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DECARBONIZING CITIES BY IMPROVING PUBLIC TRANSPORT AND MANAGING LAND USE AND TRAFFIC

Discussion Paper
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TRANSPORT DECARBONIZATION INVESTMENT

Table Contents

Transport Decarbonization Investment (TDI) Series

The TDI Series is a partnership between the World Bank, the Government of the Netherlands, and the World Resources Institute (WRI) with the goal of sharing recommendations for overcoming investment barriers to decarbonizing transport and spurring joint action by governments, companies, civil society, and international development and financial institutions. This discussion paper on "Decarbonizing cities by improving public transport and managing land use and traffic" is the third in a series of technical notes in the lead up to COP26 in November 2021. The other reports in the series are:

1. Motorization management and the trade of used vehicles: How collective action and investment can help decarbonize the global transport sector [published]
2. Cleaner Vehicles and Charging Infrastructure: Greening Passenger Fleets for Sustainable Mobility [published]
3. Investing of Momentum in Active Mobility [forthcoming]
4. Unlocking and adopting green freight and logistics [forthcoming]
5. Financing Low Carbon Transport Solutions in Developing Countries [forthcoming]

Many of the topics covered in other papers in the series are complementary to the topic discussed here. To avoid overlap, we refer the reader to these other discussion papers for details and only note specific considerations as they related to public transit provision, land use regulation, or traffic management.

https://www.worldbank.org/en/topic/transport/publication/transport-decarbonization-investment-series

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List of Acronyms

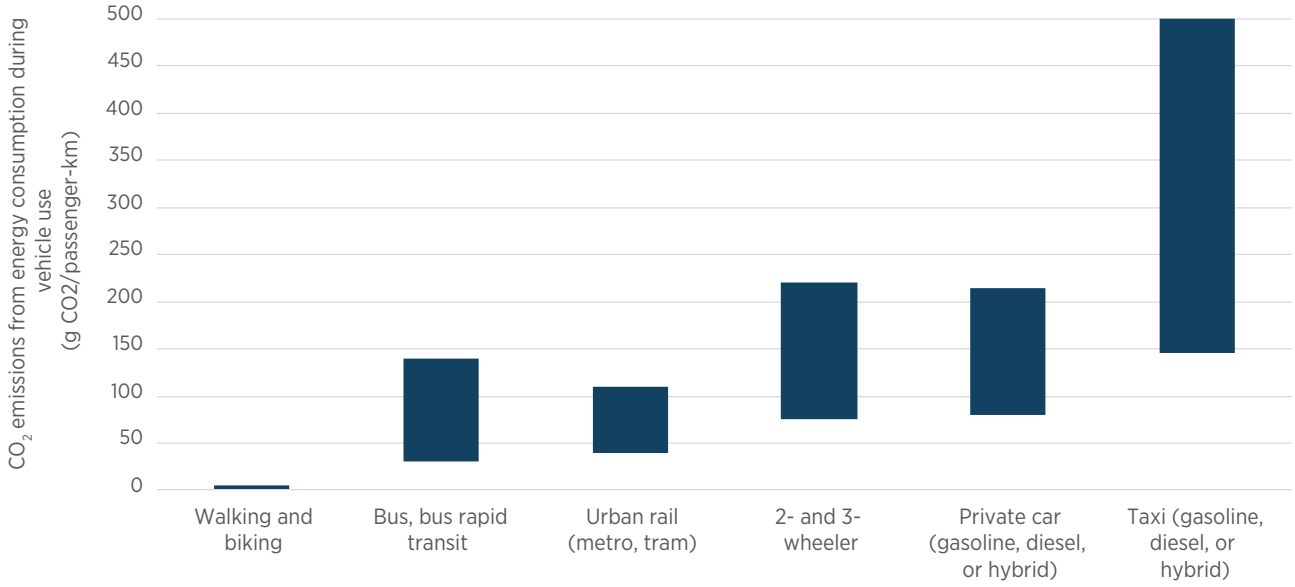
BRT	bus rapid transit
CS	complete streets
FAR	floor area ratio
GHG	Greenhouse gas
HITS	hierarchically integrated transit system
ICM	integrated corridor management
COVID-19	coronavirus infectious disease caused by the SARS-CoV-2 virus
ICT	information and communications technology
MS	multimodal streets
TOD	Transit-oriented development

1. Introduction

Cities continue to agglomerate populations and economic activity. Already, cities account for more than 50 percent of the world's population and 80 percent of its economic output (International Energy Agency, 2021). And the concentration of people in cities is expected to continue through 2050, at which point an estimated 70 percent of the world's population will reside in cities (United Nations, 2018a). Thus, cities are an increasingly critical frontier for climate action. More than 70 percent of global carbon dioxide emissions come from cities, making mitigation efforts at the local level an important contributor to decarbonization.[1]

Urban transport is a significant contributor to climate-warming greenhouse gas (GHG) emissions in cities, with most urban transport emissions coming from cars. Cars and low-occupancy taxis (including ride-hailing and other newer service models) are carbon inefficient per passenger-km served (figure 1). Managing motorization and encouraging the use of much more carbon efficient modes such as walking and biking and public transport—by 2- or 3-wheeler, bus, or train—is fundamental to a low-carbon development trajectory while supporting sustainable development goals for livable cities, social inclusion, clean air, and road safety.

Figure 1. Relative carbon efficiency of urban passenger transport modes



Source: Adapted from Figure 8.6 (Sims et al., 2014).

Note: Ranges provide indication of CO_2 emissions from fuel combustion (and electricity in the case of urban rail). They exclude emissions arising from vehicle manufacture, infrastructure, and other sources of emissions included in lifecycle analyses.

Urban transport also plays a fundamental role in the economic activity and welfare of urban citizens. Therefore, developing cities must find a way to continue to improve accessibility (box 1), while decoupling growth in travel demand from growth in GHG emissions. Affordable, safe, and convenient urban passenger mobility systems are critical for the welfare of urban residents, connecting people to jobs, education, health care, and recreation (Sustainable Mobility for All, 2019). Efficient and reliable urban mobility systems are also critical enablers of economic activity and labor markets in cities (Bertaud, 2018). Public transport is particularly relevant for helping people of lower income access opportunities, generate income, and gain education.

Box 1. Accessibility and mobility: Putting people first

Accessibility can be defined as the ability of an urban transport system to provide its users with access to opportunities in a defined length of travel time. Travel time is defined as door-to-door and is usually 60 minutes for large cities and 30 minutes for smaller ones.[a] Opportunities are usually jobs, but can also be hospitals, schools, theaters, parks, etc. Mobility in turn is the capacity of a system to move people per unit of time.[b] The more people per unit of time an urban transport system can move, the higher the mobility it offers to its users. Accessibility and mobility are therefore two sides of the same coin. If mobility increases, people can access more opportunities in the same amount of time. Accessibility also increases if land uses allow higher density and mixed land uses. Accessibility and mobility are people centric: what matters is how many opportunities people in the city can access per unit of time thanks to the mobility system (Ardila-Gomez, Arroyo-Arroyo and Peralta-Quiros, 2019).

Notes:

a Calls for a '15-minute city' mean the mobility system has to be superefficient to cope with existing mismatches in the locations of housing, schools, and jobs. Forcing the 15-minute city without proper mobility can make the urban labor market collapse because it is impossible for all firms to find the best employees and for all employees to find the schools they want for their children and jobs that satisfy them. Some people will be able to live and work in the 15-minute city, but a large majority will lose (Bertaud, 2018).

b The view of mobility in this paper is slightly different from the one espoused by the literature because of the focus on people and not vehicles. "Mobility measures the ability to move from one place to another. Mobility defines transportation issues in terms of constraints on physical movement and assumes that any increase in travel mileage or speed benefits society. Pursuit of congestion reduction is often at the core of mobility improvement. However, congestion relief through added capacity can cause destinations to move further apart, which could be associated with more time and money spent on travel. Mobility is often measured in person-miles, ton-miles, and travel speeds. Traditional level-of-service measures used in transportation planning are in fact measures of mobility. Furthermore, mobility is sometimes also measured by either the number of trips made, or total kilometers traveled." (Ardila-Gomez, Arroyo-Arroyo and Peralta-Quiros, 2019)

A typical city in the developing world, already have many elements of low-carbon passenger mobility: large modal shares of travel by public and active modes; low ownership and use of private cars. Most people walk, bike, or take public transport—formal or informal—and only a minority travel by car. Motorization levels—private cars per 1,000 residents—are still moderate or low and motorization by motorcycle is often a first step towards private vehicle travel.[2] Still, the large modal shares of travel by public and active modes are typically not by choice. In many cities, public transport coverage and quality of service is inadequate, resulting in many people walking very long distances to access opportunities or abstaining altogether from participating in the labor market, accessing education or health care services, or sharing in other activities.

Despite lower levels of car ownership and use in these cities, urban roads are being designed for cars and not for the majority of people moving by public and active modes. This poor design contributes to issues of congestion, road traffic crashes, and social exclusion. Congestion disproportionately hurts female and low-income users of formal and informal public transport services because buses, mini-buses, and other public transport vehicles are often less maneuverable than private cars or motorcycles (Ardila-Gomez and Ortegón Sanchez, 2016). In addition, public transport vehicles must frequently stop to pick up and drop off passengers. This creates points of conflict as the vehicles enter and exit traffic flows, often exacerbated when fragmented public transport operators compete for each additional passenger.

Maintaining the low-carbon footprint of urban mobility systems in developing countries consequently requires a different approach to street space allocation, transport system investment, and urban design—one that prioritizes and protects the users of public transport, cyclists, and pedestrians, including the very poor, and that recognizes the needs of users such as women and people with disabilities.

Cities in developing countries also have higher overall densities than cities in developed countries (Bertaud and Malpezzi, 2003; Bertaud, 2004; Güneralp et al., 2020; Lall, Lebrand, Sturm and Venables, 2021), but these more sustainable urban development patterns are under threat. In many developing cities, inappropriate land use regulations—for example, low floor area ratios, single-use zones, setback and backyard requirements, and minimum parking requirements—are obstacles for achieving compact, mixed use, and transit-oriented development that can foster greater use of public and active modes. Therefore, new approaches to urban development and land use planning are necessary to enable investments and reforms in transport infrastructure and services.

Cities in developing countries require ambitious investments to expand and improve their urban transport system, but the total funds available are usually only a fraction of what is needed. The "underfunding trap" exists when actual expenditures for capacity expansion and maintenance of existing assets—key aspect for sustainability—are insufficient (Ardila-Gomez and Ortegón Sanchez, 2016). This is because transport systems are a public good with limited ways of generating their own revenue. Roads, public transport systems, sidewalks, and bike paths provide access to opportunities and therefore their benefits extend beyond the users themselves. To ensure inclusive access throughout the city, it would not be fair to charge a toll for walking on a sidewalk or using a bike lane and affordable public transport fares do not typically recover the complete cost of operations and maintenance, let alone capital costs for infrastructure. Addressing the underfunding trap can also help cities access financing—bonds, loans, and guarantees—needed for large, upfront capital investments.[3]

In current urban transport systems, private vehicles—particularly cars—demand a lot of valuable space and infrastructure but contribute minimally to the systems' revenues. Registration fees mainly cover the cost of recording who owns the vehicle; fuel taxes are often too low to reflect the environmental and social cost of burning fossil fuels and their revenues are often earmarked for road capacity expansion that motivates more private vehicle use.[4] As the least space- and energy-efficient mode of urban transport, cars do not pay their full costs. Car use is subsidized implicitly, which leaves less room for political controversy, but still distorts behavior. The underfinancing trap contributes to congestion[5] despite low levels of motorization.

This paper argues that cities in developing countries have a unique opportunity to preserve and encourage sustainable urban passenger mobility by building on their existing modal shares in public transport, walking, and biking—low carbon modes. This approach requires significant improvements to urban infrastructure for public transit, walking, and biking—a reprioritization of investment and space allocation away from the cars driven by the minority to the modes used by the majority—and reforms to public transit service provision that reduce competition within the market, address underfunding, and put the needs of the user first. If cities accompany these investments with the right policies and enabling environment—for instance, making land use regulations more efficient and disincentivizing and managing further vehicle ownership and use—they can raise additional funds to continue to invest in greener transport facilities. Indeed, the modern approach to sustainable urban transport financing falls under the "if you benefit, you pay principle" (Ardila-Gomez and Ortegón Sanchez, 2016). For example, local access roads and sidewalks provide general benefits, and it is impossible to exclude users that do not pay a fee for using these roads and sidewalks.

The property tax becomes the natural instrument to finance these roads. If an urban expressway is considered, then users can pay tolls.

Section 2 of this paper, "Challenges," provides additional detail on key mobility and land use challenges that developing cities are facing. Section 3 "Recommendations and Investments" outlines strategies to overcome the challenges discussed in Section 2. And Section 4 summarizes the high-level take-aways and suggests a way forward for the international community to support city governments in providing better transport infrastructure, services, and enabling environments to ensure their long-term financial and environmental sustainability. Rather than present a comprehensive list of recommendations for decarbonization of urban passenger mobility systems, this paper highlights a few areas deemed especially critical for immediate and collective action.

2. Challenges

This section explains the key challenges that prevent the mobility systems in developing cities from delivering their full potential. The challenges are presented in no particular order of importance. Rather, grouped together, they illustrate the complexity of the situation.

2.1 Inadequate road design and traffic management

Urban roads are frequently designed with car traffic in mind with little consideration of the different needs of public transport users, pedestrians, and people with disabilities (Global Designing Cities Initiative, 2016). Many streets do not have sidewalks or marked pedestrian crossings (Szell, 2018); and (Luis A. Guzman, 2021), or if they do, they are occupied by illegally parked cars. This forces pedestrians to walk on roadways—putting them at high risk of injury or death from traffic crashes. Bicyclists do not have infrastructure such as bike-lanes to ride their bikes safely. This road design contributes to social exclusion, therefore.

Despite the low to medium motorization levels, inadequate roads and poor traffic management lead to congested streets. Intersections congest because intersecting traffic flows do not clear the intersection in an orderly manner. In poor developing cities, urban roads often lack proper traffic signals, pavement markings, and other instructions for drivers. Frequently, intersections become bottlenecks that generate long lines of buses, cars, and trucks. These lines congest other intersections, which in turn lead to long queues on more streets (Frame and Arroyo-Arroyo, 2021; Kumar and Barret, 2008). Congestion spreads rapidly and social costs increase (World Bank, 2010; Akbar and Duranton, 2017).

Enforcement is a critical part of proper traffic management. Yet in many cities, enforcement is weak, sporadic, and lacks the randomness that helps catch offenders. The traffic police are often ill-equipped, lacking motorcycles or cars which are essential for enforcement of vehicles on the move. Without vehicles, a greater number of officers is needed to enforce traffic light violations, it is more difficult to meet due process requirements, and enforcement takes time during which lanes of traffic can be blocked by the stopped car.[6] Queues can form and increase congestion. In some instances, authorities forbid traffic police from enforcing during rush hour to prevent congestion. Drivers therefore feel the probability of being caught is quite low, contrary to what good enforcement should achieve.[7]

Modern technologies such as closed-circuit television (CCTV) cameras can help enforce traffic laws. However, for CCTV cameras to be effective the government must have the legal structures to be able to fine violators without the presence of an officer and a database that links a vehicle's license plate to updated information on the registered owner and the address where this person lives. Yet, in developing cities this database either doesn't exist or is outdated; it is difficult to track when cars are sold (but ownership is not legally transferred) or lent out to other drivers or when owners move. The CCTV camera usually registers the vehicle violation, but does not identify the driver. Some courts have ruled that face recognition software is therefore needed as part of the enforcement because due process says the person driving the car, not the car, committed the violation.[8]

2.2 Inefficient land use regulations and 3-d urban development

More than one billion people live in slum areas, equivalent to a third of the world's urban population (Avis, 2016; United Nations, 2018b). Slums develop outside of the complex set of land use regulations that most cities have. Land use regulations are a primary reason behind slum formation because they increase the cost of the built space by limiting supply. "Typically these planning regulations set high minimum standards for land plots and buildings, low development density and high infrastructure requirements based on developed country standards that are unrealistic in developing countries. Consequently, such planning regulations restrict the supply of land and housing and, coupled with a chronic lack of housing finance, skew the urban land markets and drive up the price of housing and out-price the relatively lower income groups" (World Bank, 2020). Consequently, the very poor must go to areas not covered by the regulations—usually in areas difficult to reach or hazard prone, far from employment centers, and often without basic services.

The resulting urban development pattern is known as distant, dispersed, and disconnected, or "3-d" development (Zamorano, 2016; Kim and Zangerling, 2016) (photo 1). Others use the term "urban sprawl." The 3-d urban development translates into long, radial travel patterns that are very expensive to serve with public transport and walking and biking are difficult. As a result, residents find it very expensive to access the labor market, preventing them from exiting poverty. If poor people travel to access jobs, then they can spend a very high share of their income because of the need to transfer several times.

Photo 1. Examples of urban development in 3-d: (right) Hohhot, Inner Mongolia, China and (left) Rio de Janeiro, Brazil. Notice the high density of houses far from concentration of jobs

Sources: (right) Gary Todd via Flickr and (left) Chris Parker via Flickr under creative commons license

Land use regulations also contribute to the lack of integration between transport and land use planning. The extensive literature on transit-oriented development (TOD) and on transport and land use calls for this integration and explains the benefits (Petersen, 2004; Kim and Zangerling, 2016; Salat and Ollivier, 2017). For example, dense, diverse, and well-designed spaces—also known as compact, connected, and coordinated—promote walking, biking and the use of public transport (Global Platform for Sustainable Cities, World Bank, 2018; Suzuki, Cervero and Iuchi, 2013). A critical reason for the high transaction cost lies precisely in the regulatory framework. The literature recommends mostly to increase floor area ratio (FAR) to achieve higher density but does not analyze how individual land use regulations and their interaction impact transit use, walking, and biking.

Land use plans intend to steer urban growth in the right direction and to allocate space to different uses. In practice, the result is a complex regulatory framework that distorts market forces by capping the supply of built space and by making the built space more expensive. Many residents are priced out and must live in 3-d areas.

i. **Floor area ratio:** A maximum value for the ratio of built space to land used or plot area; anything below is legal. Many cities have values of 0.8 to 2.0. The higher the value, the larger the area of space that can be built per unit of land area. Yet even with low FARs, cities can still be dense, but buildings will be low and public space missing. Higher FARs lead to high rises if there is demand because market forces decide if meeting the higher FAR is profitable. For example, the Shanghai World Financial Center with 101 floors has 377,000 m^2 of built space on 27,800 m^2 of land, for a FAR of 13.5 (Bertaud, 2018).

ii. **Minimum lot size:** A minimum land area or lot size to be legal to build on. Houses in slum areas typically do not meet this requirement because the owners cannot afford so much land as required by the norm. Requirements for large lot sizes lead to lower density, particularly when coupled to low FAR or requirements to build only single-family homes. Public transport becomes infeasible in this urban development pattern because of lower density of travel demand. Cars offer a better solution.

iii. **Plot (or building) coverage ratio:** The fraction of the plot area that can be built up, as if looking down from the sky. If the plot coverage area is 50 percent, it means that construction can happen on half the area and no construction on the other half. Lower plot coverage ratios mean less construction can happen on a given plot. The price of built space increases to cover the same land, pricing out the poor.

iv. **Minimum parking requirements:** A minimum number of parking spots per area of built space or per number of units. This requirement is car-oriented because it assumes the household will eventually own a car, even if it does not have the income. Parking requirements increase the cost of the built space and can make it unaffordable for lower income people who cannot afford a car either. Frequently, parking spaces are empty, even in downtown area which shows the parking requirements are too high (Shoup, 2011). Further, parking requirements subordinate urban density to the needs of car-based travel (Manville, 2021). Buildings are farther apart, for example, because of areas used for parking. Density falls, and therefore public transport cannot provide service. Parking requirements do not solve the lack of a proper parking policy at the city level, which begins by recognizing that free parking, particularly on sidewalks and on streets, is not desirable because of its negative externalities (Shoup, 2011).

v. **Single use requirement:** Prohibition on mixing housing with offices and shops, for example, which leads to downtown areas with only offices and no residents. As a result, at nights and on weekends the streets in downtown are fairly empty, devoid of life and can feel dangerous. Allowing mixed land uses—provided they are not incompatible, such as certain industrial use and residential—is one of the main tenets of TOD because of the possibilities for generating walking and public transport trips.

vi. **Maximum number of housing units per block:** A cap on the number of housing units per unit area. If FAR is increased to promote TOD and this requirement is not changed, no actual change in the built space happens (Bertaud, 2018).

vii. **Cumbersome land consolidation:** Developers might need to join several lots of land to build a high rise. Yet the process for consolidating lots in the land registry might take years. If lots are small, developers might incur a high cost to consolidate many lots, particularly if they want to meet an updated minimum lot size regulation (Suzuki, Cervero and Iuchi, 2013).

viii. **Minimum setback:** A minimum distance from the street or the sidewalk that buildings, particularly houses, must start. The result is a front yard. Analogous regulations might mandate a backyard in addition. For wealthy households these requirements—like all regulations—are

not difficult to afford. However, for the less affluent these regulations translate into less built space per unit of area of land. Not surprisingly, houses in slums and other low income areas do not have setbacks. A lower setback requirement increases the density of people per unit area. These populations depend on public transport to access opportunities. Higher setback requirements have the opposite effect resulting in car dependence. Some cities that enforced these high setback requirements are reconsidering allowing a smaller house in the front or back yard to increase housing density.

ix. **Public space requirements not enforced:** Regulations that call for public spaces. These requirements often exist on the books, but developers may not allocate this space without proper enforcement from governments. Many cities have very low public space per inhabitant, with sidewalks and local streets being the most basic expression of public space. Yet private cars illegally park on sidewalks and local streets can be clogged by traffic overflowing from congested avenues. Furthermore, without plans that properly allocate space for streets and sidewalks and proper public financing for these facilities, informal urban developments will allocate minimal space for roads (World Bank, 2020).

In economic terms, land use regulations—such as FAR, minimum lot size, minimum parking requirements, etc.—cap the supply of built space. If supply is capped, any increase in demand leads to increase in prices of the built space. The wealthy can pay, but the less well-off are priced out. Regulations can even exclude the very poor. Yet the very poor need to live somewhere so they move into fringe or hilly areas outside of the official land use plans and illegally develop housing. Slum areas are affordable to the very poor because they do not have parking spaces and the lot size is smaller than mandated. Slums offer a housing solution to one billion people worldwide (Glaeser, 2011; Bertaud, 2018).

Land use regulations lead, therefore, to economic inefficiencies and welfare losses. If land use regulations allowed more built space, then prices would decrease because there is more supply. The lowest-cost way to provide affordable housing is by allowing markets with fewer land use regulations (Glaeser, 2011). Supply of built space will increase, and prices will go down— leading to affordable housing. Property tax collection will also increase because of more built space.

In conclusion, land use regulations are inefficient in economic terms because they distort the market from working by capping the supply of built space.[9] Land use regulations therefore generate welfare losses particularly to the lower income groups, which are priced out and forced into 3-d development or slums (for the very poor) instead. Lall et al. (2021) echoes this view: "Building regulations, such as floor-area restrictions (FARs), can be economically counterproductive by limiting density (residential and commercial) and by lengthening commutes. Zoning restrictions can be damaging if they lock in patterns of land use that become inefficient as a city develops." A minimal regulatory framework is needed that allows market forces to work better, particularly by enforcing property rights (Lall et al., 2021). Over regulation is the problem because of its impacts on the supply of built space which translates also into excessive land consumption and high prices that hurt the poor the most.

To address this conundrum and in the context of the effort to decarbonize urban mobility, the Transport Practice at the World Bank has started a new analytical activity titled "Low carbon mobility and efficient urban form." The objectives are to lower the transaction costs of implementing TOD and to generate a citywide virtuous cycle that promotes the use of lower carbon modes—public transport, walking, and biking. A second objective is to propose more efficient land use regulations that price out lower income groups that depend on public transport. As their incomes grow, they will continue to use convenient and reliable public transport—nourished by a well-designed urban environment—instead of commuting by car.

2.3 Competition in the market: Public transit organization

Public transport users want frequent, reliable, and safe public transport. In most cities in developing countries, public transport is organized along the lines of competition in the market. Each bus or public transport unit is owned by one or more persons, one of whom could be the driver. This arrangement allocates commercial risk or demand risk to the bus owner: the owner loses money if not enough passengers ride the bus. To mitigate the risk, bus owners rent out the bus to the driver. This move effectively transfers the commercial risk to the driver. The driver must carry enough paying passengers to cover the rent on the bus, plus fuel, cleaning, and basic maintenance. The result is cutthroat competition for each additional passenger. Drivers careen their units in search for an additional passenger. Drivers can avoid fully stopping their bus to pick up or drop off passengers which is very dangerous for the users (photo 2) (Gomez-Lobo, 2007; Ardila-Gomez, 2004; Montezuma, 1996).

In other cities, bus companies own the buses, but the incentives are similar if routes overlap. Buses of one company compete for each additional passenger against the buses of all other companies. In some settings the bus companies do not own the buses; rather, they own bus routes, under a permit issued by the government. The bus company periodically charges a fee to the bus owners. The bus company faces no commercial risk, which is entirely allocated to the bus owners or, if the bus owner rents out the bus, to the drivers. These bus companies maximize revenue by having more routes that can be rented out to more bus owners which also increases frequency of service.

Frequency is indeed a critical component of good quality service, because users want to minimize time waiting for the bus.[10] These preferences generate incentives to provide more frequent service: bus companies and bus owners invest in more buses. Authorities issue permits for more buses. In some cities permits never expire (Gomez-Lobo, 2007; Hoyos Guerrero and Lopez Dodero, 2021). While users benefit from shorter wait times, demand seldomly grows as fast. The result is a decreasing productivity measured, for example, as passengers per day per bus or passenger per kilometer logged per bus. As these indicators go down over time, profitability also decreases. Bus owners are drawn to buying used buses that are inexpensive. The incentive is also buy smaller and smaller buses. Cities can start with 12-meter buses for 80 passengers and good frequency of service and end with thousands of mini-buses for eight to 12 passengers. The predatory competition continues among the mini-buses deepening the vicious cycle. Some cities end up with motorcycles that provide public transport service (e.g., moto-taxi).

Thousands of engines mean also more GHG emissions and lower air quality. In African cities, for example, mini-buses are prevalent, and few large buses remain (Foster and Briceno-Garmendia, 2010). Other cities are not as fortunate because they import fully depreciated mini-buses from cities in other developing countries. While used cars can have 200,000 km logged, these mini-buses could have over 500,000 and even one million at the time they were exported. At arrival, the engines go through some maintenance and then enter service on the city streets. These engines pollute a lot because of their old age. Also, the vehicles lack emission control technologies and filters. Coupled to diesel fuel with very large sulfur content, the result is very large pollutant emissions. Air quality deteriorates quickly. Indeed, quality of fuels also plays a role. In the end, there can even be an oversupply of buses (photo 2).

Photo 2. Competition in the market can put users in danger and lead to oversupply of buses. Scene from Kampala, Uganda.

Scenes from (left) Berastagi, Sumatera Utara, Indonesia and (right) Kampala, Uganda

Source: (left) Dillon Marsh via Wikimedia Commons under creative commons license, (right) Ken Marshall via Flickr.

In economic terms, the barriers to entry to compete in this market are low because buses can be added at a low capital and transaction cost. The positive side is that frequency of service will be high, wait times short, and routes will cover a significant part of the city—the slum areas, informally developed might have feeder services using old sedans or people might walk long distances if roads do not allow motorized vehicles. These incentives result in public transport networks that move thousands per day making the city work. Corridors with mixed land uses and therefore many origins and destinations concentrate economic activity, which in turn generate incentives for higher densities—if the land use regulations allow. Some public transport networks have clear nodes where feeder units transfer to larger ones. The lack of a mass transit line does not mean public transport is absent (Kumar, Zimmerman and Arroyo Arroyo, 2021).

Competition in the market delivers public transport service, but with significant externalities in terms of air quality, road crashes, and by exploiting drivers who are informally employed. The drivers, for one, work very long ours, experience high stress, and can even be in charge of maintaining the unit they have (Montezuma, 1996). The drivers are also informally employed because they make income only if they carry passengers above a quota. Few have medical insurance or retirement benefits. Cut-throat competition and long work hours often translate to risky driving behavior and road crashes, which kill or injure users. Air quality suffers because of the thousands of units on the road, many of them fully depreciated in another country. Fuel quality can be low, which aggravates the air quality problem. Reforms along the lines of Competition for the market have improved public transport and formalized labor. Section 3 explains under what specific conditions competition for the market has delivered positive results.

2.4 Failure to meet the greener travel patterns of women

Transport and mobility are not gender neutral. The design of transport policies and projects that focus on peak-hour, commute travel—which only accounts for 20 percent of trips in most cities—often ignores the different and complex travel needs of women. Compared with men, women travel more during off-peak hours, travel shorter distances from home, and are more likely to link several trips together across different modes. Women walk and use public transport more than men (Aloul, Naffa and Monsour, 2018; Dominguez Gonzalez, 2020; Alam et al., 2022). These habits expose them more to the consequences of poor quality and frequency of service such as onerous wait times at transfers and to the health risks from low air quality. Public transport can be unaffordable, can be too far away to walk to on roads with no sidewalks, or frequency of service drops during the off peak making it difficult to arrive on time. Women's travel patterns also increase their safety and security risks. For example, women represent 60 percent of pedestrian fatalities and have a higher risk of being injured or killed during off-peak hour and at night (Moscoso, 2020). Women also face harassment in public transport and on streets. In developing cities, between two thirds and three quarters of women surveyed report being harassed in public transport (e.g., Allen, 2018). Despite simpler commutes from home to work, men drive more—during the peak hour—cycle, ride motorcycles, and e-scooters more than women (Ramboll, 2021).

These different travel patterns emerge because of unequal division of labor in households. Women worldwide have more responsibility for child and elderly care—women oversee 75 percent of the unpaid care work in the world—plus shopping and errands. And women's participation in the labor force is lower than men's. Indeed, transport is necessary to access jobs, education, and services. Girls can miss school and women can limit the geographic scope of their job search or pull out altogether from the remunerated labor force (Dominguez Gonzalez, 2020).

Because women travel shorter distances, chain trips together, and use more carbon-efficient forms of travel, they have a significantly lower carbon footprint than men (Ng and Acker, 2018). For example, a study in Germany and Norway showed that men consume between 70-80 percent more energy for transport than women; in Greece, the difference was 350 percent (Raty and Carlsson-Kanyama, 2010). This evidence suggests that proper attention paid to the different travel needs of women in transport infrastructure and service provision could be a "win-win" for climate and inclusive development, supporting the greenest urban travelers and their access to economic opportunities and services.

2.5 The high cost of free parking: Lack of parking policy

Most developing cities lack a comprehensive parking policy that balances supply and demand for public and private parking spaces. Typically, the amount of private parking is overly controlled by piecemeal land use regulations that often mandate minimum parking requirements for new real estate developments. Many of these parking spaces are empty most of the day, and even when they are fully used the costs of unpursued alternative land uses end up reflected in land prices (Russo, van Ommeren and Dimitropoulos, 2019). Removing these minimum parking regulations could allow the real estate market to balance supply and demand more efficiently for private parking.

Piecemeal regulations and underinvestment in paid parking spaces on-street and off-street result in cars parked for free on urban streets and on sidewalks. Yet many cities have not built complete streets because the sidewalks were not built and cars park in this space (see photo 3). Cars can also park "freely" on the curb. Allocating a lane or two—one on each side of the road—for parking makes the street wider, which increases the cost of building the road and generates no revenue if

parking is free (Shoup, 2011; Speck, 2012)—an example of an explicit but powerful subsidy to car use (Ardila-Gomez and Ortegón Sanchez, 2016).

In all cases, the result is pedestrians walking on the carriage way facing moving cars at close distance, which is not safe. That is one reason why the majority of people killed in road crashes are in developing countries and the majority are pedestrians—vulnerable users that need the protection of a sidewalk.[11] Poor enforcement by the traffic police allows this situation to happen. But the main reason is the lack of a coherent parking policy.

The lack of a coherent parking policy also results in the paradoxical situation of oversupply of parking space in some buildings and lack of public parking space in areas around those buildings. Land use regulations can mandate many parking spots for an office building downtown. The lack of public parking incentivizes drivers visiting downtown to park on the carriageways and on sidewalks. If parking is allowed on the carriageway, it means that the road is wider than necessary and that space for movement is allocated for parking. The cost of this land is high. In addition, parking is all too frequently free so the market does not respond by building public parking facilities that can cater to this demand. If the competition charges zero and authorities allow parking for free on the carriageway and on sidewalks, why invest in a parking lot that will charge?

With ample demand, however, some investors do build parking lots, frequently on empty pieces of land that are waiting for better conditions to build up or that land use regulations allow the construction of too little built space. The investment in the parking lot is low, many do not have pavement. Rarely, investors build three- to five-story buildings for public parking.

Photo 3. Examples of the negative consequences of cars parked on sidewalks: (top) Delhi, India, (bottom left) Dakar, Senegal, and (bottom right) Cairo, Egypt.

Sources: (top left) TenSafeFrogs, (top middle) trisb, (top right) Stefan Weiss, and (bottom left) Tom Burke all via Flickr under creative commons license; (bottom right) Arturo Ardila-Gomez reproduced with permission; further permission required for reuse.

Low investment is motivated by the ample unfair competition and aggravated by regulations—both in developing and developed countries—that over charge for short stays and subsidize long ones. Specifically, the typical fee structure for parking charges X for the first hour, 2X for up to two hours, and 3X for stays of 3 hours or more. A commuter that arrives in the morning peak and leaves in the evening peak will pay 3X. People running errands or shopping travel in the off peak and pay X or up to 3X. This structure generates a cross-subsidy from the shopper to the commuter, which is the wrong incentive because this fee structure subsidizes travel during the peak and discourages travel during the off-peak hours to generate business in downtown.

A survey of parking prices in 65 cities around the world found that middle-income cities of Istanbul, Bogota, Mexico City, Mumbai, Cape Town, Buenos Aires and Delhi rank at the first quintile with the lowest prices to the consumer in the parking spaces of shopping, city hall, and airport districts (Parkopedia, 2019). Further, it exhibited high variability in parking fees, with publicly run on-street parking being significantly cheaper than private parking garages, reinforcing the lack of appreciation of the value of the curbside asset. While per capita incomes in developing cities are much lower than in developed cities with much higher parking prices, car owners tend to be from the higher income brackets and therefore may be able to afford higher parking fees.

Finally, it is important to highlight the equity considerations of parking policies in the developing world. In the developing world, having access to a motorized personal-use vehicle is in reality for a small share of the population from the highest income groups. Unregulated curb side, “free” or underpriced parking, and parking minimums work as a car subsidy, shared by all taxpayers to car owners, incentivizing individual motorization. With those policies, governments miss the opportunity to incentivize more efficient modes of transport, curb traffic congestion, lower real estate prices, and generate additional revenues (Despacio and Institute for Transportation and Development Policy, 2013) that can be reinvested in creating and maintaining transport infrastructures that target benefits for all users.

The next section of this paper will focus on recommendations to address the problems mentioned in this section. The next section will also describe investments needed to materialize these investments, and will explore possible sources of revenue, for example through a sound parking policy—a key aspect of transport demand management.

3. Recommendations and Investments

The recommendations proposed in this section take into consideration the budget constraint that makes cities fall into the underfunding trap. Specifically, cities should invest in projects that do not increase the transport system's deficit. For example, a congested intersection can lead planners and decision makers to build an overpass. Yet proper traffic management coupled to building sidewalks and other elements, as explained below, can solve the bottleneck at intersections without building the overpass. The section begins precisely with improving road design by corridor without forgetting the area implications. The section then suggests ways to improve public transport. The section then discussing the enabling environment which include more efficient land use policies and transport demand management, including parking policy, road pricing, and behavioral nudges.

3.1 Improving infrastructure for public and active transport: Complete, multimodal streets

Complete streets (CS), multimodal streets (MS), and integrated corridor management (ICM) manage traffic flows from all road users, including pedestrians, bicycles, buses, private motorcycles and cars, and trucks (Kingsbury KT, 2011; Global Designing Cities Initiative, 2016; Zimmerman, Dahdah and Wei, 2021). Public transport vehicles users are key beneficiaries. Remember that in cities in developing countries, the majority depends on public transport and walking. Road safety is an integral part to these approaches. Indeed, 50 percent of all road safety fatalities are pedestrians, cyclists, and motorcyclists and 93 percent occur in low- and middle-income countries. Women will benefit in particular as they walk more and use more public transport. They are also 60 percent of pedestrian casualties.

Key to CS, MS, and ICM is first building proper sidewalks and preventing cars from parking on the sidewalk because they are for pedestrians that need to access public transport and opportunities reachable by foot. A second key element is proper intersection management. The capacity of a road is determined by the delay at intersections. Therefore, proper traffic management solutions are needed, including traffic lights. Installing proper traffic management only in the corridor, however, is incomplete because incoming traffic from neighboring streets will likely also need a proper solution. That is why, these corridor approaches need to have area traffic control in which the neighboring streets are also considered. Indeed, traffic management must become a city-wide practice with emphasis on key corridors that concentrate more traffic. Absent this city-wide approach, congestion in a secondary street can end up delaying traffic in the main corridor.

A third key element is that CS, MS, and ICM improve public space. Sidewalks are a key public space element. Adding trees and benches can further improve the public space. Land use also plays a role here as explained below. Last but not least, these options embed also universal accessibility considerations. Ramps for wheelchairs, podotactile surfaces are a minimum. Audible signals are also desirable to tell people with visual impairment when to cross what street.

In slum areas transport solutions play a key role as part of upgrading programs. First is to identify spaces for roads that can provide improved public transport. Due to the narrow space, sidewalks can be minimal, but still important. Widening roads will relocate many people and increase costs. Yet feeder buses could be needed in some suitable roads. Second, paving other roads, many 2 to 3 meters wide due to the informal nature of urban development in slums. Paving these roads can only

happen as part of a comprehensive upgrading program that also includes utilities such as water, sanitation, and power.

3.2 Improving public transit services: Competition and remuneration

Improving public transport must have as key objective to improve the service provided to the user. The key attributes are frequency of service, total travel time, including in vehicle time, wait time, transfer time, and reliability. A reform to improve public transport therefore must provide frequent service, decrease total travel time, and improve reliability. If the reform creates transfers for some users, then total travel time must go down to compensate for the discomfort caused by the transfer (Hoyos Guerrero and Lopez Dodero, 2021). Infrastructure interventions that isolate public transport vehicles from generalized congestion allow reduction in total travel time and to increase reliability. Frequency of service can increase or even decrease as long as the total travel time is the same or lower.[x]

To meet these goals, improving public transport has broadly speaking two key parts. The first is moving toward competition for the market and away from competition in the market. In competition for the market, the government competitively selects operators that must meet quality standards measured through key performance indicators. The contracts have also clear end date and define the risk allocation between operators and government—which in turn determines the remuneration to the operators. Competition for the market works delivers all its benefits if there are barriers that prevent competitors from entering the market to compete. The competition took place for the right to operate for example by offering a low price per kilometer logged (WB, 2002; Ardila-Gomez, 2004; 2008b).

Bus rapid transit (BRT) is a technology that allocates exclusive busways to the authorized buses—selected under competition for the market arrangements. These buses are different to the regular bus because the doors are wider and dock to a station to pick up passengers at grade. Passengers must climb no steps—ramps provide access to the stations from the street also helping people on wheelchairs. Regular buses with two or three steps to climb cannot dock to these stations—in some cases the doors are on opposite sides. BRT is the best example of introducing barriers that protect the operators that won the right to operate through competition for the market. These operators won the right to operate through a competitive bid, but do not face direct competition after.

CS, MS, and ICM do not have the same advantage, but do improve traffic flows benefiting public transport vehicles. Still, authorities can couple improvements in the infrastructure in the corridor with small steps towards competition for the market (Zimmerman, Dahdah and Wei, 2021). The key is that authorities ask an operator to improve service, they must protect that operator from predatory competition. The operator is taking some risks. If predatory competition happened, then the operator will lose its investment in new buses, for instance. The key is to understand that users favorably respond to frequent and reliable service. CS, MS, and ICM precisely allow improvements in frequency and reliability because of improved traffic management, particularly for public transport.

In all cases, existing bus routes need to be restructured. The BRT routes will be new and operate only within the corridor alignment.[12] The bus routes that used to operate in that corridor cannot ran anymore and must be realigned—sometimes becoming feeders to the mass transit service provided by the BRT. Existing bus routes must also be restructured in CS, MS, and ICM so that the operators selected under competition for the market do not face predatory competition. Route restructuring calls for ample consultations with affected operators and finding creative solutions. Sometimes, authorities ask the new BRT operators to buy and scrap some old buses for every new BRT bus. This purchase compensates the owner of these buses that will be replaced (Ardila-Gomez, 2004).

Competition for the market has the additional benefit that usually authorities demand that operators become formal and employ drivers and mechanics under a formal labor contract. Working hours go down compared to the competition in the market arrangement. Drivers improve their welfare in addition because they receive health insurance and retirement benefits—absent also in competition in the market (Ardila-Gomez, 2008b). Formal employment can also draw more women to jobs such as drivers and mechanics that pay better than cleaning jobs usually assigned to women (Escalante et al., 2021).

Notice that when a city implements a metro line, the expectation is that all employees will be formally hired by the metro operator. Metros are indeed the deepest expression of barriers to entry to compete against the new operator. Only the operator's trains can run on the metro. Metro implementation always implies restructuring existing bus routes, moreover, precisely to reduce the competition in the market.

The second key broad part in the reform of public transport is to separate what users pay—the farebox—from the remuneration to operators for the service they render. In competition in the market, the tariff times the number of passengers carried in a day is the remuneration to the driver, which then pays rent on the bus, cleaning, and some maintenance. This figure allocates the risk of not having enough ridership to the driver. The result is cut-throat competition with very negative consequences on road safety and air quality.

The first step to separate farebox from remuneration is to group the farebox at the route level, at the bus company level or even at the city level. The total farebox plus subsidies plus ancillary revenues must cover all costs of service provision including remuneration to operators (Rebelo, 1996). When remuneration is different than farebox revenue incentives improve. Consider an example from a bus company that rents out routes to understand the power of this element of the reform.

First, owners will be remunerated not daily but say weekly. The change in periodicity allows buses to rest one day for proper maintenance. All buses in the route will provide service six out of seven days. No bus has an advantage, and all make the same income on average (Ardila-Gomez, 2008b). This change also allows drivers to rest once a week—a welcomed change because competition in the market arrangement does not allow drivers to rest but some days per year let alone one day per week (Montezuma, 1996). Drivers that rest are less prone to crashes, more so if they do not have to aggressively compete for each additional passenger.

A second incentive is related to risk allocation. For instance, commercial risk can be allocated differently mainly because it is spread among all buses in the route and not by individual bus. Drivers have an incentive to compete less and drive better —very much aligned with competition for the market. Some reforms have coupled this step with uniformed drivers and training on preventing sexual harassment (Ardila-Gomez, 2004). Users especially women responded positively, more if service is frequent and reliable. Notice the links of the reform to improving corridor conditions through CS, MS, or ICM to reduce the congestion buses face, and to protecting these operators from predatory competition.

Residents of slum areas rely on public transport. Feeder vehicles such as sedans and jeeps can take these residents to the corridor with improved public transport. Informal operators like these ones and others provide public transport service to many, especially the very poor (Kumar, Zimmerman and Arroyo Arroyo, 2021). Yet integrating these informal operators is more difficult. Affordability issues could emerge, which call for demand-side subsidies. Also, narrow streets in slum areas once improved lend themselves for walking and biking. Walking is an alternative if the distance is not too long to access the corridor. Biking can be a better option—therefore safe and affordable parking for bikes becomes one more element in corridor improvement.

Improving public transport is not easy and costs could increase. For example, the switch to competition for the market implies stronger contractual relationships between the authority and the operator. In turn, the government asks the operators to incorporate formal enterprises that own the bus fleet and not rent out the route to individual bus owners. Drivers also become formal employees who must work reasonable hours, contrary to the very long workdays under competition in the market. Labor laws apply to drivers, mechanics, and other employees of these operators. Formalizing transport increases costs versus competition in the market where drivers provided implicit subsidies to bus and route owners—drivers even folded as mechanics in some cases. This increase in cost validates why reform implies also separating the farebox from the remuneration to operators. To cover operating costs, explicit subsidies might be needed.

Yet these reforms do not operate in a political vacuum. Assume a city implemented one BRT line. Some existing bus operators can lobby to get a new route that indirectly competes against the BRT service. These operators can claim they serve a different market segment. Soon after other routes emerge. Worse is if planners did not correctly value the onerous cost of transfers from feeder to trunk buses in the BRT. Some people will prefer a direct route in mixed traffic over a feeder bus and transfer to a BRT. More routes can emerge to satisfy this demand.[13]

Operators procured through competition for the market can soon fall into a similar situation to competition in the market (Ardila-Gomez, 2008b). Yet not all is lost. These examples actually illustrate a pathway to public transport reform. For one, the operators under competition for the market have incentives to provide better service. For another, cities such as Curitiba and Bogota have realized that the next step in the reform is to move the entire city to competition for the market. Specifically, the city is split into exclusive areas where only one competitively selected operator can run bus services, meeting key performance indicators, and for a certain number of years. The operators design the routes in agreement with authorities. Usually the central business district is open to all operators because of the high density of destinations. The exclusive areas work if the farebox is also unified at the city level and if remuneration is separate from the farebox as explained above. Remuneration indeed reflects risk allocation between operators and government. Remuneration further incentivizes operators to provide service. Operators are protected from in the market competition inside their exclusive areas. Remuneration also shields them from competing for passengers on the streets of the central business district. Drivers no longer needing to compete for additional passengers also improves road safety and reducing forces passengers face inside the vehicle.

The steps above incorporate lessons from experience, for example Curitiba, Brazil, Santiago, Chile and Bogota, Colombia. Reforms can take years. Improved corridors that reduce the impact of congestion on public transport facilitate the reform because public transport users benefit from frequent and reliable service. In all cases, reforms imply changing risk allocation, remuneration, and protecting operators that invested from predatory competition. Formalizing contractual relationships and the much-needed formalization of labor are parts also of the reforms. As reform advances, cities realize they need a city-wide approach through selective areas. Reforms, to conclude, are about internalizing the externalities present in the competition in the market arrangement. Formalizing labor is one example of internalization. Formal labor costs much more than informal one. Formal labor however delivers quality and safe service. Subsidies are needed in many cases to cover higher costs while keeping fares affordable, particularly for women and other users who are transferring (Estupiñán, et al 2007).

Greater operational efficiency of public transport services can reduce the number of low-occupancy vehicle-km traveled, reducing emissions per passenger served on an already carbon-efficient mode. These GHG savings can be further amplified if operational reforms are also leveraged as an

opportunity for fleet renewal. Reorganization of public transit operators into "companies" competing for the market can provide new avenues for accessing government incentives or commercial financing for the introduction of better buses—either more efficient internal combustion engine vehicles or electric—with lower carbon footprint. Reformed public transport should generate modal shift from cars thus reducing the carbon footprint of mobility.

In addition, public transport service reforms and fleet renewal provide opportunities to better address the needs of women. Improved frequency and quality of service with operational organization can reduce wait times for women who transfer. Newer vehicles can be better designed with areas and seats for women with bags or escorting children and can provide holding bars or straps at a more comfortable height for women passengers. Furthermore, if electronic fare collection systems are implemented, the signal in the card reader can be strengthened so that women can swipe the purse and not the card (World Bank Group, 2016a; World Bank Group, 2016b).

3.3 More efficient land use regulations

Accessibility gained from improving public transit infrastructure and services is greater when paired with reforms to land use regulations. Poor land use regulations lead to economic inefficiencies and loss of welfare because they artificially cap the supply of built space. This cap raises prices and prices out the poor.

Reducing the land use regulatory burden will allow market forces to work better and increase the supply of built space. Land use regulations cannot always foresee the opportunities that developers see and invest in. Flexible land use regulations allow developers to offer more built space while catering to different market segments, especially by income levels.[14]

If a city improves public transit infrastructure and service along a corridor, accessibility benefits should lure market forces to invest in the neighboring areas, not just the properties that face the improved corridor. And if the city has a good property tax with a sound property registry, then tax collection will increase. This additional revenue will allow the city to improve other corridors. Although the property tax is not earmarked for transport, transport is usually a big investment item in most cities and therefore receives an important part of any additional revenue. As the city grows, these corridors might need mass transit solutions such as BRT, light rail transit, and heavy rail transit. Higher tax revenue can allow the city to access loans and issue bonds to finance the large upfront cost. Public transport can become an attractive option to ride even as incomes grow instead of cars.

Seen differently, more efficient land use regulations will generate more built space, densify corridors, generate mixed land uses, and promote good design—complete streets with sidewalks. As travel demand concentrates in these areas, mass transit becomes more efficient and attractive. The latest literature on TOD recommends interventions on public space and on land use regulations to allow even higher density and therefore higher demand. The aforementioned analytical activity started by the Transport Practice argues that the next step in the line of work of transport and land use is to start with more efficient regulations and complete streets. Many of the recommendations by the TOD literature can be applied before mass transit because they identify how good design for sidewalks, public space, first floors with restaurants and shops generate an environment pleasant to walk on and use public transport.[15]

First, in large cities this approach can result in other corridors that will need mass transit in the future in order to achieve a network or hierarchically integrated transit system (HITS) (Pulido, Darido, Munoz-Raskin and Moody, 2018). HITS integrates several mass transit technologies such

as metro, light rail, bus rapid transit, buses operating in an improved corridor, and even buses in mixed traffic. Informal transport must also be considered because it provides service in most cities. Physical integration reduces walking distances between modes—a pivotal aspect because total travel time is what matters to the user. Fare integration strives to have the user pay once, hence the need to separate farebox from operator remuneration. Finally, operational integration seeks to minimize wait time, particularly when a user must transfer.

Second, 75 percent of the world's population lives in urban settlements of less than 500,000 people (Cities Alliance, 2019). In these cities in developing countries, the majority travels by public transport—even if precarious or informal—walks and bikes. More efficient land uses will generate dense, diverse, and well-designed spaces, which will concentrate demand for public transport and allow more efficient service. As these cities grow, they might need mass transit solutions that will provide better service and prevent people from using cars, as income grow. These cities have a significant role to play in the decarbonization effort if they follow proper policies (Coalition for Urban Transitions, 2019).

Finally, in slum areas the key step is to improve tenure or property rights. Secure tenure rights allows households to invest in improving their house. The best slum upgrading programs follow comprehensive approaches that include infrastructure, social, and economic aspects. On the infrastructure side, road improvement is matched with water, sewage, and power improvement as much as possible to dig once. Social aspects includes schools, childcare, and health care facilities. Economic aspects includes income generating opportunities. Some can work inside the neighborhood where they live. Many others will have to travel to other areas to work in formal and informal jobs. Access to opportunities via a good mobility system is what makes cities work.

3.4 Transport demand management: Parking policy, road pricing, and nudging

Transport demand management (TDM) is a set of policies and regulations that shapes the incentives around an individual's travel decisions, particularly choice of travel mode. In cities in higher income and upper middle-income countries with high shares of car ownership and use, TDM measures often focused on how to shift travel from private cars to more carbon-efficient modes such as public transit and active mobility. In cities in lower-income countries, where car ownership and use are less prevalent and mode shares of public transit and active modes are already high, TDM must work in combination with planning and investment policies to avoid the lock-ins of the high-carbon, vehicle-dependent trajectory seen in many developed cities around the world, while improving accessibility of all.

Typically, TDM measures influence individual travel choice in one of two ways:

i. Hard measures, such as regulations or pricing schemes, change the relative attributes of travel alternatives, such as travel time and cost. These hard measures improve the comparative advantage of environmentally and socially desirable alternatives such as walking, cycling and public transport, whether formal or informal, over low occupancy more inefficient and potentially unsafe modes such as cars and motorcycles.

ii. Soft measures are designed to change attitudes, perceptions, social norms, habits that also influence travel decisions. These measures can be triggered by governmental programs but are often implemented through corporations, civil society organizations, or other institutions. They range from qualitative interventions such as marketing campaigns to operational interventions such as small pecuniary incentives or physical interventions.

The main objective of TDM is to help individuals internalize the full cost to society of their travel decisions, including externalities such as congestion, local air pollution, and GHG emissions. A critical secondary objective of TDM is to generate revenues that can be reinvested in the transport system to expand infrastructure and service, improving overall urban accessibility, or to compensate for negative externalities of transport. Finding the balance between these two objectives is one of the most challenging aspects of TDM.

The first set of investments needed to implement TDM policies are related to information and communication technologies (ICT) (see box 2). The role of ICT in facilitating, complementing, and substituting travel has been studied frequently. A game changer in personal mobility and the capacity of influencing travel behavior comes from the emergence of smartphones, with tracking and application capabilities, and sensors that identify vehicle and person flows (Gossling, 2018). ICT now permeates transport along many dimensions. ICT can help with travel information, trip planning, vehicle and service routing, and more seamless information and operational integration among modes. New payment technologies tied to ICT can make paying for transfers between modes easier, help separate the collection of fares from remuneration to operators, and enable pricing of parking and road use which were previously difficult to monitor or enforce. ICT can also promote sharing and mobility-as-a-service (Bianchi Alves et al., 2021) and improve traffic management and road safety.

Box 2. Governance of ICT for urban mobility

Despite the recent innovations in ICT-enabled transport services and opportunities for telework and teleshopping, significant delays occur in adapting institutions, procedures, and regulations to embrace innovations and welcome new players while at the same time mitigating risks that these new entrants bring. Within the context of technologies, governments must procure—often through private-public partnerships—the equipment and service for on-street and off-street parking, traffic lighting, radars, and other types of sensors and payment systems for farecards, tolling booths. Establishing a series of planning and monitoring tools is essential and requires strong data collection and experimental and analytical methodologies. The effort to gather data must recognize different types of users: women, people with disability, as well as pay attention to off-peak hour travel patterns.

The role of government, most of the times, is to facilitate the deployment of these technologies in partnership with the private sector and not necessarily to provide the services and tools themselves. Governments must therefore make the investments to collect data—for instance for on-street parking databases and other sensors or purchase data from cellphone and other service providers—process these datasets, and sometimes develop or support the development of tools, encourage pilots, and make complementary investments that will allow for these technologies to function, such as building Wi-Fi hotspots, providing energy supply, among others. The government role shifts to having the capability of receiving and analyzing these datasets for planning and monitoring purposes. With government as a facilitator of those technologies, the second set of "investments" they must make include establishing the right governance model, instituting legal and policy frameworks to partner, promoting innovation, and leveraging private sector participation.

As long as political understanding prevails of user needs and societal and environmental goals for urban mobility systems, innovation can present an opportunity for leapfrogging to lower-carbon development trajectories. This approach can also be more inclusive by considering the travel patterns and needs beyond the rush hour which is dominated by men's patterns and needs. The transport system must cater to other market segments such as women, children, and people with disabilities.

In what follows we describe in more detail the most used, relevant, and impactful hard and soft measures that compose the menu of TDM possibilities while discussing equity issues associated with these measures and stakeholder acceptability.

3.4.1 Parking policies

Parking policies and regulations—including the allocation of space and pricing of parking—are among the most powerful tools to disincentivize mode choices with high negative externalities, and one of the key links between transport and land use policy. Yet, governments all around the world overlook opportunities for improving city efficiency and equity through parking and underutilize these policies. For example, curb space is a municipal asset, but there is significant under exploration of this asset because of non-existent regulations or poor enforcement (AlMujadidi et al., 2019). Cities in developing countries often lack a unified authority and framework for delivering the correct supply of parking space and the right incentives (Frame and Arroyo-Arroyo, 2021).

Charging for parking, either on-street or through taxation of privately operated garages, can generate significant revenues for cities that struggle fiscally, and are an effective way to nudge individuals toward more sustainable and efficient modes of transport. For example, Frank, et al. (2011) indicate that increasing parking fees from approximately $0.28 to $1.19 per hour (from the 50th to 75th percentile) reduced vehicle miles traveled by 11.5 percent and emissions by 9.9 percent. Finding the right balance between generating revenues, securing accessibility, and managing unwanted externalities such as congestion is one of any city's greatest challenges. This right balance is achieved by having a comprehensive parking policy, whose main goal is to manage both on-street and off-street spaces more efficiently to limit all-day commuter parking and allow a turnover of vehicles to serve local communities and business and generate revenue (Frame and Arroyo-Arroyo, 2021).

Broadly speaking, a comprehensive parking policy has the following parts. First, residential areas should have no minimum parking requirements. Rather, developers will determine if the market segment they target needs parking spaces or not. Developments for low-income population or in the area of good public transport need less parking than that set by the existing minimum parking regulations. One of the principal causes of slum development is how land use regulations make the built space unaffordable. If developers want to make their housing units more affordable, then efficient regulations will allow them to offer zero parking per unit because low-income dwellers cannot afford a car. For developments for higher income dwellers, developers will choose one or more parking spaces per unit. Many regulations call for parking spaces per housing unit built regardless of the actual area of the unit. Small units might not need parking as they target dwellers with lower income or different preferences. Mexico City was one of the first cities to adopt a maximum parking requirement. Alternatively, cities can let market forces work by allowing developers to build as much parking as they see fit given the market segment they target. For example, in Bogotá after the Transmilenio BRT entered operation in an area of downtown where the land use regulations imposed no limits on the FAR, two 25-story buildings were built without parking (Ardila-Gomez, 2008a). The developers targeted a market segment that wanted to use public transport and would not buy a car. This example shows also why in areas close to good public transport, developers can choose to build more affordable housing.

Second, car users must never park on sidewalks because they are for pedestrians, children, and other vulnerable users. Parking on the sidewalk is a huge subsidy for car users. Cities will improve sidewalks as part of corridor improvements. The upgraded sidewalks should be a bit higher so that cars cannot climb over the curb. Another option is inserting bollards and also adding trees and

benches because they generate barriers to parking on the sidewalk. This option not only prevents cars from taking over, but also creates a more attractive, low-carbon, and livable public space.

Third, car users must pay for parking on curbside lanes and on parking lots open to the public. Charging for parking has benefits such as raising revenue. Interestingly, commercial areas benefit from charging parking because parked cars rotate. When parking is free, drivers that arrive during the morning peak park all day for free and then leave in the afternoon peak. Customers seeking a place to park for an hour or less cannot find a spot. Charging for parking promotes economic activity because it induces rotation.

Fourth and closely related, the parking fee structure needs to reinforce that parking is for customers and not commuters—those that travel during peak hours. Specifically, the fee structure should be, for example, X for the first hour, 1.5X for the second hour for a total of 2.5X for two hours. Each additional hour the car is parked should cost more per hour. A commuter, therefore, pays 10X. Contrasted with the example where after three hours parking the fee is flat at 3X, which is the wrong structure because it punishes shoppers and encourages long stays. A pro-shopping and therefore pro-economic activity parking price scheme encourages shopping and discourages long stays. This parking fare structure is also more inclusive, avoiding the current issue where women who drive often park for shorter stints—for example, to drop off a child or to run an errand—end up subsidizing the parking for men that commute and park long hours.

Fifth, encourage good design for parking buildings or parking levels in buildings. Inside the building, the functionality requirements establish the design parameters. The façade should look like a regular building—including windows—to fit with the rest of the area. The same applies to commercial and residential buildings that devote the first floors to parking. Specifically, the first level is the closest one to the sidewalk. A design with shops and restaurants is ideal as they generate urban activity and revenue for the owner of the parking. People in shops and restaurants moreover see what is happening in the street thus meeting the see and be seen ideal. The levels above this retail level can be for parking. If that is not possible, then the façade can have windows to at least give the idea of activity inside the building. Good urban design promotes walking. If parking fees are adequate, investors will recover the small additional cost. Moreover, a nice parking building attracts cars because once drivers get out of their cars, they become pedestrians.

3.4.2 Road or congestion pricing

Careful use of road pricing mechanisms, differentiated geographically and temporally, improves the efficiency of urban mobility systems and contributes to a more optimal allocation of scarce urban space to roads and among road users (Perkins, Wagner, and Leung, 2018). Road pricing may also work as a tool for increasing the attractiveness of more sustainable transport alternatives versus low occupancy road-based ones and can generate sizeable revenues to be reinvested into these sustainable transport alternatives.

Road pricing includes a set of tools of road, area and cordon line fees and can be applied during peak-hours (congestion charging), be based on distance (distance-based tolls) or occupancy (high-occupancy vehicle lanes), or on a credit-base (rationing road space) (Victoria Transport Policy Institute, 2019). To correctly apply road pricing, the price of the toll must be set to equal to the marginal social cost to society that the driver's journey imposes on other drivers (Hau, 2021). Road pricing is a more flexible policy than fuel pricing as it allows for more customization of when and where to charge the users, in a manner that is compatible to these societal costs.

While road pricing in the form of tolling is not uncommon in developing countries, although underutilized, urban road pricing, more commonly known as congestion pricing, has not been implemented to date in a city in a developing country. This is despite numerous studies indicating its possible benefits in Brazil, China, India, and Mexico, among other countries. The most well-known examples of road pricing are from developed countries, with Singapore as the pioneer and London and Stockholm later implementing congestion charging schemes. These schemes initially reduced congestion significantly and increased the share of public transport travel (Santos and Shaffer, 2004; Borjesson, 2018; Theseira, 2020; Givoni, 2021). But recent analyses on their longer-term effects show that the schemes have opportunities for improvement, such as the need for flexibility of the price structure to reflect actual costs drivers impose depending on location and time, and more importantly, that a series of other complementary measures such as improving quality of public transportation should be implemented before or in conjunction with these pricing policies (Saleh, 2007).

In lieu of congestion charging, many developing cities have adopted license plate restriction schemes whereby cars are permitted to run in all but a few days of the week—examples include Beijing, Bogota, Delhi, Medellin, Quito, Sao Paulo, among the largest cities. The system has been heavily criticized because it can actually increase congestion, due to temporal or geographical shift, the purchase of a second car, the use of alternative modes of transportation, and impacts on atmospheric chemistry (Zhang, Lawell and Umanskaya, 2017). Further, the system is inflexible as there is very little buy-in for increasing the number of restriction days, and it can be regressive, with the richest brackets affording a second vehicle being less affected by the policy.

Surprisingly, a rather restrictive policy such as the license plate schemes have seen better acceptance than congestion pricing schemes, possibly given perceptions of fairness among car users and car-aspiring users. Matters of acceptability are particularly important for all pricing mechanisms discussed (see box 3). While TDM measures face challenges of public acceptance and are politically hard to implement, they are particularly useful because they often require a fraction of the costs of implementing heavy infrastructure and may result in significant short-term and long-term impacts on individual travel choices and the efficiency and sustainability of transport systems.

Box 3. Acceptability of TDM Measures

Public acceptability is key for the successful implementation of TDM measures. While TDM policies are shown to lead to economic efficiency gains and environmental improvements, and generally to positive distributional benefits, they are generally a hard sell because these measures may result in perceived or real loss of utility for some influential segments of public opinion. Given the stronger value individuals pose on losing—loss aversion effect—politicians prefer to focus their policies on increasing transport availability through investment in, for instance, improving infrastructure, instead of creating restrictions or pricing instruments. However, investments alone are shown not to be sufficient in drawing people to more sustainable modes, with a combination of push-and-pull measures seeming to be necessary for significant impacts.

Some of these influential segments of public opinion are organized groups such as trucking and public transport unions and organizations. Increases in fuel pricing from a tax increase or a subsidy removal directly affect out-of-pocket costs for truck or bus services, who year after year, and all over the world, organize strikes and often violent protests that generate intense disruptions, by closing main roads and shutting down essential services. These may have devastating consequences to the entire city functioning, causing record traffic congestion, affecting economic activity and health services, among others. Even when there are good intentions to move toward a more sustainable policy, at times, governments end up succumbing to the pressures as in France, Ecuador, and Brazil in recent years.

Another important segment is car owners, despite not necessarily under organized groups, who generally come from wealthier segments in developing countries and tend to be politically influential. While these more affluent groups may be less sensitive to fuel pricing, support for congestion charging schemes is known to be lower for people that own or use a private vehicle (Wang, Rodriguez and Mahendra, 2021). This is in part because of the perception that they may not directly benefit from that charge, as it would fall to the community more widely, including people using public transport (Perkins, Wagner and Leung, 2018). Similar behavior happens towards parking policies, reinforced by a culture of "acquired rights" over free use of street space.

Acceptability of these measures is highly and closely correlated with people's perceived social norms, effectiveness, and equity of the measures. Somewhat contradictorily, in a study about Latin America, cities with higher income inequality support only driving restrictions and cities with higher GDP per capita have lower support only for congestion pricing (Schade and Schlag, 2003). This is why social marketing becomes an important tool before implementing these policies. These campaigns should focus on increasing awareness toward more equitable and sustainable forms of transport, changing social norms, and also emphasizing impacts of these measures to alleviate health related respiratory diseases and improve road safety, which are problems that affect all segments of society.

3.4.3 Nudging modal shift: The "soft" side of TDM

Soft measures, or "nudges", shift travel choices indirectly by acknowledging that the way in which information is provided, biases, and attitudes all impact individual behaviors. For instance, providing better information about relative costs or about the level of emissions that a certain travel choice can generate, might encourage people to try out a different behavior. Similarly, getting a ride to the nearest metro station may be what is needed for a woman who is afraid to walk in a dangerous public space to use public transportation. These nudges might also be accompanied by operational incentives, which can range from small pecuniary incentives and infrastructure provisions—for

example, prizes for bike or public transport commuters, allowing employees to keep the money of a parking space subsidy, special parking facilities for low emission vehicles, or providing locker rooms for cyclists.[16] Another operational incentive that has become increasingly common, even in the developing world, is telework policy. While the potential for teleworking reaches a much smaller fraction of employees in developing cities, it generally correlates with the highest paid employees who are also the ones with higher access to private motorized vehicles. This is why, during the COVID-19 pandemic, traffic congestion eased significantly even in countries where teleworking was a reality only for a small fraction of the population.

One important assumption of these nudging interventions is the actual existence of sustainable transport alternatives that are at least comparable to private vehicles when it comes to quality of service. When commuting by car or motorcycle is the easiest and cheapest option available, behavioral interventions alone will not be enough to nudge commuting behaviors (Whillans et al., 2020). In developing countries, where this gap is too wide, soft measures may be of more limited reach.

Nevertheless, a systematic review of well controlled experimental studies in the developing world has shown they can have a seven percent effect on reduction of car use (Semenscu, Gavreliuc and Sarbescu, 2020), at a minimal cost smaller in order of magnitude from infrastructure interventions. Given the high share of people in developing countries that already use greener modes of transport, soft measures have a role in complementing hard and investment measures in trying to maintain these high shares, reduce the potential growth of more polluting modes, such as cars or motorcycles. They also have a role in creating awareness among influencers about societal aspects of transport, which might lead to better acceptance of TDM measures.

City governments have a role in leading, sponsoring, and fomenting social marketing campaigns, telework programs, and incentives to active mobility in partnership with institutions and corporations. These can start as pilots that can be expanded to larger programs, especially when an opportunity surfaces to combine with transport infrastructure investments such as road construction or rehabilitation, metro, BRT, and bicycle lanes.

3.5 Empowering green female travelers

The reforms outlined in this paper promise to reduce the carbon footprint of mobility. These reforms also stand to benefit women because they begin to recognize their different travel needs and improve personal security. Public transport reform allows more women to gain formal employment in transport in higher paying jobs. Transfers between metro and bus, for example, are less onerous and targeted demand-side subsidies could exist. These reforms also allow introducing lower carbon footprint buses with bars to hold from at the proper height and bigger windows so people can see what happens inside the bus.

Improving personal security for women's mobility has six dimensions, all impacted positively by the reforms outlined in this paper (Ortiz Escalante et al., 2021). First, vitality, expressed in mixed land uses with foot traffic. Second, see and be seen thanks to improved roads and public transport. Third, with proper equipment such as sidewalks and bars to hold from in a bus. Fourth, signalized to orient users which is a key element of complete streets and traffic management, including pedestrians. Fifth, community driven thanks to active women participation. Reforms of public transport, for example, must talk to women about their travel needs and how to satisfy them. Finally, formal and informal policing and security facilitated by traffic reforms and better public spaces in complete streets.

In cities with very good public transport and streets, women travel more than men by sustainable modes (Ramboll, 2021). Women in developing countries have a lower carbon footprint, but often not by choice. Better understanding of women's needs is key including their active participation coupled to monitoring and evaluation to assess impacts (Ortiz Escalente et al., 2021).

3.6 The post-pandemic: Uncertainty and change

The COVID-19 pandemic that started in 2020 demanded quarantines and lockdowns to slow it down. A significant share of workers were able to work from home as long as they had good access to the internet. Still, many others needed to travel because they were essential workers or must leave their homes to generate income. Public transport ridership plummeted. Walking and biking increased in many cities as did car travel. Still, decarbonizing transport continues to be relevant in the post-pandemic world showing that public transport, walking, and biking are even more relevant (Ardila-Gomez, 2021).

As the world enters the post-pandemic status, public transport ridership is recovering, while many continue to walk and bike. A broad pattern that emerges is that people that can work from home will continue to telework at least some days of the week with different patterns. Others will continue to travel because they are essential workers or traveling is essential for them for making income—a majority in cities in developing countries. Demand patterns will change permanently with fewer trips during the peak. The off-peak will gain importance. Fewer trains and buses will be needed to serve the rush hour, which lowers costs. Planners must pay more attention to the off-peak period and the travel patterns such as those by women.

The post-pandemic work will therefore be uncertain. Flexibility is key to manage uncertainty. For example, demand for office space in downtown will likely be lower, because people will telework part of the time. Downtown will therefore need fewer restaurants. Yet in parallel, people working from home will need more restaurants close to their homes. Land use regulations therefore need to become more flexible. Mixing land uses is a key aspect. In downtown, allowing residential uses will be key, even within the same building. Downtown areas will benefit from having more activity at night and on weekends thanks to people residing amid office buildings. In residential areas, allowing more commercial uses are a must. People that work in restaurants and shops now in residential areas will need to travel by public transport to get to work. Land use regulations must also allow logistic functions in residential areas. As more people order packages delivered to their homes, more trucks will be needed. Consolidation and distribution centers in residential areas could lower the logistic cost.

4. Way Forward

Cities in developing countries have the opportunity to avoid further vehicle-dependent, distant, dispersed, and disconnected development by prioritizing more carbon efficient, space efficient, and inclusive modes of public and active transport over private vehicles. Doing so will not only put developing cities on a favorable trajectory toward decarbonized mobility systems; it will also better serve the diverse travel needs of urban residents. The opportunity for determining more transit-oriented development pathways in these cities is timely, with levels of private vehicle ownership and use lower than in developed cities although growing quickly and with robust shares of travel by public transit and active modes.

Urban mobility systems reimagined to simultaneously improve the welfare of urban cities—by expanding access and addressing current issues such as congestion, air pollution, and social exclusion—while meeting climate goals will require critical investments in improving infrastructure and services for public transit and active modes, all supported by an enabling environment encompassing travel demand management measures, land use regulations, and strategic deployment of ICT technologies and travel demand management policies (see table 1).

This paper posits that by improving streets along the lines of complete streets, multi-modal streets, or integrated corridor management, cities can improve conditions for all users, in particular of public transport. Coupled to more efficient land use regulations, these improved corridors can induce denser, more diverse, and well-designed uses of urban space. In turn, this additional built space will demand more public transport and generate more pedestrians. Restaurants and shops can thrive, benefiting the local economy. The paper also indicates the key steps for improving public transport: switching to competition for the market and separating the farebox revenue from the formula to remunerate operators, which allows better commercial risk allocation for example. Ultimately, cities might need mass transit solutions, which will benefit from dense, diverse, and well-designed urban space.

Yet investments on infrastructure alone are not enough to produce efficient and green travel patterns in cities, even if they are directed towards “green” infrastructure. The pressures of increased (individual) motorization as a result of economic growth in developing countries require a re-alignment of policy priorities that target maximized efficiency of the urban transport system through a shift to public transport, walking, and biking. Transport demand management (TDM) is also part of the solution. TDM may include a set of planning, regulatory, pricing, informational and technological instruments that create set of incentives and disincentives to influence individuals towards choosing more sustainable travel behavior and have both a short-term and long-term impact on individuals’ travel choices (Broaddus, Litman and Menon, 2009). We focused on some of the most important examples of TDM—parking management and road pricing—complemented by “softer” measures, which include policies, technology, and informational instruments to persuade users towards green behavior, such as social marketing, corporate incentives, telework policies, among others.

The recommendations in this paper require political and financial capital and capacity to achieve substantial returns on the investment. Many of the enabling environment reforms encourage greater revenue generation, such as more intense land use which increases the efficiency of the property tax and TDM measures such as pricing of parking and road use also generate revenue. These revenues can be re-invested into the mobility system to continue to improve infrastructure and service for the majority of travelers using public transit and active modes. In turn, complete streets

demand careful designs, same as mass transit systems. All these require operation and maintenance. Data becomes useful when thoughtful questions are asked and answered. A city can therefore build capacity as it travels this lower carbon pathway.

Table 1. Summary of the recommended actions for decarbonizing urban transport while simultaneously contributing to many other sustainable development goals

Recommendation	Contribution to decarbonization	Contribution to other sustainable development goals
Invest in infrastructure for public and active transport: Complete, multimodal streets	• Encourages use of the most space-efficient and environmentally-friendly forms of collective and personal transport • Maintains (or increases) existing share of trips taken by sustainable modes in developing cities	• Provides better access to opportunities • Prioritizes the needs of female and low-income travelers who rely most on public and active transport • Improves road safety by protecting vulnerable road users • Improves public health by encouraging activity
Improve public transit service through reorganization of operations and fleet renewal	• Provides operational efficiencies (potentially including smaller vehicle fleet) that reduce low-occupancy vehicle-km traveled, reducing emissions per passenger served • Reduces fuel combustion and GHG emissions from the public transport fleet with newer, more fuel-efficient vehicle technologies	• Provides operational efficiencies that improve quality of service for users, and potentially affordability • Improves working conditions for those employed in informal service provision • Improves air quality • Uses newer vehicles that are better designed for safety and inclusion
Implement more efficient land use regulations	• Brings people and opportunities closer together, leading to less need for travel, particularly by highly-polluting private vehicles • Enables more efficient collective transport by agglomerating people and activities	• Discourages distant, dispersed, and disconnected (3-d) development • Generates more built space and mixed land uses • Increases supply of housing, improving affordability
Use travel demand management to appropriately price the negative externalities of vehicle use and nudge travel towards more sustainable alternatives	• Disincentivizes use of private vehicles by better internalizing their environmental and social costs • Encourages use of the most space-efficient and environmentally-friendly forms of collective and personal transport • Reduces energy consumed by cars searching for parking or idling in intersection queues	• Improves livability, accessibility, and inclusion of public spaces • Improves air quality • Minimizes conflict points among road users, particularly at curbs and intersections • Reduces congestion and improves efficiency of travel for all road users
	• Generates revenue for city governments that can be re-invested in (or used to backstop financing for) public and active transport infrastructure and services	

More importantly, cities can enter a virtuous cycle in which people will have easier access to walking, biking, and public transport. Transfers will be easy and cost less. Land use will allow more built space that will be more affordable thanks to increased supply and the targeting of specific market segments. All users will benefit thanks to a focus beyond the peak hour and the needs of men to include women and people with disabilities.

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Endnotes

1 Worldwide, over 10,000 cities and local governments representing more than 900 million people have committed to combat climate change under the Global Covenant of Mayors for Climate and Energy (GCoM). By 2030, the GCoM cities and local governments could account for an annual emissions reduction of 2.3 billion tonnes of CO_2 (IEA 2021).

2 Developing countries currently have motorization rates that are at least four and eight times lower than developed countries (based on 2015 motorization rate from Organisation Internationale des Constructeurs d'Automobiles).

3 Funding refers to the transport system's capacity to raise funds from its users, ranging from public transport passengers to car drivers. Financing refers to the capacity to access loans to finance the large investments required to build a metro line, for example.

4 In many countries decentralization efforts have assigned responsibilities for transport infrastructure provision and maintenance to local governments, but not associated sources of revenue. Roads that used to be national are transferred to municipalities, who do not have the tools to properly fund its upkeep. A key example is the property tax and the associated registry of properties. The property tax works better when the registry is updating yearly. But national governments sometimes maintain the responsibility for registry management and updating (Paez, 2018). An outdated registry reflects lower property values and results in lower revenues from the property tax. The property tax is critical because of the impossibility for tolling pedestrians on sidewalks and cars on local streets—expressways offer an opportunity for tolling, but they increase the demand for car use.

5 The intersections of roads are not operated well, generating bottlenecks with long queues. The majority that depends on and travels by public transport suffers longer delays. Congestion is therefore a regressive tax that raises no revenue. Congestion is a tax because all users waste time stuck in traffic. Regressive because the lower income groups that depend on public transport face longer travel time. (Ardila-Gomez and Ortegón Sanchez, 2016). Yet the cost of congestion does not raise revenue. See the following references for measures of the economic costs of urban traffic congestion: World Bank (2010); Victoria Transport Policy Institute (2020); and Catayud et al. (2021).

6 In some settings, the result is that two sets of police officers are needed to enforce a traffic light violation. One set stands before the intersection and witnesses the car running a red light. The second set stands after the intersection and stops the car—assuming the first set radioed the plate number of the offending vehicle. Strictly speaking, this second set did not witness the car running the red light. Therefore, the first set must then walk to where the car is stopped to sign the traffic summons, accusing the driver of a moving violation. This set of maneuvers to meet due process requirements can take many minutes during which one lane is blocked by the stopped car.

7 Vision Zero for Road Safety or Safe Systems set the as zero the goal of killed and severely injured from traffic crashes. In this context, the ideal number of traffic fines should also be zero. People should behave well and not ran red lights, for example, which can lead to a crash with killed and severely injured people. Traffic violations should not be a source of revenue, therefore, let alone a revenue to be maximized.

8 CCTV cameras do not have face recognition capabilities as such. CCTV cameras have resolution which makes the image more precise. Software in the backend is needed to process the images and recognize them. A database of faces is needed also (Engelhaupt, 2015).

9 The economic cost of land use regulations is extensively documented in the literature. See for example: Bertaud and Brueckner (2005); Brueckner and Sridhar (2012); Suzuki, Cervero, and Iuchi (2013); Tsivanidis (2019); and Brooks and Denoeux (2021).

10 Users wait time value is twice or more the time in vehicle. Users find even more onerous time spent transferring. For examples of reforms that did not consider properly how onerous transfers can be, see Gomez-Lobo (2020).

11 The WHO (2021) estimates that 1.3 million people die per year as a result of road crashes and between 20 to 50 million suffer severe injuries with life-long impacts. The existing TOD literature does consider road safety as part of a holistic view to TOD (World Bank, 2018).

12 BRTs can be closed or open. Closed BRTs have buses that operate only where the BRT infrastructure exist. These buses are not allowed in other streets. Feeder buses in mixed traffic take passengers from neighborhoods to the BRT station. Open BRT, on the other hand, allow the buses that operate in the BRT to ran in streets that lack the stations and other aspects of BRT infrastructure. These buses are feeder buses and trunk or BRT buses at the same time. However, BRT is a flexible technology that allows a closed system to adopt open aspects. For example, the original closed system had high-floor buses with doors on the left side that docked to a station with platforms at the same height as the floor of the bus. Later on, these systems introduced a "hybrid" bus with high floors and door on the left plus steps and doors on the right side. To be fully inclusive, these "hybrid" buses will need accessories to help people on wheelchairs navigate the steps on the right-hand side.

13 Hence the importance of using realistic values of time for each part of the trip when planning reforms. For a comprehensive discussion of these issues see: Gomez-Lobo (2020) and Hoyos Guerrero and Lopez Dodero (2021).

14 Developers know that building can house different apartment sizes and cosmetic materials, to name one example. Building height is another attribute because after five or six stories an elevator is needed. Elevators generate recurrent operations and maintenance costs that all residents must cover. The higher the fees associated to living in a building, the higher the income of its residents.

15 The TOD literature has added significantly to the definition of what good design means. See, for example: Cervero and Kockelman (1997); Vergel-Tovar (2016); Global Designing Cities Initiative (2016); Salat and Ollivier (2016); ITDP (2017); and World Bank (2018).

16 We differentiate these small pecuniary incentives of the harder policy instruments such as the "versement transport" in France or the "Vale Transporte" in Brazil, which are major taxation mechanisms to subsidize public transportation investment and operation costs.

TRANSPORT
DECARBONIZATION
INVESTMENT