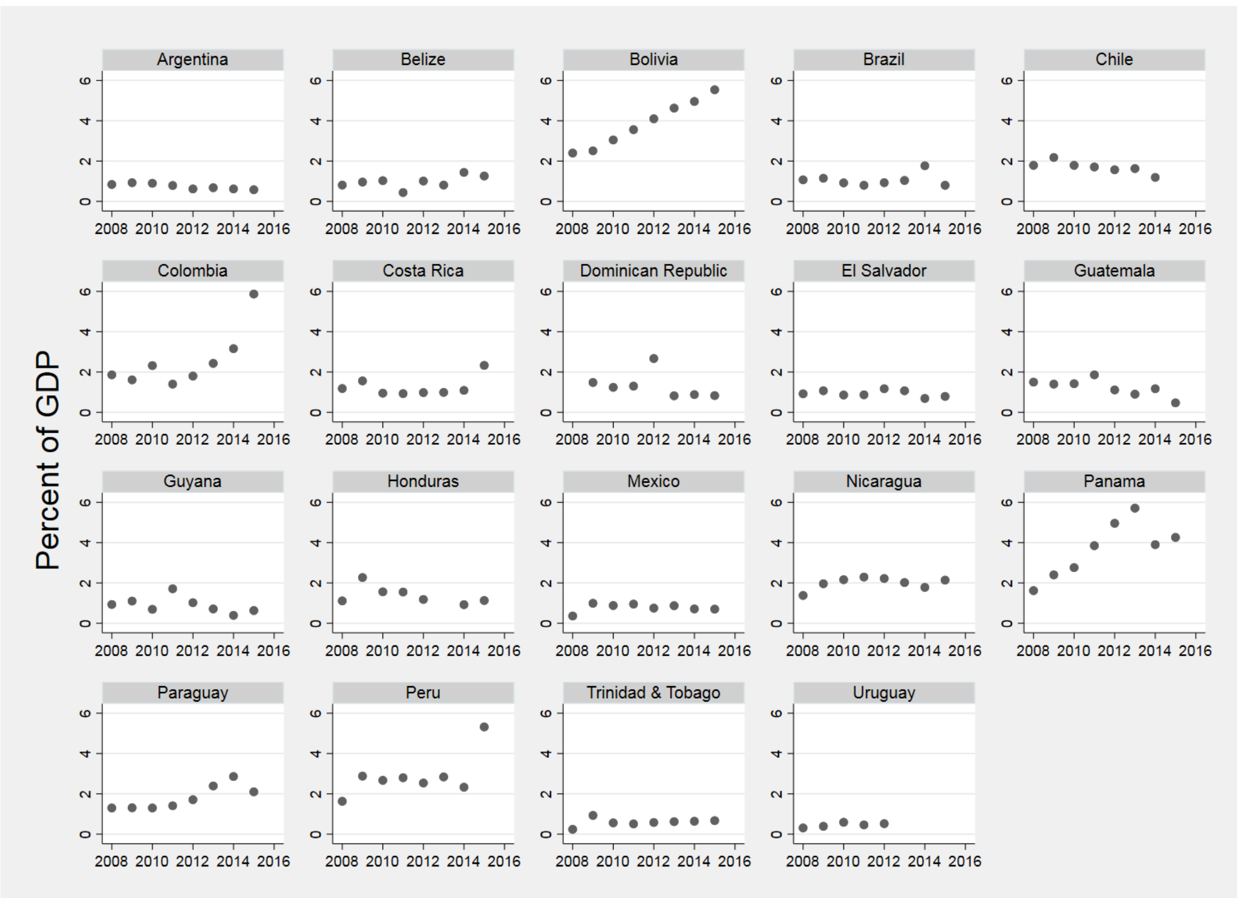
On average, 68 percent of all trips in LAC are via collective or public transport (Estupiñan et al. 2018). The bus sector dominates these trips. Initially publicly owned, the bus sector in the region underwent widespread deregulation and privatization in the early 1980s and 1990s, spurring an oversupply of mini-bus operators that often maintain overlapping routes and compete fiercely for passengers in what has been coined "the war of the penny," leading to chaotic, unsafe, and congested traffic conditions. Public transport users spend between 50 and 100 percent more on travel time than automobile and motorcycle users, and their safety and comfort levels are lower

(Vasconcellos and Mendoça 2016). Given low car ownership rates for the poorest segments of the population, the affordability and efficiency of public bus services are also particularly important. In most LAC cities, the monthly cost of fares is over the desirable 6 percent of the minimum wage. As an example, in metropolitan areas in Brazil the monthly expenditure on public transportation represents 25 percent of the minimum wage.

Public transit systems in the periphery of urban areas tend to be poorly coordinated (Cervero 2000), resulting in the poor having the longest travel times and incurring more transfers (Ardila-Gomez 2012). This in turn diminishes their access to jobs and other economic opportunities (Carruthers, Dick, and Saurkar 2005). Research on women's travel in LAC and other developing regions has found that, on average, women tend to work closer to home, take shorter and more frequent trips, walk and take transit more often, trip chain (combining multiple trips together over the course of a day for a wider variety of purposes), travel more often during off-peak hours, and experience more safety concerns on transit systems and as pedestrians (Simicevic, Milosavljevic, and Djoric 2016; Duchéne 2011; GTZ Sector Project Transport Policy Advisory Service 2007; Loukaituou-Sideri 2008; Osmond and Woodcock 2015).

Over the past two decades, governments across the LAC region have begun investing in modern urban transport systems, with the bulk of the financing taking place between 2002 and 2013. Investments began rising in 2004 and grew significantly through 2009. These investments have represented around 1 to 1.25 percent of GDP since 2007, more than other infrastructure sectors. Nonetheless, the region shows significant heterogeneity in investment levels across countries. Most larger and higher-income countries, such as Argentina, Brazil, and Mexico, spent around 1 percent of GDP on urban transport over 2008–2013, while others such as Bolivia, Nicaragua, Panama, and Peru invested two to three times higher shares of their GDP (Figure 1). Despite these efforts, the region's infrastructure still suffers from an international perception of low quality, which affects its overall level of global competitiveness. LAC's paved road density, at 0.05 paved lanes per square kilometer, ranks among the lowest worldwide, just above that of Africa (0.04 paved lanes per square kilometer). In comparison, member countries of the Organization for Economic Cooperation and Development (OECD) have a road density of 2.1 paved lanes per square kilometer (Fay et al. 2017).

Figure 1. Transport infrastructure expenditures as a percent of GDP in Latin America and the Caribbean

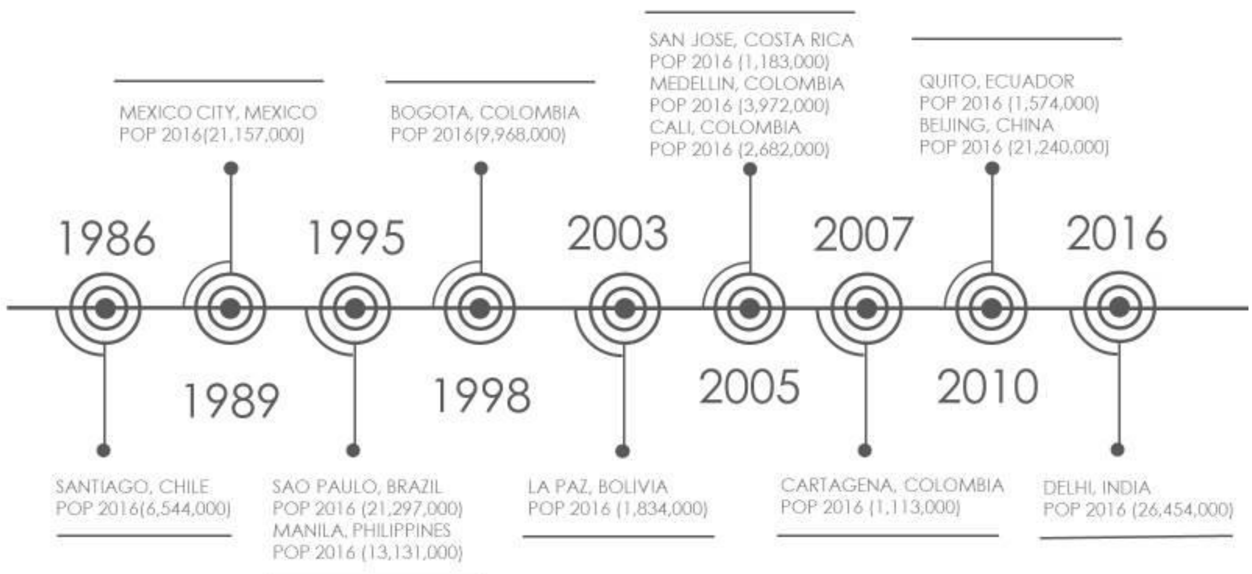


Source: Prepared by the authors based on data from Infralatam (2018).

As a result of these investments, the region has seen a proliferation of bus rapid transit systems. Today such systems operate in 54 cities in LAC and in 167 cities globally (WRI Brazil Ross Center for Sustainable Cities 2018). As these systems have matured, and in many cases have reached ridership saturation levels, larger cities in higher-income LAC countries have begun investing in metro systems and light rail. In 2014, 157 cities around the world had an operational metro system. There are 54 networks in Asia, 46 in Europe, and 18 in LAC, where Mexico City is the busiest network (UITP 2015). Other cities, based on their geographic characteristics and given the advantages in terms of construction costs and lower displacement of people, have implemented aerial cable cars systems. The first cable car designed as a transport system in LAC opened in Medellín, Colombia in 2004. Since then, Caracas (Venezuela), Cali (Colombia), Mexico City (Mexico), Rio de Janeiro (Brazil), and La Paz (Bolivia) have built similar systems. Today the system in La Paz, Mi Teleférico, is considered the longest system in the world.

Finally, driving restrictions have been another important policy, and LAC has actually been the pioneer on this issue (Figure 2). Following the restrictions imposed in Santiago, Chile in 1986, several major LAC cities followed, including Mexico City, São Paulo, La Paz, San José, Quito, and several cities in Colombia. More recently, cities such as Delhi, India and Beijing, China have implemented similar approaches.

Figure 2. Timeline of driving restriction policies around the world



Source: Prepared by the authors.
Note: POP indicates the size of the population for each city in 2016.

3. Urban transport modeling

3.1. Transport use forecasting

The mobility of people in urban areas is a complex phenomenon due to the substantial number of factors that can influence the decision-making process. According to Rodriguez (1991), three interacting aspects have an effect on individual mobility decisions: (1) spatial considerations, which highlight that different uses of land and the distribution of activities in a given area create the need for individuals to move depending on the location of the activities they want to perform; (2) social aspects, which indicate that mobility decisions are the result of the socioeconomic characteristics of the individual who undertakes them; and (3) perceptions, which refer to personal values and stimuli of each person that affect mobility decisions, and which could lead to different assessments of the same data in decision-making.

Multiple theories have been developed to guide urban transportation planning. In the classic model, individuals take sequential decisions in what is known as the four-step model. The first step, trip generation, predicts the number of trips originated in or destined for a traffic analysis zone as a function of land use, household demographics, and other socioeconomic factors.[1] At the center of this first step is the idea that the intensity of activity declines with distance from the central business district. The second step is trip distribution, which matches origins with destinations, often using a gravity model, where the interaction between two locations is assumed to decline with increasing distance, time, and cost between them, but is positively associated with the amount of activity at each location (Isard 1956). The third step involves the mode choice, which computes the proportion of trips between each origin and destination that uses a particular transportation mode. Models emphasizing consumer and choice behavior concepts from economics and psychology have been used (Domencich and McFadden 1975). The fourth in the model is route assignment, which allocates trips between an origin and destination, by a particular mode, to a route. For this, modeling assumes drivers choose the shortest (travel time) path, subject to every other driver doing the same (Wardrop and Whitehead 1952), or else they follow the lead of a traffic manager as in a Stackelberg competition model (Stackelberg 2011).

Although the four-step model is still widely referenced in the transport literature, new types of decisions have been included in the analysis, such as the decision about the time of the trip, which has given rise to time distribution models. Another class of models, activity-based models, predict where and when specific activities (e.g., work, leisure, shopping) for individuals are conducted. The major premise behind these models is that travel demand is derived from activities that people need or wish to perform, with travel decisions forming part of the scheduling decisions. Travel is then seen as just one of the attributes of a system. Activity-based models have recently been used to predict emissions (Bekx et al. 2009) and air quality (Shiftan 2000; Hatzopoulou and Miller 2010).

Integrated transport-land use models are intended to forecast the effect of changes in the transport network on the future location of activities, and then forecast the effect of these new locations on transport demand. As data science technologies and big data become more available, research is moving toward predicting behaviors of individual drivers, which is known as per-driver models (Fox 2018). This may be done by using driver-level data collected on cameras, social network profiles, store card purchase data, and search engine history, among other activities. This could lead to more accurate predictions, but also raises challenges about data storage and confidentiality.

3.2.Employment, productivity, and transport

The role of transport infrastructure on unemployment and labor informality is theorized to occur due to two main factors. The first factor is the spatial mismatch hypothesis posed by Kain (1968), who argues that the spatial segregation of low-income minorities from skill-appropriate job centers decreases the affordability of job searches and commutes, and thus increases unemployment rates among such isolated and predominately transit-dependent communities. The second factor is the reservation wage hypothesis, which states that the wage at which a person is willing to supply labor is likely to be higher the higher the transport costs. Therefore, increased transport costs are more likely to limit the geographic range of job opportunities (Patacchini and

Zenou 2005). The impact of transportation costs is higher on less-skilled workers who have lower wages. Therefore, the limiting effect of the reservation wage on job search radius could be more pronounced within the lower-skilled labor force.

More recently, Franklin (2017) argues that cash-constrained job seekers decide on their optimal search intensity to equate the marginal cost of foregone consumption, due to the costs of the search, with the marginal gain of the increased probability of having a good job. In this setting, poorer individuals find it harder to search intensively because the marginal cost of searching is much greater for them. Franklin hypothesizes that lowering the costs of the job search (through transport subsidies) would increase the intensity and duration of job-search activities through three main (possibly interrelated) channels: (1) a price effect, by changing the relative price of the search when transport subsidies are provided; (2) a wealth effect, by lowering total spending on the search, which alleviates cash constraints, lowers the marginal disutility of additional searches, and prevents the running down of savings; and (3) a time effect, by which the alleviation of cash needs can decrease the need for unemployed individuals to take temporary forms of work that impose a large time constraint that can impair their ability to search for better work.

3.3. Land-use and transport[2]

Several descriptive and analytical models have been developed over time to explain the relationship between transport and land-use structures. Von Thünen's model, developed in the early 19th century, is the oldest representation based on a central location and its concentric impact on surrounding land use. The underlying principles of this model have been the foundation of many others where economic considerations, namely land rent and distance-decay, are incorporated.

The Burgess concentric model, an adaptation of the Von Thünen model, was one of the first attempts to investigate spatial patterns at the urban level (Park and Burgess 1925) proposing a concentric representation from the central business district. Later developments include sector models, by which transport corridors, such as rail lines, public transit and major roads, are mainly responsible for the creation of sectors (Hoyt 1939). Multiple nuclei models argue there is a progressive integration of a number of separate nuclei in the urban spatial structure with different levels of accessibility (Harris and Ullman 1945). Hybrid models combine the concentric effect of central locations (central and sub-central business districts) and the radial effect of a transport axis, all overlaid to form a land-use pattern (Isard 1955). Land rent theory, a geographic economic theory based on some of the urban growth ideas presented before, has been widely acknowledged in transportation research. This theory discusses how the price and demand for real estate change as the distance from the central business district increases. More specifically, there is a market where different urban activities compete for land use at a location. The more desirable a location, the higher its rent value. Transportation, through accessibility and distance-decay, becomes a strong explanatory factor for the price of land and its use (Kenworthy et al. 2015; Medda 2012; Debrezion et al. 2007).

The most recent trend in modeling land-use changes across space in response to transport interventions is based on cellular automata or dynamic land-use models, where the unit of analysis is represented as a cell or grid (Tobler 1979). This approach enables a higher level of spatial detail (resolution) in the analysis, and links the changes in transportation structures to outcomes on the spatial structure of urban areas. According to authors such as Lau and Kam

(2005), the cellular automata model outperforms the alternative model with only a distance function, confirming the importance of incorporating local attributes in modeling land-use changes.

4. Evidence on urban transport interventions

4.1. Evidence on bus rapid transit systems

While designs can vary widely, bus rapid transit systems generally are bus-based systems that operate in dedicated lanes, with rapid service through the implementation of several operational features such as off-board payment, at-level bus boarding, intersection signal priority, passing lanes, and frequent service.[3] The introduction of these systems has also generally been accompanied by government reforms of the bus sector that employ various public-private contracting schemes, or a mix of centralized planning and private investment and service operation. Curitiba, Brazil was the first city to develop a bus rapid transit system in 1977. Based on Curitiba's model, Bogota, Colombia built its first bus rapid transit line in 2000, incorporating technological innovations that led to it achieving the highest capacities and speeds of any bus rapid transit system in the world. As these systems are considered a cost-effective and flexible approach to providing high-capacity and more environmentally sustainable transportation, they have grown rapidly around the world. Today bus rapid transit systems operate in 54 cities in LAC and 167 cities globally (WRI Brazil Ross Center for Sustainable Cities 2018).

There is not a straightforward theoretical explanation of the impact that bus rapid transit systems can have on land values and land-use changes. Increases in property values may depend upon the quality of public transport systems and its subsequent ability to reduce travel times (Cervero and Kang 2011; Bocarejo et al. 2013). As bus rapid transit system designs and their associated travel time savings can vary widely, the effects on property values can also vary. As posited by Medda (2012), travel time reductions may also be valued differently by customers depending on the locations to which these new systems provide access. Moreover, the extent to which accessibility benefits translate into land values will depend on the sensitivity of users to improvements in access (Rodriguez and Mojica 2009). Bus rapid transit systems and other mass transit investments that operate at surface or above ground can also have negative effects on property values and land use near the system due to nuisance effects such as noise, air pollution, and crowds of passengers. Finally, some studies hypothesize that the potential of bus rapid transit systems to increase property values may be lower compared to heavy and light rail systems due to their flexibility, perceived lower level of permanence, and rigidity as an infrastructure service (Rodriguez and Targa 2004; Vuchic 2002).

Several studies that examine the effects of bus rapid transit systems on property values and real estate development yield mixed results,[4] but only a handful of papers use empirical strategies seeking to determine attribution. Perdomo (2011) uses propensity score matching to evaluate the impact on property values of TransMilenio, Bogota's bus rapid transit system, finding a positive impact in areas in the vicinity of the system. The absence of time-varying information, however, does not allow for controlling for unobservable characteristics that might affect the results. Rodriguez and Mojica (2009) evaluate the impact of the extension of TransMilenio on property asking prices. They exploit a difference-in-differences estimation and find increases in prices in areas that were already served by the TransMilenio but that benefited from an extension, and detect no impact in areas that gain new access to the system. Their empirical approach lacks an analysis of how similar treatment and control groups were at baseline and a discussion about whether the parallel trends assumptions, required for difference-in-differences to be valid, holds in this case. For Lima, Peru, Martinez et al. (2018) rely on a combination of propensity score matching and difference-in-differences methods. They find evidence of residential rent-price increases in feeder lines connected to the Metropolitano bus rapid transit system, but no significant impact around the Metropolitano line itself. This suggests that prices may absorb larger accessibility gains. Martinez et al. (2018) also present evidence on reductions in housing affordability given a significant increase in total household expenditures directed to housing payments, which is above the 30 percent affordability threshold[5] after implementation of the transport system.

The increased value of property is also theorized to stimulate land-use change by increasing the attractiveness of development or redevelopment of parcels near the stations (Rodríguez and Mojica 2009). Previously vacant parcels may become more attractive to real estate investors, and those that are built up may become targets for more intensive development or infill. Timing of effects might be important: while land-price effects can be instantaneous, land-use changes tend to occur more slowly, partly due to institutional lags (e.g., securing building permits and zoning amendments) (Perez et al. 2003). The literature looking at the urban development effects or land-used changes from bus rapid transit investments is still scarce and also shows mixed results (Stokenberga 2014). Again, most of this literature is based on before-and-after comparisons, or cross-sectional analysis exploiting distance to the system, without explicit consideration of the counterfactual scenarios.[6] The only study identified here that offers a difference-in-differences estimation is Bocarejo et al. (2013), who show that areas served by Bogota's Transmilenio have higher population growth than areas without access to the system, particularly feeder areas, but that there are no significant changes in land use.[7]

By reducing transport costs and improving accessibility, bus rapid transit investments may also have effects on facilitating access to markets and services. Along these lines, multiple studies, most conducted in developed countries, have analyzed the impact of urban transit investments on employment outcomes. The studies are mostly non-causal and can be classified in three groups. The first focuses on predicting changes in access to employment opportunities from bus rapid transit systems in terms of ease of access to jobs (Dutta and Henze 2015; Jaramillo et al. 2012; Delmelle and Casas 2012; Bocarejo and Oviedo 2012; Bocarejo, Portilla, and Meléndez 2016). The second group empirically estimates employment effects based on correlation studies to show that proximity to a bus or subway stop, or transit service frequency, is correlated with lower levels of unemployment (see Sanchez, 1999, and Sanchez et al., 2004, for the United States; and Oviedo-Dávila, 2017, for Bogota). The third group uses a before-and-after approach to show that growth is largest near downtown stations of bus rapid transit corridors, particularly for white-collar and high-wage employment (Guthrie 2016).[8]

Recent studies have sought to address causality when looking at the employment impact of bus rapid transit systems. Scholl et al. (2018), in analyzing the Metropolitano bus rapid transit of Lima, Peru, rely on a combination of difference-in-differences and propensity-score-based overlap analyses. They find that only several years after the introduction of the bus rapid transit line are there positive effects on employment outcomes (employment, formal employment, hours worked, and monthly labor income) for individuals living in originally worse-off areas, and that those positive effects are only for the bus rapid transit feeder lines' areas of influence.

Tsivanidis (2018) looks at the aggregate and distributional effects of TransMilenio. Based on work featuring gravity equations for commute flows (Ahlfeldt et al. 2015), he proposes a new reduced-form methodology derived from general equilibrium theory based on "commuter market access," arguing that distance-based approaches might be misleading in capturing the intensity of treatment. To address the non-random route placement, he uses instrumental variables estimation exploiting historic data on the tram system and engineering estimates of the cost to build bus rapid transit systems on different types of land. The author finds that while the system caused increases in welfare and output larger than its cost, gains accrued slightly more to high-skilled workers. The analysis of mechanisms suggests a potential increase in residential segregation by skills.

Another recent strand of the bus rapid transit literature has analyzed the effects of such systems on pollution. Bel and Holst (2018) study the effect of Mexico City's Metrobus on air pollution emissions. Using difference-in-differences and quantile regression techniques, they estimate the atmospheric concentration of pollutants in Mexico City between 2003 and 2007 in order to assess the impact of the introduction of the Metrobus. They conclude that the bus rapid transit system constitutes an effective environmental policy, reducing emissions of CO, NO_X, $PM_{2.5}$ and PM_{10}.

4.2. Evidence on light rail and subway systems

Urban light rail and subway systems are expensive enough that these projects generally require large subsidies. To justify these subsidies, proponents often assert the ability of these systems to have a transformative effect on the city and to encourage employment growth (Gonzalez-Navarro and Turner 2018). However, the evidence is limited regarding such transformative effects. This section focuses on the small set of papers that attempt to solve the causality problem caused by the non-random assignment of these systems and their stations.

Baum-Snow and Kahn (2000) study the impact of new rail transit on usage and housing values. They exploit variation in transit access changes among census tracks within five major cities in the United States that upgraded their rail transit systems in the 1980s, using distance as a proxy for transit access. The authors find that rail transit improvements lead to increased mass transit use for commuting, but to a small capitalization of transit infrastructure into housing prices and rents. In related research, Gibbons and Machin (2004), for the case of the London Underground and Docklands Light Railway in South East London, and Billings (2011), for the case of the new light rail line in Charlotte, North Carolina, show increases in prices in areas closer to the systems using difference-in-differences approaches. More recently, Dorna and Ruffo (2017), using a difference-in-differences approach combined with matching analysis, find that the electrification of a light rail suburban line in Buenos Aires had positive effects on housing prices around the areas of influence of the stations. Using a synthetic control methodology, they also find that the increased reliability of the service had large effects on ridership.

While these studies provide evidence regarding the effects of mass transit on property values, they do not provide information on the relationship between light rail and subway systems and the growth of cities. If these systems affect urban growth, those effects will appear both near and far from the stations and might take more time to appear. Such citywide effects are, by construction, not captured by a difference-in-differences methodology, as noted by Gonzalez-Navarro and Turner (2018), who studied the relationship between the extent of a city's subway network, its population, and its spatial configuration in the 632 largest cities in the world. For this, they construct panel data describing the subway systems in these cities, their population, and measures of centralization calculated from night lights data. Their evidence suggests that when big cities build subways, the subways have at most a small effect on urban population growth. However, they find that subways allow the central cores of large cities to spread out and reorganize activity in the cities, suggesting that when transportation costs fall, economic activity can spread out.

Regarding employment, Holzer et al. (2003) exploit the exogenous change in accessibility to employment brought by the expansion of the Bay Area Rapid Transit System (BART) (including heavy rail and subway). Using a difference-in-differences approach the authors estimate the impact of the expansion of BART on the propensity of suburban firms to hire minority populations, finding sizable increases in the hiring rates of Latino workers but no increases in the hiring rates of African-Americans. Using historical data on manufacturing establishments from 1850 to 1870, in difference-in-differences and instrumental variables models, Atack, Margo and Haines (2008) find that the introduction of the railroad increased establishment size in manufacturing. More recently, the impact of an exogenous shock from Hurricane Sandy, which shut down a portion of New York's metro system (the R train) in 2013, was exploited to estimate the effect of the system on access to employment (Tyndall 2017). Findings show that living next to the R train during the shutdown resulted in an overall increase in the probability of being unemployed, and that effects were lower for individuals who had access to a vehicle and much higher for those who were transit-dependent.

Another important strand of the literature on the effects of light rail and subways studies their impact on air pollution. Chen and Whalley (2012) use a sharp regression discontinuity design to examine rail transit ridership on the opening day of a new rail transit system in Taipei, China. The assumption behind this design is that in the absence of opening the Taipei Metro, air quality would have changed smoothly for that day (i.e., air pollution levels on the days just before the opening of the Taipei Metro form a valid counterfactual for air pollution levels in Taipei on days just after the opening of the Taipei Metro), conditional on differences in weather, a host of time-specific fixed effects, and a very flexible smooth time trend. The authors find that the opening of the Taipei Metro reduced CO_2 air pollution by 5 to 15 percent, but they find little evidence that ground-level ozone pollution was affected by the opening of the Metro. Goel and Gupta (2015) use a similar strategy to measure the effects of the Delhi Metro in India on air pollution. The authors exploit the sharp discontinuities in metro ridership resulting from each extension of the rail network and examine whether they coincide with corresponding discontinuities in pollutant measures. They find evidence of large reductions in NO_2 and CO_2 levels.

4.3. Evidence on cable cars

Cable cars are mainly touristic attractions in rich western countries, but in LAC cities they have been implemented as transport systems to connect isolated low-income neighborhoods with the city center. Cable cars offer multiple advantages over subways or light rails systems. They can be built in a shorter amount of time, do not require the displacement of large groups of people, and seem more suited for cities with mountainous geographies (The Economist 2017). However, these systems tend to be heavily subsidized and do not have the same capacity as other massive transport systems. The first cable car designed as a transport system in LAC opened in Medellín, Colombia in 2004. Since then, Caracas (Venezuela), Cali (Colombia), Mexico City (Mexico), Rio de Janeiro (Brazil), and La Paz (Bolivia) have built similar systems.

There are still few causal studies quantifying the impact of cable cars. This is probably due to the fact that it has been a long time since cable cars were used as transport systems in developed countries (Dale 2010),[9] and all causal evaluations available pertain to cities in the LAC region, namely Medellín and La Paz. Following non-causal methodologies, the cable car of Medellín

(Metrocable) has been the most studied in the literature. Evidence on this system suggests that it is correlated with improvements in urban integration and the modernization of neighborhoods (Brand and Dávila 2011; Goodship 2015), accessibility and improved citizen security, particularly for women (Heinrichs and Bernet 2014), improved quality of life (Roldan and Zapata 2013), increased employment opportunities for the poor (Bocarejo et al. 2014), and reduced in emissions (Dávila and Daste 2012).

Using causal methodologies, Cerdá et al. (2012) examine the effects of the Metrocable in Medellín on violence, based on homicide reports at the neighborhood level and household surveys. The empirical strategy compares neighborhoods that are serviced by the Metrocable versus comparable neighborhoods not serviced by this system (obtained through propensity-score-matching techniques) before (2003) and after (2008) completion of the transit project. Their findings show that the decline in homicide rates was greater in treated neighborhoods and that resident reports of violence also decrease in the proximity of the system. Using more detailed geo-coded information, Canavire-Bacarreza, Duque, and Urrego (2016) also find reduced homicides rates in neighborhoods served by the Metrocable.

Bocarejo et al. (2014) also study the effects of the Metrocable in Medellín, looking at changes in accessibility to jobs, travel-time savings and costs, and housing values. The authors use data from origin-and-destination surveys before and after the project's implementation. Their results show that the access provided by Metrocable to the main employment centers doubled the number of job opportunities reachable by people in the area of influence of the project. However, they do not observe large changes in reported travel-time savings and costs. Moreover, the authors do not find a statistically significant relationship between the Metrocable and housing costs.

It is often assumed that cable cars, as well as other urban transport systems, lead to travel time savings, but few impact evaluation studies quantify these savings. Suárez-Alemán and Serebrinsky (2016) conduct a quantitative estimation of travel time savings arising from Mi Teleférico, the cable car system in La Paz. The authors use individual-level, origin-and-destination surveys and compare travel times between trips, with the same origin-destination pair, that are made on Mi Teleférico versus those that are made on alternative transport systems. Their findings suggest that, on average, Mi Teleférico reduces travel times by 22 percent.

More recently, Martinez et al. (2018a) estimate the impact of Mi Teleférico on changes in household-level transport expenditures, individual time allocation decisions, and employment outcomes. Given that stations were located in an ad hoc manner and that households cannot easily manipulate their location (particularly property owners), the identification strategy exploits distance to the closest station of the Mi Teleférico system as an instrumental variable to predict the use of the system. The results point towards a transport modal shift, as treated households report larger expenditures on public transportation and lower expenditures on private transportation. In terms of time allocation, there is a significant reduction in transport time and an increase in the time devoted to educational and recreational activities. Finally, there is evidence of increases in self-employment activities and associated increases in labor income.

4.4. Evidence on driving restrictions

Increasing levels of urbanization and productivity and a fast-growing middle class in LAC in recent decades have resulted in the region having the largest rate of growth in motorization in the world, and the region is projected to triple its vehicle fleet in 25 years (United Nations Environment Program 2016). Heavily populated cities have benefited greatly from this growth process while simultaneously facing the difficulties of increased pollution and congestion. Currently, capital cities in LAC exceed the recommended annual WHO limits for PM_{10} and PM_{25} emissions (WHO 2017) while also ranking poorly on the Waze (2016) driver satisfaction index and the TomTom (2017) traffic index.

To deal with both pollution and congestion levels, and to ultimately try to influence the mode of transport choice of the population, several cities around the world have tried policies to curb emissions and/or reduce traffic congestion during peak hours. These policies include large investments in public transport, designated lanes for high-capacity vehicles, and congestion pricing schemes, such as those in place in London, Milan, Stockholm, and Singapore. However, these initiatives are either costly or politically charged for city governments to easily implement. Several cities, primarily in LAC, have opted for a less expensive alternative: vehicle driving restrictions. Normally, these restrictions ban the use of private light vehicles during specific times of a weekday in certain areas of a city, based on a given rule like the last digits of the vehicles' license plates. The restrictions are in place during rush hours in both the morning and the evening. Compliance with the program comes from enforcement either by police officers on the street or traffic cameras, and hefty fines are imposed for violations.

The most well-known of these programs in LAC is "Hoy No Circula" ("Today You Do Not Travel"), which started in 1989 in Mexico City to curb pollution within the metropolitan area. Santiago, Chile introduced a license-plate-based restriction in 1986 for vehicles lacking catalytic converters and later expanded it to all vehicles. São Paulo, Brazil started restricting drivers in 1996 following the initiative in Mexico City, and so did Bogota, Colombia in 1998, although mostly to deal with traffic congestion. Other cities in Colombia followed the example of the capital, including Cali, Cartagena, and Medellin, as did other LAC cities such as San Jose (Costa Rica), Quito (Ecuador) and La Paz (Bolivia).

Several studies have used empirically robust methodologies to assess the effectiveness of these types of restrictions, and their findings have been mostly disappointing. Permanent restrictions do not have a lasting effect on reducing pollution or traffic and might even induce households to buy a second highly polluting car to circumvent the restriction completely.[10] Studies of the "Hoy No Circula" program in Mexico City, such as Eskeland and Feyzioglu (1997) conclude that the driving restrictions increased gasoline use, most likely from a second car in the household. Davis (2008) finds an increase of 20 percent in the car fleet with a decrease in bus ridership and an increase in car sales, while also finding that it has no discernible effect on air quality. Gallego, Montero, and Salas (2013) find that households adjust their vehicle stock in a little less than a year and thus the benefits of the restrictions disappear by the second year. Davis (2017) suggests that expanding the restriction to Saturdays has not reduced air pollution, as households rely on other private car trips. Finally, Blackman et al. (2018) uses a contingent valuation methodology for the willingness to pay to avoid the traffic restriction. They find an average annual willingness to pay equivalent to US$130 per vehicle, which represents up to 2 percent of a driver's annual income.

Methodologies for assessing the impact of these restrictions typically exploit the timing of the intervention. Studies of the impact on pollution of Mexico City's restrictions use air quality monitoring stations throughout the city and a regression discontinuity design centered around the date of implementation, while also controlling for environmental covariates and flexible polynomial adjustment terms (Davis 2008, 2017; Gallego, Montero, and Salas 2013). This methodology has been replicated in other studies (see Blackman, Li, and Liu, forthcoming, for a review of developing countries studies) and the results are comparable to the one for Mexico City's program. Studies of the programs in Bogotá, Santiago, São Paulo, and Quito have found short-term gains, but mixed or even negligible long-term results because drivers adopt strategies to circumvent the restriction (Troncoso, de Grange, and Cifuentes 2012; Bonilla 2016; Carrillo, Malik, and Yoo 2016; Zhang, Lawell, and Umanskaya 2017). In sum, the existing literature suggests that driving restrictions can work for short-term pollution emergencies, but that using driving restrictions as long-term fixes for pollution and congestion must take into account available public or non-pollutant substitutes and behavioral responses by drivers.

4.5. Evidence on transport network companies

In recent years, transport network companies (also known as ride-sourcing companies) have received remarkable attention from consumers, the media, and policymakers. These types of companies have emerged as app-based, on-demand ride services and they have generated a debate over their role in urban transport. Transport network companies have become more common over the last decade, with small local or regional services giving way to national and global companies. Examples include Car2go, Zipcar, ReachNow, Via, Cabify, Lyft, and Uber.

The transport sector of many cities (those in LAC included) is now experiencing a high level of disruption with the introduction and evolution of technology and transport services. As these new layers of technology-based transportation options spread, it is important to understand how they affect the transportation systems and society. The literature on this topic appears to be very limited, in part due to their novelty and lack of open data on these services. In addition, there are difficulties in constructing valid counterfactual scenarios, given that in many cases transport network companies are introduced in whole cities or countries at the same time.

Ride-sourcing has been mainly compared with taxis. This is primarily because both services involve passengers paying a fee for the travel. However, there are many differences between them, including the use of technology, labor market differences, and government regulations. In the different countries where ride-sourcing companies have tried to enter, there has been resistance by current providers (mostly taxis) and controversy because the new companies disrupt the industry, competing and taking away many customers from taxis. Rayle et al. (2014) compare ride-sourcing and traditional taxis in San Francisco using an intercept survey. Their findings suggest that ride-sourcing meets a latent demand for urban travel, appealing to generally younger, well-educated users looking for short wait times and fast point-to-point service, while avoiding the inconveniences of driving like parking, or restrictions on drinking and driving.

One of the main concerns with the rise of ride-sourcing companies has been the effect that they may have on traffic congestion, especially considering that the areas in which they operate are large cities with heavy traffic. Using a difference-in-differences approach, Li, Hong, and Zhang. (2017) find that the entry of Uber into the United States market significantly decreases traffic congestion time, congestion costs, and excessive fuel consumption. The authors argue that ride-sharing services have the potential to reduce car ownership, shift the traffic mode from single occupancy to ride-sharing, and delay travel plans during peak hours, thus reducing overall traffic congestion in an urban area. This study is to the best of our knowledge the only study that attempts to show a causal effect of the entry of a transport network company.

4.6. Incentives to increase demand of urban transport systems

As urban transport systems are constructed and consolidate their operations, new evaluation questions emerge related to the operational aspects of the system. From the operators' perspective (in several cases a private sector actor), some of these questions could relate to what the most appropriate tariffs are to maximize the demand of the system or what type of promotion strategies could be most effective to incentivize its use, among others. From a policy perspective, incentivizing demand could be key to promoting a modal shift to transport systems that are more environmentally friendly. It could also be relevant to understand how transport systems can maximize social inclusion effects through well-designed and targeted subsidies. This section presents evidence around some of these questions.

Willingness-to-pay studies

As important as it is to know the effects of different urban interventions, it is also important to understand how much people are willing to pay for those interventions. Several studies, the majority in developed countries, have looked at the willingness to pay of travelers or consumers for different transport services or attributes. In several cases, this information is elicited through experimental designs (stated preferences) while in others it is based on observations of actual behavior or choices (revealed preferences approach).

Some studies have looked at the willingness to pay to reduce travel time in the context of toll highways, which has been used to guide the design of congestion pricing or time of day pricing programs. The main idea behind these estimations is to obtain the value of time or the amount of money that a respondent would be willing to pay in tolls for one-hour time savings in order to keep the respondent's transport choice unchanged (Brownstone et al. 2002). Calfee and Winston (1998) apply stated preference models to a sample of drivers who regularly drove to work in major metropolitan areas of the United States. They find that the willingness to pay is surprisingly low (between \$3.5 and \$5 per hour) and insensitive to travel conditions and to how toll revenues are used. Using revealed preference data, Brownstone et al. (2003) estimate that users have a median willingness to pay of $30 to reduce travel time by one hour on San Diego's Route I-15, which highlights the fact that stated preference studies generally yield lower values than revealed preference studies (Wardman 2001). For Route 91 in Southern California, Lam and Small (2001) estimate the value of time to be between $19 and $24 per hour depending on model specification. They look at day pricing, which might explain the variation in results in comparison to Brownstone et al. (2002) that look at congestion pricing.

Willingness to pay studies have also been applied to value improvements in the quality of transport services. Molin and Timmermans (2006) and Khattak, Yim, and Stalker Prokopy (2003) evaluate the value for consumers of different information aspects that can be included in web-enabled or electronic public transport information systems in the Netherlands and the United States, respectively. Their results indicate that travelers are willing to pay for better quality and more interactive information systems. Eboli and Mazzulla (2008) estimate the willingness to pay for improving the quality levels of a bus service among Spanish students. Their results show that the maximum valuation corresponds to service frequency and the minimum value pertains to information at bus stops. More specifically, users would pay an increase of 44 percent in weekly and monthly cards for more service frequency. In a similar vein, Worku (2013) examines the willingness to use and pay for improved public transport services in the United Arab Emirates. The results suggest that residents are willing to use and pay higher fees for public buses, provided that the quality of service is improved.

Another way of using willingness to pay results is to characterize the demand of existing or new transport systems. Results from multiple studies highlight the heterogeneity in willingness to pay across individuals, which is key to improving the design and targeting of certain transport interventions. For example, for certain settings, females seem to value more the expressways when compared to men (Senbil and Kitamura 2004). Higher-income persons are willing to pay more to reduce travel time because of their greater opportunity cost (Markose et al. 2007). Individuals who are more aware of environmental issues are more likely to use public transport (Carson 2000; Lee and Cheah 2014), and those with more children and who are older save travel time by using more expensive or shorter routes (Asensio and Matas 2008).

Experiments with subsidies to increase demand and encourage employment search

Subsidies for public urban transport have been adopted, both in developed and developing countries, to make transport more affordable. As these subsidies usually encourage the use or more frequent use of transport systems, they might also facilitate access to services and economic opportunities. Phillips (2014) studies whether transportation costs constrain job searches in urban low-wage labor markets. He provides transit subsidies to randomly selected clients of a non-profit employment agency in Washington, DC. The subsidies generate a large, short-run increase in search intensity for the transit subsidy group relative to a control group receiving standard job search services but no transit subsidy. In the first two weeks, individuals assigned to the transit subsidy group apply and interview for 19 percent more jobs than those not receiving subsidies. These results provide experimental evidence in support of the theory that search costs over time can depress job search intensity, contributing to persistent urban poverty in neighborhoods far from job opportunities. Similar findings have been obtained by Franklin (2017) looking at the case of young job seekers who live far from the center of Addis Ababa, Ethiopia. The author concludes that search costs impose significant constraints to find employment, as experimentally treated individuals increase job search intensity and are more likely find good and permanent jobs.

5. Discussion, policy implications, and future avenues of research

This paper summarizes the existing knowledge arising from causal studies looking at the impact of urban transport systems. Driving restriction interventions are also discussed, given their potential to affect the demand for passenger transport systems. The review highlights the increasing number of causal evaluations that have emerged in this area, probably following the important growth in public and private investments in the sector in response to congestion, pollution, and transport safety problems in many urban areas around the world.

The available literature shows that studies have been concentrated on certain types of interventions and the majority have been conducted in developed countries. The evidence on bus rapid transit systems and subways, as well as on driving restrictions, is among the most developed. In contrast, there are still few studies of recent interventions such as traffic network companies or ride-sharing systems. Moreover, there is great potential for conducting evaluations on interventions that seek to improve the operational efficiency of systems and those that seek to promote behavioral changes in users. The review also highlights that there are still few causal studies in the LAC region. Those identified are concentrated on evaluating traffic restriction policies and bus rapid transit systems. From an external validity point of view, creating more evidence for the region is essential to guide policymaking.

In terms of methodological approaches, many studies in this literature, particularly the oldest ones, suffer from several limitations when addressing causality. Multiple studies rely on before-and-after comparisons without considering the counterfactual scenario. Others have used distance to the system, but cross-sectional comparisons across space do not allow for controlling for key time-invariant unobservable characteristics. A smaller number of studies use difference-in-differences methods, but several papers lack a proper discussion of the validity of parallel trends assumptions underlying this causal approach. In recent years, some studies have moved toward combining matching with difference-in-differences techniques to reduce some of these concerns. In other cases, particularly for environmental outcomes that can change quickly over time, the strategies have been based on regression discontinuity designs. This review only finds a few cases using experimental designs, and this is probably due to the difficulties in randomizing many of the elements around transport systems. More recently, a few authors have proposed the use of quantitative general equilibrium frameworks given the expected impacts in the entire network and the difficulties in identifying pure treatment and control groups.

Regarding the main lessons learned about impact, bus rapid transit has been the most studied, but the evidence has been mixed on both prices and land-use changes. This could be due to the different evaluation methods used and how (or whether) they have approached causality. It could also respond to the fact that these systems might not be perceived to be permanent by the real estate market, as they could be moved or changed over time, and their quality differs across countries and regions. The most recent literature tackling causality suggests that bus rapid transit systems could have an impact on increasing land values. In the case of subways and light rail, results seem to be more conclusive, suggesting positive effects on land values. The evidence also indicates that subways may lead the central cores of large cities to spread out by reorganizing activity in the cities.

There are still few studies exploring the socioeconomic impact and displacement effects arising from bus rapid transit and subway or light rail systems, possibly due to data limitations, including the difficulty of following households over time and of selecting credible comparison groups. Findings in this area are mixed, but those arising from recent causal studies seem to indicate that, to the extent that accessibility gains are large, these investments could have effects on employment, both by increasing the probability of being employed and on access to formal jobs. Finally, for environmental outcomes, the studies conducted in this area are probably the most rigorous from a causal point of view and point to positive environmental effects, particularly reductions in pollution.

For cable cars, although these systems are becoming increasingly popular in the region, the causal evidence is limited to the case of Medellín (Metrocable) and La Paz (Mi Teleférico). There is evidence that these systems do indeed bring important travel time savings and thus have impacts in time allocation decisions and employment outcomes. They also seem to affect the development of neighborhoods, particularly those that have accessibility gains, suggesting impacts on crime reduction.

Regarding driving restrictions, the existing literature suggests that these policies can work for short-term pollution emergencies, but that using driving restrictions as long-term fixes for pollution and congestion must take into account behavioral responses by drivers. Studies of such programs in Bogota, Santiago, São Paulo, and Quito have found short-term gains but mixed or even negligible long-term results because drivers adopt strategies to circumvent the restriction, buying a second, sometimes highly polluting car.

In the case of transport network companies, which are increasingly being used in urban areas, the only available causal study, which is for the United States, concludes that ride-sharing services have the potential to reduce car ownership, shift the traffic mode from single occupancy to ride-sharing, and delay travel plans during peak hours, thus reducing overall traffic congestion in an urban area. The scarcity of studies in this high-growth area points to the need to develop studies that can evaluate the causal effect of the entry of these companies in a market.

Willingness to pay studies have been conducted for a long time and will continue to be relevant to guide the design of new transport services and to better understand travelers´ behavioral responses. Experiments in this area need to be carefully designed to avoid any bias in the responses. Findings show that people are willing to pay to reduce travel time and to use public transit systems under certain conditions. The evidence reviewed offers insights on the establishment of tolls, the improvement of quality attributes in bus services, and the design of web-enabled transport information, among others. Results show that contingent valuation is affected by personal characteristics, by the system, and by the environment surrounding the users. For example, people are willing to pay higher fees to use public buses provided that service quality is improved. Also, concerns about the environment, previous experience with urban transport, and problems of insufficient parking might affect the demand of these systems.

Subsidies for public urban transport have been adopted in both developed and developing countries to make these systems more affordable, particularly for lower-income populations. A few experimental studies in this area analyze whether transportation costs constrain job search in urban low-wage labor markets and access to formal jobs. Results from studies in Africa and the United States show that transit subsidies can generate increases in job search intensity and in the probability of finding permanent work.

The review highlights the broad portfolio of urban transport interventions that are being implemented across the globe to reduce mobility problems. Measured impacts show that beyond the reduction in travel times, which is usually what motivates these interventions, there are important socioeconomic effects that need to be quantified and incorporated in cost-benefit considerations. Some types of interventions seem to have more conclusive results, but it is also evident that different segments of the population and different areas, based on their geographic location, socioeconomic characteristics, and other factors, might benefit from these policies in various ways. As results could be context-specific, more studies are needed to build a strong base of evidence that has external validity and that can appropriately guide the design and implementation of future transport projects. Finally, although urban transport investments have the potential to promote poverty reduction and social inclusion, more targeted policies are needed to fully achieve this goal.

From an analytical perspective, this review confirms that there is ample room to generate causal evidence on the impact of urban transport investments, not only in Latin America and the Caribbean but also in other developing countries. It is important to acknowledge that these evaluations can take several years to be concluded, as they need to follow the timing of the construction and implementation of transportation systems. Moreover, as these systems cannot be randomly located across space, many of these studies will continue to rely on quasi-experimental designs. These two aspects have probably contributed to reducing the interest of academics in exploring this field. However, to the extent that studies can present robust evidence to justify their underlying causal assumptions, they will be able to provide important contributions. The knowledge agenda is now increasingly moving toward using non-traditional sources of data, such as data generated by mobile phone calls and apps, digital sensors, cameras, and satellite information, among other things. Administrative data from transport operators could also be quite valuable, and have not been used frequently for causal evaluation. These new sources of data raise the possibility of conducting retrospective evaluations and reducing the burden and risks associated with primary data collection. In addition, in the presence of high-frequency data, and to the extent that transport interventions bring important accessibility changes to large areas, new methodological approaches such as synthetic control methods might be explored. In addition, general equilibrium models offer the possibility of structurally measuring the full and indirect effects of transport system interventions in a connected network. Evaluations related to “soft” components, such as optimal tariffs and subsidies as well as other incentives to increase demand, are another promising area of analysis. These studies could possibly be undertaken using experimental designs and could bring about results in the short term that would allow operators to improve their services. Finally, given the wide variation in the quality and reliability of services, much research is needed on the impact of service quality on elements such as ridership, employment, and pollution.

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Endnotes

[1] A traffic analysis zone is the unit of geography most commonly used in conventional transportation planning models. The size of a zone varies, but usually encompasses areas that are as homogenous as possible in terms of their transport characteristics and, in general, have less than 3,000 people. Therefore, the size of a traffic analysis zone could vary from very large areas in the suburbs to as small as a city block in central business districts. Usually, traffic analysis zones are constructed by relying on census block-level information. Most often the critical information includes the number of automobiles per household, household income, and employment within these zones. This information helps to further the understanding of trips that are produced and attracted within and between traffic analysis zones (Miller and Shiu-Lung 2001).

[2] This section summarizes material presented in Rodrigue et al. (2017).

[3] They can often transport as many passengers as most conventional light rail systems at a fraction of the cost and compare well with heavy rail systems, except when demand exceeds 50,000 passengers per hour per direction (Rodriguez and Mojica 2009).

[4] Some studies, using cross-sectional designs and hedonic price functions, conclude that properties that are closer to the bus rapid transit corridor have higher values (see Rodriguez and Targa, 2004, Mendieta and Perdomo, 2007, and Muñoz-Raskin, 2010, for Bogota; and Cervero and Kang, 2011, for Seoul, South Korea). Moreover, effects appear to be larger for non-residential properties that are closer to the bus rapid transit stops (Cervero and Kang 2011). These studies, however, do not consider that there might have already been differences in prices between areas that are closer and further away from bus rapid transit stations even before the system was opened, thus making attribution difficult.

[5] The 30 percent threshold of household income that a household can devote to housing costs evolved from the United States National Housing Act of 1937 that created the public housing program to support low-income families. At first, the threshold was that income could not exceed five to six times the rent; over time the threshold evolved to 20 percent, 25 percent, and since 1981 to 30 percent. This threshold constitutes until today the rent standard for most rental housing programs (Schwartz and Wilson 2006).

[6] For example, Knight and Trygg (1977) concluded that exclusive bus lanes in several North American cities had no impact on either residential or commercial development, while Mullins et al. (1990), using a before-and-after comparison, found that the bus rapid transit system in Ottawa, Canada had some effect on land development in areas surrounding stations. Cervero and Kang (2011) use distance to the bus rapid transit system in a regressions framework with controls to conclude that bus rapid transit improvements in Seoul prompted property owners to convert single-family residences to higher-density apartments and condominiums.

[7] Land-use changes are approximated by housing, commercial, and office-built areas.

[8] Sanchez (1999) examines how proximity to a bus or subway stop, or transit service frequency, are correlated with lower levels of unemployment, particularly for poor black communities in two U.S. cities (Atlanta and Portland). He finds that unemployment is higher for those who live more than 400 meters from a public transit node. In a later study, he analyzes a wider sample of cities and concludes that transit access is negatively correlated with the probability of a household receiving government assistance (Sanchez et al. 2004). Guthrie (2016) compares the before-and-after job changes around dedicated bus rapid transit corridors, arterial bus rapid transit (in which buses operate primarily in mixed traffic), and in light-rail transit corridors in 15 regions of the United States. Results suggest that job growth is largest near downtown stations, particularly for white-collar and high-wage employment. In LAC, Oviedo-Dávila (2017) estimates the probability of an individual finding formal employment as a function of distance from Bogota's bus rapid transit system. He uses data from labor market and quality of life surveys and finds that workers living close to Bogota's Transmilenio stations are less likely to be informally employed.

[9] According to Dale (2010), around 1890 there were roughly 500 miles of cable car lines in the United States. Chicago, for instance, moved 27 million passengers per year. But by the turn of the century, virtually all cable car systems had been converted to electrified streetcars, which at the time were more cost-effective and safer.

[10] One of the ways the restriction has shown an unintended effect on the secondary car market is the inclusion of the license plates numbers in all advertisements, so households can choose a car with a license plate that has a restriction on a different day.