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Introduction to Sustainable Public Transport Solutions in Latin America and the Caribbean (LAC) and Asia

Report for the "Inclusive and sustainable smart cities in the framework of the 2030 Agenda for Sustainable Development" Project

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Draft version

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Abbreviations

AFC	Automated Fare Collection
A-S-I	Avoid-Shift-Improve
BAU	Business-as-Usual
BRT	Bus Rapid Transit
CAF	Development Bank of Latin America
CNG	Compressed Natural Gas
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
EV	Electric Vehicle
FDI	Foreign Direct Investment
F/L/O	First-, Last- and Only-Mile
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IDOS	German Institute of Development and Sustainability
IPT	Intermediate Public Transport
LAC	Latin America and the Caribbean
LRT	Light Rail Transit
LVC	Land Value Capture
MDB	Multilateral Development Bank
MRT	Mass-Rapid Transit
NDC	Nationally Determined Contribution
NEV	New Energy Vehicle
phpdt	Passengers per hour per direction of transit
PM	Particulate Matter
PTA	Public Transport Authority
SDG	Sustainable Development Goal
TCO	Total Costs of Ownership
TDM	Transport Demand Management
TOD	Transit-Oriented Development
USD	United States dollar
VNR	Voluntary National Review
WHO	World Health Organization

1 Introduction

Latin America and the Caribbean (LAC) and Asia are regions under rapid urbanisation processes. While the first one started urbanising since the second half of the 20th century and accounts for the biggest percentage of urban population, the latter still has half of its population living in rural areas. Yet, Asia also gathers the largest amount of urban population and megacities (cities with ten million or more inhabitants) in the world. Urban areas in both regions are characterised by centres that gather employment offer and services, and dense peripheries where low-income neighbourhoods are located, which heavily depend on the central parts of the city.

These urban characteristics have a heavy impact on the urban mobility patterns of their citizens, with a great share travelling in transit (term that refers to public transport and will be used as such throughout this report). Although this is desirable from an environmental perspective, most of the transit fleet is of bad quality, polluting and without proper government regulation in terms of quality of service. Rather than trying to improve these services, most government policies favour private cars, offering fossil-fuel subsidies, reduced taxes for the purchase of new vehicles, offering scarce public space for free street parking and making expensive road investments that benefit only a small sector of the population with greater purchasing power, while the majority ends up travelling long distances at a high fare cost and suffers the consequences of pollution and social inequality. In face of these distorted incentives undermining the development of better public transport, an increasing number of middle-class citizens from emerging economies are seeing in cars and motorcycles as the only way to improve their travel conditions, which is currently producing the rapid motorisation growth in these regions. Without measures to correct this path, LAC and Asian metropolises will face even more serious problems in the future due to congestion and pollution.

Recognising the cost of urban air pollution and traffic congestion, some local governments in emerging economies are now shifting gears in favour of sustainable urban mobility. The introduction of sustainable public transport solutions however faces three main challenges. The first relates to the difficulties of **phasing in** new transit systems and technologies into existing consolidated urban areas with already established informal transit networks. This requires integrating elements of the old and new systems, changing regulations and last but not least careful process design to ensure public acceptance and support not only by the users but also the providers of traditional, often informal transport service providers. The second challenge regards **affordable fares**, **accessibility** and **good connectivity** of the solutions to benefit the low-income, peripheral areas that highly depend on transit to reach the city centres, despite the high upfront cost and maintenance these involve. The third challenge is to introduce the new systems in such a way that they generate maximum **co-benefits** in terms of technological learning and development of competitive and sustainable new businesses and employment.

These challenges and opportunities are presented in this report, which represents the first document for the research project *Inclusive and sustainable smart cities in the framework of the 2030 Agenda for Sustainable Development* carried out by the German Institute of Development and Sustainability (IDOS) and the United Nations Economic Commission for Latin America and the Caribbean (ECLAC). Within the framework of the Big Push for Sustainability, this paper will introduce three selected public transport solutions, which will be studied throughout the project with representative case studies in Latin America and Asia. The selected solutions are the implementation of bus rapid transit (BRT) systems in Bogotá and Jakarta, metro as mass-rapid transit (MRT) systems in Mexico City and Delhi, and the introduction of electric buses in São Paulo and Shenzhen. IDOS would like to acknowledge the financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ).

This paper aims to introduce these transit solutions within the context of sustainable urban mobility and key concepts related to this field to understand that these systems do not only involve the construction of transport infrastructure, but they rather have implications on a metropolitan scale, face challenges specific to these regions and represent opportunities for economic growth with social and environmental responsibility. For this reason, this preliminary report is structured with a first general overview of the urban mobility challenges in LAC and Asia, followed by the presentation of the Big Push for Sustainability Framework directed towards achieving sustainable urban mobility and its economic, social and environmental benefits, in compliance with the three dimensions of sustainability. The third section will expose important concepts in urban mobility that will lead to the presentation of the three selected transit solutions. This will allow to establish the research questions for the analysis of each solution and the comparability between the selected Latin American and Asian case studies.

2 Urban mobility challenges in Latin America and the Caribbean (LAC) and Asia

The transport sector is fundamental for the development of societies with deep economic implications, such as the conveyance of people and goods, creation of networks and localisation of activities (Rodrigue, 2020). However, it also accounts for 23% of global energy-related CO_2 emissions (SLoCat, 2018). As countries agreed in the Paris Agreement, greenhouse gas (GHG) emissions produced by this sector need to be cut significantly to limit global warming below 2°C by 2050. This scenario does not comply with the current projections of the Business-as-Usual (BAU) scenario, which predict a rise of transport emissions, especially in emerging economies, that could lead to a rise to 3.7°C to 4.8°C by 2100 (SLoCat, 2018; Lah et al., 2020). Urban passenger transport is especially relevant within this sector as it represents 41% of global passenger transport demand, above non-urban passenger transport and domestic and international aviation (ITF, 2019). At the same time, this is responsible for 32% of emissions of such sector, above any other passenger and freight transport (ITF, 2019).

Urban passenger transport does not follow the same patterns in every region. The growth of gross domestic product (GDP) and international trade activity in emerging economies are increasing urban transport demand as more citizens from dense metropolises with greater disposable income require to travel longer distances. This results in rapid motorisation growth in the Global South with a tendency towards private vehicle ownership (cars and motorcycles) in middle-income families (ITF, 2019). On the other hand, quick urban population growth during the second half of the 20th century, lack of institutional transit infrastructure to cover the demand and absence of appropriate transit planning that requires a considerable capital investment have contributed to the deterioration of urban mobility in such region.

2.1 Urban and mobility characteristics

Latin America and the Caribbean (LAC) account for the biggest percentage of urban population, with 80% of people living in cities or metropolitan areas (ECLAC, 2020). Its rapid population growth since the second half of the 20th century is reflected in the fact that six of the thirty-three world’s megacities (cities with ten million or more inhabitants) are located in the region. As of 2018, 14.2% of LAC citizens lived in these megacities (United Nations, 2018a). The region also gathers sixty-six cities with over a million people (United Nations, 2018a). These levels of urbanisation reach those of many developed countries, with 526 million urban dwellers in 2018 (United Nations, 2019). On the other hand, Asia has the largest number of people living in urban areas, with 2.3 billion citizens in 2018 (United Nations, 2019), the largest amount of world’s megacities with twenty megacities, and 278 cities with over a million people (United Nations, 2018a). Although as of 2018, over half of the population still lived in rural areas, it is expected that the number of cities with 500 thousand people or more will grow by 23% by 2030, while seven additional metropolises will reach the category of megacity by the same year (United Nations, 2018a). Furthermore, it is expected that by 2050, the region will gather 3.5 billion citizens living in urban areas (United Nations, 2019).

LAC and Asian metropolises are characterised by centres that gather employment offer and services, and dense peripheries that house newcomers from rural areas that settled on vast areas under occupation logics outside formal planning processes (Jehanno, Niang, Ortiz, Laborde, & López Camacho, 2018; Tiwari, 2005). Nevertheless, these informal neighbourhoods can appear as well in central areas or close to employment and commercial centres in some Asian cities (Tiwari, 2005). In any case, these marginal settlements have become big pockets of poverty that shelter low-skilled workers who live on daily profit (Cervero, 2000) and serve as labour for the formal sectors in households, factories and commercial establishments. Therefore, the growth of the urban formal sectors implies the growth of the informal sector to serve the first one and itself (Tiwari, 2005). Despite this dependence, the informal settlements are not recognised as an integral part of cities, which reproduces exclusion and inequality patterns. In fact, LAC accounts for the highest level of income inequality, with a combined Gini coefficient for urban areas of 0.494 in 2010 (UN-Habitat, 2020).

This urban background has a considerable influence on the mobility patterns in LAC and Asian cities, which still heavily rely on walking, cycling and transit (Jehanno et al., 2018; Tiwari, 2005). This marks a difference with urban areas from the Global North, where the share of private mobility is usually above that of transit. However, the increase of income per capita, industrial relocation and the development of the periphery have increased travel distances (Tiwari, 2005), reducing the share of non-motorised modes (walking and cycling).

Economic growth has resulted in constant private motorisation growth, which represents a threat to the already weak urban transport infrastructure and service. A survey carried out by Vasconcellos and Mendonça (2016) in twenty-nine Latin American cities revealed that between 2007 and 2014, the fleet of automobiles increased in 45% with an average annual growth of 4.4%, while the fleet of motorcycles for the same years increased in 153% with an average annual growth of 13.6%. This is encouraged by unsustainable investments to solve the problem of urban transport congestion, such as US-type wide urban freeways and grade separated intersections that aim to increase the speed of private motorised vehicles and remain as symbols of economic progress (Dimitriou ,2011: Tiwari, 2005).

These monstrous road infrastructures do not benefit pedestrians, cyclists and transit users, which still account for the greatest share of daily trips. In Latin America, the urban space for car use occupies an area thirty times bigger than the space needed by a person travelling by bus (Montero & García, 2017). The average percentage of reserved routes for bus transit is only 1% of the total length of existing roads in the city (Vasconcellos & Mendonça, 2016). Investment in transit infrastructure and vehicles represents 20% of the total investment in transport, whereas investment in cars and roads for private mobility represents 63% and 17%, respectively (CAF, 2009). As car ownership is still a characteristic of the most privileged sectors, these end up benefiting from fossil-fuel subsidies, reduced taxes for the purchase of new vehicles, and free parking in most of the streets, in addition to the already mentioned investments in road infrastructure for cars (ECLAC, 2016; Vasconcellos, 2019).

The accelerated motorisation rates have a major environmental impact in cities, as transport is the main source of air pollution. At least 100 million people in LAC are exposed to levels above those recommended by the World Health Organization (WHO) (Cifuentes, Krupnick, O'Ryan, & Toman, 2005). A private car produces 2.5 times more CO_2 per passenger than a bus trip and five times more than a trip in metro (ECLAC, 2018). Private cars are responsible for 43.9% of CO_2 emissions and 66% of particulate matter (PM_{10}) emissions in the region, above any other transport mode (Galván Zacarías, Melo Álvares, Alcantara de Vasconcellos, 2014). Considering that vehicles are owned by the high-income levels, the less privileged sectors, which produce less emissions, end up being the most affected group. Pollution also has economic repercussions. According to the World Bank, health impacts related to transport emissions represent up to 2% of the GDP in countries like Bolivia, Peru and Ecuador (Vassallo & Bueno, 2019).

The impact of these car-oriented urban patterns is not easy to remove. Although Asian metropolises are currently doing great efforts to invest in railway infrastructure, it is getting harder to revert the car-oriented effect with mass-transit-oriented patterns. This slows down the spread of the great impact and benefits of transit solutions. As a result, many Asian megacities are facing the challenge to become transit-oriented cities or to be entrenched as car-oriented, congested cities (Kidokoro, 2019). Latin America has not reached this critical situation yet. However, if new strategies to slow down the rapid growth of private motorisation in favour of more sustainable mobility solutions are not implemented, LAC and Asian cities may face the collapse of their roads due to heavy traffic and pollution produced by private vehicles.

2.2 Current transit offer

In Latin America, transit accounts for 43% of the modal split with 92.3 million daily trips, above private modes (29%) and non-motorised modes (28%) (CAF, 2009). As most of the cities in the world, standard buses dominate the transit offer, because of their cost effectiveness and adaptability to changing service requirements (Brader, Jennings, & Tvedt, 2019). In this region, standard buses provide 49.1% of the transit passenger capacity, and they are followed by minibuses with 17.8%. Railway modes represent 7.5% (metro) and 4.6% (train) of the passenger capacity (Vasconcellos & Mendonça, 2016). However, the transit offer can be classified into two types of services in LAC and Asian cities. The knowledge of the current available transit offer is essential in order to select what transit solutions suit best for a city.

2.2.1 Institutional transit

This denomination refers to the structured transit that operates as a scheduled public service, provided by public or private companies in accordance to the requirements of public transport authorities (PTAs) in terms of the quality of the service and vehicles (Godard, 2001; Salazar Ferro, 2015). To this type of transit belong modes of large passenger capacity, such as mass-rapid transit (MRT) (heavy rail and metro), light rail transit (LRT) and bus rapid transit (BRT). These services have fixed routes and stops, and especially reserved lanes that assure their right-of-way and prevent from delays due to mixed-traffic congestion. Because they are institutionalised and regulated, their transition towards cleaner energies can be achieved more easily with governmental support on various levels. However, institutional transit faces some major challenges in LAC and Asian cities. Although transit companies are required to set low fares, which strains their operational budget (Salazar Ferro, 2015), this service ends up satisfying mobility needs of middle-class citizens as standard fares are still not affordable for a great part of the low-income sectors and the required road infrastructure does not supply the peripheral areas (Cervero, 2000; Godard, 2001).

2.2.2 Informal transit

Parallel to institutional transit, low-performance vehicles of low capacity run through the city, driven by private, small-scale operators (Cervero, 2000). Contrary to institutional mass-transit, informal transit offers a wider range of small-scale modes (Godard, 2001) with a wider coverage, higher frequencies and longer service hours that allow short waiting periods and even shorter walking distances between bus stops (Ardila-Gomez, 2012; Salazar Ferro, 2015), ensuring minimal walking mobility for the low-income population (Godard, 2001). The way this service operates is through concessions to private transport companies, which may be offered through less legally stable licenses and sometimes linked to corruption cases (Vasconcellos and Mendonça, 2016). Public policy is explicitly permissive without a proper control of the service provided by this sector, which in turn creates numerous jobs for an unqualified population without a legal framework nor institutional action. Governments provide incentives for industrial production of small transit vehicles and/or the importation of the same type of vehicles (new and/or used) from other countries (Jehanno et al., 2018). As a result, informal transit supports a great part of the population that works in informal conditions without proper working benefits and who live on the daily profit (Vasconcellos and Mendonça, 2016).

As informal transit appeared within a free-market framework, it was expected that free-market competition would self-regulate the offer (Salazar Ferro, 2015). On the contrary, privatisation of transit has finally encouraged ruthless competition among drivers, who operate on the routes with higher user demand to maximise profit (Câmara and Banister, 1993; Godard, 2001), while leaving areas with low demand without coverage. Without regulation, informal transit requires low operating costs as small-scale private companies are not required to invest in the quality, safety and maintenance of their vehicles, nor providing social benefits to their employees (Godard, 2001). These work more hours than formally employed drivers to achieve profitability targets in vehicles with much lower capacity. Informal transit offer is then characterised by its vehicle oversupply, high travel times and accident rates as drivers compete to get more passengers, who end up travelling in low-quality, old and overloaded vehicles, and remain as the most affected party without the ability to change this situation (Ardila-Gomez, 2012). The lack of regulation regarding working hours and employment benefits marks a significant difference between the cost of informal and formal transit. The total average cost per kilometre of institutional transit in Curitiba can be three to five times the cost of informal transit in Lima (Vasconcellos, 2019).

2.2.3 Paratransit transport

This transport mode is usually included as part of the informal transit offer. However, its service shares some features with private modes (such as taxis and motorcycles). Paratransit is described as a door-to-door service carried out in vehicles of a comparatively smaller capacity (up to six passengers) over a limited area of coverage (Shimazaki & Rahman, 1996; Tangphaisankun, 2010). While informal transit can be described as *bus-like* services with some certain level of defined routes and intermediate stops, paratransit vehicles are completely flexible according to the destination set by the passenger (Fouracre & Maunder, 1979). Unlike informal transit that extends over the city overlapping institutional-formal routes, paratransit is provided in areas without service coverage due to the physical characteristics of the neighbourhoods, lack of proper transport infrastructure, or low passenger demand and little interest by private or public bus operators (Cervero, 2000). In this way, paratransit service can be defined as intermediate public transport (IPT) (Fouracre & Maunder, 1979), which complements institutional transit as it is used to reach MRT stations in order to connect to the rest of the city (Tangphaisankun, 2010), as well as for local, short trips. These displacement patterns are defined as first-, last- and only-mile mobility (F/L/O mile mobility) (EEA, 2020).

2.3 Urban mobility challenges

The costs of rapid motorisation and preference for private cars in terms of air pollution and traffic congestion have contributed to some local governments in emerging economies opting for sustainable urban mobility solutions. Their introduction, however, is far from trivial and presupposes strong political, technical and financial commitment. This report identifies three main challenges for policymakers.

2.3.1 Phasing in a new solution

Phasing in new transit systems and technologies into existing consolidated urban fabrics requires changes in urban infrastructure for the building of exclusive routes reserved for transit vehicles and stations onto the streets. However, the introduction of a new system faces more than just the infrastructure investment. Emerging economies have already established informal transit networks with comparatively cheaper tariffs that support a considerable amount of the working population directly and indirectly. In addition, the governance of the current transit system is split into several entities without the capacities to face the organisational commitments that the implementation of a transit solution requires. These two problems are explained below.

The transport sector is a major source of employment and income, many of which accrue in the informal economy, providing jobs to unqualified men in their twenties and thirties who otherwise would be unemployed or in lower paying formal-sector jobs (Cervero, 2000). As an example, the informal and paratransit sector in Lagos provide direct employment to around 15% of the population (Kumar, Zimmerman, & Agarwal, 2012). Consequently, this sector supports a large proportion of families. The existing informal transit industry is categorised into three groups: vehicle operators, which could be part of different associations, owners of operating franchises and fleet, and the mechanic and assembly industry with workshops and assembly parts businesses (Kumar et al., 2012).

Although new transit solutions can provide a better organisational regime with better pay and working conditions for a certain number of people already working in the transport sector, there is still a risk that not all employees will be able to transition to the new regime, particularly people who have indirectly benefited from the informal transit industry (bus, taxi and motorcycle operators, fare collectors, mechanics, etc.). This represents a risk that could limit acceptance by informal service providers (Kumar et al., 2012). Moreover, new metro and BRT corridors necessarily cut through and compete with some established bus and para-transit routes, forcing them to operate with fewer customers, rearrange their services (e.g. providing feeder services to metro stations and BRT stops) or even to give up their services.

Finally, new transit systems imply a shift from less organised and less taxed structures to one that is strictly regulated and controlled by the government in terms of service quality, safety and vehicle maintenance. This demands a significant shift of the traditional informal business models for fleet and franchise owners, who rent their vehicles and franchises to bus operators who live on the daily profit without receiving any benefits. Therefore, this major shift may not always be well accepted and can result in the owners using their influence to buy political favours and stop the formalisation of transit (Kumar et al., 2012).

2.3.2 Accessibility, affordability and connectivity

New solutions need to be at least as good as the old ones in terms of accessibility to every member of society, with affordable fares especially for the less privileged groups and good connectivity to benefit citizens from marginal areas that highly depend on transit as part of their mobility patterns. Accessibility, affordability and connectivity are challenges that the current urban mobility system has not been able to meet.

Considering the urban characteristics of Latin American metropolises with centres that gather jobs and services and peripheries where the low-income population lives, urban mobility becomes an explicit expression of the inequality in the region. The relation between the time spent in bus trips and trips carried out in private vehicles varies from 1.5 to 3.2, with additional times between 50% y 220% due to the additional stops that buses make, longer travel distances and traffic congestion due to the lack of exclusive lanes for buses (Vasconcellos & Mendonça, 2016; Vasconcellos, 2019). Peripheral citizens, who account for the larger majority of transit users, spend more time travelling than citizens from the central areas, which concentrate the larger levels of car ownership. Long travel times also mean less time spent at home with families, as these citizens leave very early to work and return very late in the evening. Long travel distances also represent difficulties in the access to health and education facilities (Ardila-Gomez, 2012).

Social inequality also translates into gender inequality. Men and women usually have different travel patterns, while typical men trips are long and related to work purposes, women take several shorter trips at more varied times and with different purposes beyond work, such as taking children to and from school, grocery shopping and running errands. Therefore, their mobility tends to be more active and disperse and the most common modes they use are walking, paratransit or informal transit. In LAC, more than half of transit users are women (Allen, 2018). Nevertheless, standard fixed-route services are usually impractical for their complex multi-purpose trip chains, and this is why door-to-door, paratransit services result more convenient for local displacement (UN-Habitat, 2013). In comparison with men, women who are employed are more likely to work part time and under informal conditions, such as domestic workers. This implies that their trip destinations are not necessarily towards the traditional employment centres in the cities, but rather residential areas, while, as their schedules are conditioned by their children and household duties, their travel times are not associated to the traditional typical working hours to which transit is planned (Allen, 2018). Yet, transit is still the cheapest mode to move throughout the city, and allows women to reach their job places and be part of the labour force, which translates into financial empowerment and self-sufficiency (UN-Habitat, 2013). In addition, women do not have a full safe freedom of movement right, as they still experience sexual harassment in overcrowded buses and personal security threats in transit facilities of bad quality and without proper lighting and security reinforcement (UN-Habitat, 2013).

Apart from the long travel times and distances, transit in emerging economies still face the problem of affordability, in regard of to what extend citizens can afford the cost of trips without sacrificing household budgets (UN-Habitat, 2013). Transit service in Latin American cities is expensive for most of the citizens, with an average cost of 10.7% of the minimum salary of metropolitan areas (Vasconcellos, 2019), which accounts for a higher percentage above all other household utilities combined (Ardila-Gomez, 2012). Only six cities in the region count with subsidised bus systems. From these, only Buenos Aires and São Paulo offer subsidies in all their transit modes. Apart from these two, other eight Latin American cities offer railway subsidies (Vasconcellos and Mendonça, 2016). Yet, as informal transit represents the main transit mode, with more accessibility in peripheral low-income areas, not everybody benefits from these subsidies.

This situation is worsened by the lack of a single transit fare, which means that users need to pay a new fare for each mode. As a result, peripheral citizens end up being the group that pays more to move throughout the city, while at the same time spending more time travelling long distances in trips that may require up to five transfers a day (Cervero, 2000). Therefore, they pay higher rates for transit use in comparison with citizens from the central parts of the city with greater disposable income. Transit costs are above three or four times the recommended levels (Câmara and Banister, 1993) and may cost up to one-quarter of a the salary of a day (Cervero, 2000). In order to avoid spending additional fares, commuters opt for only one mode per trip, as it occurs in Lima. Yet, this only means longer travel times due to the extension of the city (Ruiz González, 2018).

New transit solutions need to be affordable to low-income populations, which represents a challenge because institutional transit covers much more expenses that unregulated informal transit does not consider, including employee benefits and a high-quality service. Therefore, it is very unlikely that new transit solutions will be able to be self-sustained based on fares revenue only at an accessible price without other additional funding sources, such as LVC, taxes on companies to pay for transit fees of their employees, and especially car use contributions through charges on road infrastructure and street parking. Financing mechanisms can associate different levels of governance, including PTAs and private actors, through public-private partnerships (AFD & MEDDE, 2014; Vasconcellos, 2019). These mechanisms contribute to keep accessible fares for the population, especially the low-income sectors that highly depend on transit.

Even after the implementation of new transit solutions, short-distance connectivity to access to mass-transit stations remains as a major challenge in emerging economies (Tangphaisankun, 2010), especially in low-income neighbourhoods located at the fringe of metropolitan areas without road infrastructure. These trips are known as first- and last-mile mobility. To cover this gap, minibuses and vans of low capacity serve as the link between metro stations and dwellings, as well as paratransit, taxi-like services such as auto-rickshaws (Cervero, 2000). In addition, the latter also fulfil the need for local short-distance trips in peripheral areas, known as only-mile mobility, which is typical of women's local multi-purpose trips. Therefore, it is necessary to consider informal neighbourhoods when developing new station areas and transit networks (Kidokoro, 2019). A wrong assumption when implementing a new transit solution is to think that this stands alone in the city and needs to replace the existing service, when it actually needs to be fed and integrated within the broader urban mobility system (VREF et al., 2019). A single transit solution cannot cover the entire urban area all at once, much less serve peripheral areas where there is not adequate road infrastructure to support mass-transit coverage or due to the geography of self-built neighbourhoods located on hilly areas.

In Western cities, bus services that cover peripheral areas that are not commercially profitable from fare-box revenues alone receive additional compensation with operational cost or support from PTAs (Brader et al., 2019). Although this is more complicated to achieve in Global South metropolises, these offer informal transit and paratransit services that have been informally fulfilling the role as feeder to institutional trunk routes as intermediate public transport (IPT) (Tiwari & Jain, 2010), which contributes to improve trip lengths from origin to final destination and the accessibility of communities around mass-transit stations. At the same time, the integration between both systems is also a strategy to promote the shift from private vehicles in favour of transit usage (Satiennam, Fukuda, & Oshima, 2006) and represents a great benefit in emerging economies with increasing motorisation rates. The provision of better options for F/L/O connectivity can contribute to broaden access to fixed-route institutional transit of larger passenger capacity (Venter et al, 2019).

2.3.3 Leveraging economic co-benefits

The implementation of new transit systems and technologies also has the potential to produce innovative industrial, technological and business developments, which can in turn provide sustainable economic growth and generate employment in urban areas. This is of particular importance as replacing old, often informal means of transport with more efficient ones may reduce the required workforce, and offering new sources of employment and incomes therefore becomes crucial to improve labour market effects and increase acceptance in the societies. Also from a macro-economic perspective, countries are well-advised to develop local capabilities instead of depending on imported technologies and services. Construction work for metro lines for example, systems operations and manufacturing of metro coaches and buses provide big opportunities for technological learning, replacing import needs and even developing new export markets. In the case of electric buses, the technological development is still at an early stage, and domestic manufacturers of diesel buses need to catch up with international competitors to preserve their market and potentially join the competition for exports. More of these co-benefits will be detailed in section 3.3.1 "Economic benefits".

3 The Big Push for Sustainability: Achieving economic, social and environmental benefits

The described unsustainable urban mobility patterns and challenges are just a glimpse of the current development path the world is following, which is unable to reduce structural gaps: technological asymmetries, income gaps and social inequality, especially in Latin America. These gaps place the region as one of the most unequal in the world and have major economic implications in the creation of a larger-scale domestic market that generates jobs and productivity under fair working conditions. Inequality also deteriorates policies and efforts, which weakens the innovation and capacity building that are indispensable for development (ECLAC, 2018; ECLAC & CGEE, 2020). Therefore, a new style is required to recover the economic dynamism, but considering social and environmental aspects, which are necessary to determine a long-term sustainable development within a world able to generate its conditions to sustain life (human and non-human) for the present and future generations. This new development style shall be based on the combination of a new governance for global public goods and national strategies and policies centred on equality and sustainability (ECLAC, 2016; Gramkow, 2019).

Guided by the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda (United Nations, 2018b), the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has developed a vision to support LAC countries towards a more sustainable path named the Big Push for Sustainability (ECLAC & CGEE, 2020). This represents a coordination of policies on different levels and sectors that aim to leverage national and foreign investments in favour of economic growth and jobs generation, while reducing inequalities and preserving the environment (Gramkow, 2019). This interlinked set of policies should lead to the *growth for equality and equality for growth*, objective that was targeted over the past decade (ECLAC, 2020). The Big Push for Sustainability reformulates the idea of P. Rosenstein-Rodan that significant, complementary investments are fundamental for a development leap and updates it within the Latin American context (ECLAC & CGEE, 2020) to its own particular economic, social and environmental problems.

In this way, today's investments are understood as the main link between the short- and a long-term productive structure, considering competitiveness and insertion in international trade in order to position regional economies as key players within the global economic systems. Investments also determine the social and environmental aspects of economic activities and are essential to turn the current structural changes into opportunities for sustainable development. Therefore, they need to consider the efficiency of sustainability in its three dimensions, which highlights that investments must consider the financing and employment sources and resources (economic dimension), a safer and fairer system that does not leave anyone behind (social dimension), and environmental stewardship and recovery of the natural capital's productive capacity (environmental dimension) (ECLAC & CGEE, 2020; ECLAC, 2020). These actions need to go hand in hand with new economic performance metrics that do not only consider GDP as the main indicator (ECLAC, 2020).

The concentrated investment effort that the Big Push represents aims to redefine new production and consumption patterns based on learning and innovation (ECLAC, 2016). Articulation and coordination between a wide range of policies on various sectors and levels are a critical challenge and a major opportunity for this new development style. With a cohesive mix of economic, social and environmental policies, but also technological and industrial ones, the necessary sustainable investments can be mobilised, with redistribution as a crucial component (ECLAC & CGEE, 2020; ECLAC, 2020). The building of local capacities is also needed within this context, together with the local creative effort to assimilate and disseminate frontier technological progress. At the same time, the Nationally Determined Contributions (NDCs) of the Paris Agreement are an important link to connect national Big Push policies with the international agenda (ECLAC, 2020).

In order to achieve a real impact, the Big Push for Sustainability requires an overhaul of public policy, including the elimination of environmentally harmful subsidies, increasing prices for less sustainable goods and services, while providing public services of high quality and searching for solutions to reduce urban congestion and pollution (Vasconcellos, 2019). The main challenge is to integrate policies for urban planning, environmental and industrial policy. This research project builds on ECLAC's and DIE's long-standing work on industrial policy in the tradition of Prebisch and Fajnzylber and more recent work on the Big Push for Sustainability by ECLAC and Green Industrial Policy by DIE.

3.1 The Big Push applied to sustainable urban mobility

As explained above, the uncontrolled city growth has had direct impact on urban mobility, with major economic, social and environmental implications that reveal the inequality in the region, especially due to the governments' preference towards investments in road infrastructure made for private vehicles. This car-oriented development is defined by Vasconcellos (2019) as the *Big Push for the Car*, with an inefficient urban mobility system that has created a vicious circle of economic inefficiencies. A shift towards sustainable urban mobility can lead to a Big Push in LAC, which can be defined as the *Big Push for Sustainable Mobility*. The decarbonisation of transport is necessary for the decarbonisation of the economy. Hence, the green economy (with the objective of eliminating energy and fossil resources use) is an effective strategy in close interaction between the environmental and technological dimensions of industrial policy within this sector (ECLAC, 2016). Table 1 summarises the differences between the current *Big Push for the Car* and the proposed *Big Push for Sustainable Mobility.*

Table 1: Characteristics of the *Big Push for the Car* and the *Big Push for Sustainable Mobility*

Big Push for the Car	*Big Push for Sustainable Mobility*
Car industry with legal support and subsidies	Car industry without production subsidies
Urban road network with dedicated taxes and investment plans	Urban road network reorganised for sustainable mobility with real priorities and demand/traffic management
Road project assuming great growth, with very high expenses and waste	Road project dimensioned primarily for non-motorised mobility and transit, with urban areas protected from general impacts
Car purchase with incentives (consortia and lower interest)	Car industry without subsidies for sale
Car use with low rates and licenses, free parking on the roads, subsidy for gasoline and poor enforcement	Car use paying social and environmental costs, with effective control
Use of fossil energy sources	Use of clean energy sources
Mobility seen as transport of vehicles, requiring the government only to build roads for their accommodation	Mobility issue seen as everyone's right, requiring planning by the government
Non-existent or very precarious non-motorised transport support system	Legal and financial incentives for the development of walking and cycling with quality, safety and comfort
Informal transit system with low accessibility, quality and regulation	Institutionalised transit system, with high accessibility, quality and regulation
Non-existent demand management or based on limited actions	Demand management based on equitable distribution of consumption and mobility impacts
Car-oriented traffic management	Non-motorised- and transit-oriented traffic management

Source: Vasconcellos (2019). Translation by author.

The proposed *Big Push for Sustainable Mobility* shall consider a set of policies that cover the following essential fields: legality, institutionality, infrastructure, social communication, technology, urban development, traffic management, demand management, knowledge production, environment and financing (Vasconcellos, 2019). The first field refers to the definition of transit as an essential public service and as governments' responsibility to plan it and control its operation. Although transit operation can be either public or private, it can no longer be seen as a market issue to be solved by the private sector without regulations. Legality and institutionality also means to provide more responsibilities and authority to local governments for the mobility planning and management (including financial resources and technical capacity building). The provision of a legal framework ensures that mobility plans are compatible with urban development plans. Infrastructure means to allocate the real space to private vehicles in favour of reserved lanes for transit. Social communication is necessary to keep the population informed about the changes towards sustainable mobility. The creation of mobility observatories with updated data is important to invite open discussion. This also promotes knowledge production as an ongoing process. Technological innovations play a key role to keep users informed in real time about the status of the transit services. The technology aspect shall also consider incentives for the renovation of transit fleet. As well, a properly integrated transport system (physically and fare-wise) improves the flow of passengers under a single system (Vasconcellos, 2019).

Urban development refers to a change in the land use needs to comply with the road and transit capacity, in favour of dense and mixed-use areas to reduce travel distances, and supported by an efficient transit network. Traffic and demand management covers the reorganisation of the movement priorities with non-motorised modes at the top, followed by transit and with private modes (cars and motorcycles) at the bottom. In this way, the most vulnerable groups are protected against traffic accidents and road unsafety, and the car is removed from its privileges. In addition, the transit offer should be flexible and consider the needs of all transit users (Vasconcellos, 2019).

Finally, the environmental and financial fields include sales taxes to the purchase and use of unsustainable vehicles (in regard of the associated social and environmental costs, as well as the consumed road space to ride and park) and provide subsidies for cleaner energy sources for transit vehicles and infrastructure. The correct disposal of waste produced by old vehicles should also be considered. The mobilisation of existing resources originally directed to private mobility towards transit can provide new financing sources. On the other hand, subsidies on non-motorised modes (e.g. for decent sidewalks and bike lanes) and transit fares contribute to the reduction of inequalities. In the latter, direct subsidies to the demand rather than to the transit offer are more effective, as they benefit commuters directly (e.g. when companies pay for an annual value for the use of transit by their employees), and avoid their misuse by the transit operators. As the ability of citizens to reach their destinations benefits the commercial and private sectors, their inclusion to cover the costs of transit can be favourable, e.g. through property taxes to owners who gain profit from new transit lines or sale of construction rights to real estate companies for extra stores beyond the authorised in urban areas in transition. The assessment of mobility projects shall not only focus on the reduction of travel times of private cars, but also the impacts on transit users and especially pedestrians and cyclists. Hence, this also contemplates the benefits for users from low-income levels who cannot afford car ownership (Vasconcellos, 2019). Table 2 summarises the impacts between the current *Big Push for the Car* and the proposed *Big Push for Sustainable Mobility.*

Table 2: Impacts of the *Big Push for the Car* and the *Big Push for Sustainable Mobility*

Big Push for the Car	*Big Push for Sustainable Mobility*
Inefficient and uncontrolled urban development	More urban efficiency and economic productivity, less congestion
Spatial isolation of low-income sectors	Inclusion of everyone regardless of their personal conditions
High vulnerability of the most socially and economically fragile	Low vulnerability of the most fragile
High accident rate and mortality	Low accident rate and mortality
High energy consumption	Low energy consumption
High emission of local pollutants and CO_2	Low emission of local pollutants and CO_2 and better public health

Source: Vasconcellos (2019). Translation by author.

3.2 The three dimensions of sustainability in urban mobility

In order to achieve sustainable urban development, it is necessary to comply with the three dimensions of sustainability –economic, social and environmental– in a balanced and integrated manner (United Nations, 2018b). However, these three dimensions arise conflicts from the divergent interests that these represent: property conflict (between economic growth and equity), resource conflict (between economic growth and environment protection) and development conflict (between equity and environment protection). While the first and second conflicts are characterised by ambivalent economic interests, the third one results from the difficulty to achieve both points at once (Campbell, 1996). This is a challenge that urban planners have identified within the sustainability triangle (Figure 1). This triangle shows not only conflicts, but also interests that can potentially complement each other. While the conflicts are unavoidable, the ability to find the complementarity of interests is an opportunity to build coalitions between separated groups (Campbell, 1996).

Figure 1: The Planner's Triangle

Source: Author, based on Campbell (1996).

Transport is linked to direct and indirect targets of eight of the 17 SDGs (SLoCat, 2018). Nonetheless, among the energy end-use sectors, it still heavily depends on fossil-fuel sources (Lah et al., 2020). When the three dimensions of sustainability are brought up to the field of urban mobility, this can be understood as a demand driven by the economic and social needs, which has deep environmental impacts (Figure 2). It is important to emphasise that urban mobility is a concept broader than transport, as it covers not only the movement of passengers and goods, but also the opportunities and accessibility of a transport system. The indicators to assess urban mobility can also be categorised in three dimensions: economic efficiency, regional development and environmental protection. Furthermore, it must be noted that only a mix of well-designed policy packages will contribute to achieve sustainable urban mobility (Schade & Rothengatter, 2011). This complies with the Big Push for Sustainability approach, which requires a coordinated policy effort to generate a new cycle of economic growth, promote equality, a build a sustainable development on its economic, social and environmental dimensions (ECLAC & CGEE, 2020; ECLAC, 2020).

Figure 2: Urban mobility and the sustainability triangle

Source: Author, based on Schade & Rothengatter (2011).

3.3 Benefits of sustainable transit solutions

The benefits of transit solutions comply with the *Big Push for Sustainable Mobility* approached and are categorised according to the three dimensions of sustainability and will be exposed in below.

3.3.1 Economic benefits

The enhancement of transit provides several benefits for the economy of cities, from reduction of costs generated by transport pollution, such as its impact on public health, to employee efficiency gains, due to the reduction of travel times in vehicles of bad quality. Efficient transit systems also attract more users away from private vehicle ownership, reducing the additional investment costs in road infrastructure for cars as a wrong solution to traffic congestion. New transit solutions also have the potential for economic growth regarding industrial production, job generation and real estate development. These benefits are presented below.

Development of a new transit industry

New transit technologies offer the opportunity to create a new industry off the ground and introduce a regional urban market that ensures predictable demand for production on a regional level. In the case of e-buses, this can be achieved through contracts between producers and cities as purchasers, which would allow to schedule production and obtain financing. In the initial phase, tax incentives for this industrial production would promote the construction of new plants or adapt existing ones to produce cleaner vehicles (ECLAC, 2020). The electrification of transport also offers governments the opportunity to build a domestic industry of vehicles with a better quality and more sustainable energy sources, and develop local brands that can become competitive beyond the domestic market (BNEF, 2018). Government support can contribute to reduce operation costs and lead to a modern regional industry.

The region offers the opportunity to provide incentives to establish processing, component and equipment manufacturing and final production lines with export taxes or fees inversely scaled in regard of the value added to essential supplies for electric vehicle (EV) industry (e.g. lithium and copper), while reducing the imported component. Moreover, the integration of different countries into the production change through regional agreements and system standardisation would increase regional manufacture of parts and components for electro-mobility. This would also need intensive coordination between private and public sectors and development banks (ECLAC, 2020). Appropriate scale is essential for a significant industrial response to face the traditional global suppliers, such as the People’s Republic of China (or China, as it will be referred to throughout this report) and other economies from the Global North that already dominate the provision of e-buses and other EVs. Organised planning and scheduling of transit fleet renovation is mandatory to provide an overview of the necessary industrial effort and coordination strategies within the region. It is also important to standardise the technical specifications that the electrification of transit demands (ECLAC, 2020)

At the same time, it is important to stop the reduction of the import tariff of vehicles powered by fossil-fuel sources. The liberalisation of the type and quality of imported vehicles contributed to the proliferation of vehicles that were not conceived for transit provision, such as vans and minibuses that are part of the informal transit fleet (Vasconcellos, 2019).

New employment opportunities and job formalisation

New institutional transit systems contribute to the formalisation of a previously informally employed labour with the same amount of people employed to a certain extend. The formalisation of employment in the transport sector provides decent working conditions, such as better pay, social benefits, fixed working hours and a formal organisational regime. This also means that these citizens would gain access to a formal economy, banking system, credit, etc., which at the same time benefits the city. Moreover, the construction of the transit infrastructure and the necessary maintenance works also represent the possibility for job generation. On the other hand, the boosting of a local EV industry also contributes to the creation of new job opportunities and maintaining employment within the transport sector, which is currently under constant change (BNEF, 2018; ECLAC, 2020).

Real estate development

Transit solutions create a better image of an organised city. Furthermore, mass-transit can increase the potential to catalyse development around stations in order to create land value capture (LVC) (UITP, 2019). Smart corridor and station location planning can endorse LVC through initiatives that provide better access and connectivity to new or existing stations (e.g. with integrated feeder buses or improved pedestrian access) (Abiad, Farrin, & Hale, 2019). LVC supports and resources facilities around MRT stations with retail and other opportunities, as well as urban planning and architectural projects. An example of LVC models applied on private property land is when the government lends to landowners the equivalent of the estimated land value gain generated by the transit infrastructure, at a low interest rate for over ten years. Then, new tax revenues attributed to transit are generated by new mixed-use developments with high density, which ends up attracting more commuters to transit and decreasing car use (AFD & MEDDE, 2014).

A key aspect of this approach is that PTAs retain control of property holdings, operations and access in the immediate surroundings to the stations for their optimal use and capitalise on the tax income produced from the land (Abiad et al., 2019; AFD & MEDDE, 2014). Therefore, it is needed that PTAs have the autonomy and capability to plan the transit infrastructure and service delivery to optimise the land use value (UITP, 2019).

LVC potential reveals the importance to conceive urban mobility projects in constant coordination with housing and land use projects. This needs planning capacities to identify new stations supported by the adequate density of people living within a walking distance and that employment is available within one-hour transit trips or active transport. This demands proper stakeholder management, vision and long-term planning to attract investors and gain citizen acceptability, consistency between national and local planning levels, land use regulation in key stations, and the necessary framework for investment (UITP, 2019). More of this topic will be explained in section 4.3 Transit-Oriented Development (TOD).

3.3.2 Social benefits

Mass transit has the potential to positively impact the quality of life of citizens, as it contributes to reduce car use and its related effects due to congestion, pollution and road insecurity, as well as obesity due to body inactivity. The impact in the quality of life affects especially peripheral citizens from low-income sectors. The reserved lanes of mass transit restore the right to mobility to transit users over the worship of private mobility, used by only a few citizens. It reduces travel times, while travelling in vehicles of larger passenger capacity that can provide more comfort and a more pleasant travel experience. This would produce a more dignified transit system and contribute to the reduction of social gaps in the city. An institutionalised transit system also represents the first step towards the integration between different transport modes, which can eventually lead to a full-fare integration and reduce travel costs for commuters that need to make many transfers in order to get to their destination. As mentioned in the previous section, institutional transit not only benefit commuters, but also provides decent working conditions to the labour force involved in this sector.

Regarding the electrification of transport, the high price of EVs keeps them inaccessible to the majority of the population. Even through carbon taxes, the subsidy for private EVs would only benefit sectors with greater purchasing power, generating popular resentment and impacting public subsidies for the promotion of EVs (Borba, 2020), without reducing all the negative effects of private motorisation (e.g. congestion and road unsafety). On the other hand, incentive policies directed towards e-buses have a greater potential of social inclusion (Borba, 2020), with cleaner vehicles that reach more sectors of the population.

New institutional transit systems provide better solutions for commuters with shorter travel times and more comfortable vehicles, which ends up benefiting women as they account for a greater share of transit users. This contributes to reduce the gender gap in Latin American cities, in opposition to the current *Big Push for the Car* model, which has prioritised car-oriented investments, which are proper of men’s travel patterns (ECLAC, 2018). As women value flexibility and convenience over time savings due to their multi-purpose trip chains, they need to pay for each trip when there is no fare integration (Allen, 2018). Once again, institutional transit represents the first step towards full-fare integration between different transit modes. Transit should comply with the goal of making transit facilities a safe and comfortable environment for women. Therefore, the role of transit companies is essential to provide safe mobility in all modes and address sexual harassment, with government support, through city ordinances and public safety policies to prevent and respond to sexual harassment cases (ADB, 2015). Capacity development of transit operators is needed to know how to react to these cases. In addition, a well-connected transit network provides more accessibility and time saving, which allows women to access to medical services, among others. This benefits not only adult women, but also older girls who already support their working parents as caretakers of family members or provide childcare to younger siblings, and need to use transit for these purposes (Allen, 2018). Safer and more accessible travels increase transit use among women, contributing to create a more equal city.

3.3.3 Environmental benefits

Mass-transit modes are a proved solution to achieve sustainable urban mobility and reduce car use as principal polluting source within the urban transport sector. In Latin America, private mobility consumed 66% of the energy produced in cities, in contrast to buses (30%) and rail transport (4%) in 2014 (Vasconcellos & Mendonça, 2016). A shift towards transit is a clear strategy to reduce energy consumption in the urban transport sector. Nonetheless, even if this shift is achieved, around 94% of urban transport use fossil fuel as energy sources (ECLAC, 2018).

The electrification of transit is the next step towards clean urban transport. EVs for transit use are a relevant solution to overcome the problem of air pollution due to GHG emissions and other local atmospheric contaminants produced in urban areas. In Brazil, it is estimated that the replacement of the bus and minibus fleet with e-buses would achieve a reduction of 91% of CO_2 emissions generated by these vehicles (Lima, Silva, & Neto, 2019; Borba, 2020). In Santiago de Chile, extrapolation on preliminary calculations shows that a fleet of 411 battery electric buses have reduced around 5% of CO_2 emissions (around 20.6 thousand tonnes of CO_2e) from 2018 levels (Galarza, 2020). An additional benefit is the reduction of noise pollution, as e-buses run more quietly than average diesel or CNG buses (BNEF, 2018), while providing operational savings (VREF et al., 2019).

Although the current e-bus fleet is contributing to the reduction of pollution and energy saving, most of these vehicles operate on the least demanding routes. The greatest positive environmental impact and improvement of air quality in urban areas can only be achieved with the electrification of the longest, fastest and busiest routes. This represents a particular challenge because the biggest and heaviest e-buses are required to operate on the busiest trunk routes (VREF et al., 2019).

Furthermore, the environmental benefits can contribute to find new climate-related mechanisms to face the high upfront investment cost that new transit solutions demand, as urban transport has been recognised as a major tool against climate change. Some major climate funds are the Global Environment Facility (GEF), Green Climate Fund (GCF), the Clean Technology Fund (CTF), and climate funding agencies, etc. (AFD & MEDDE, 2014).

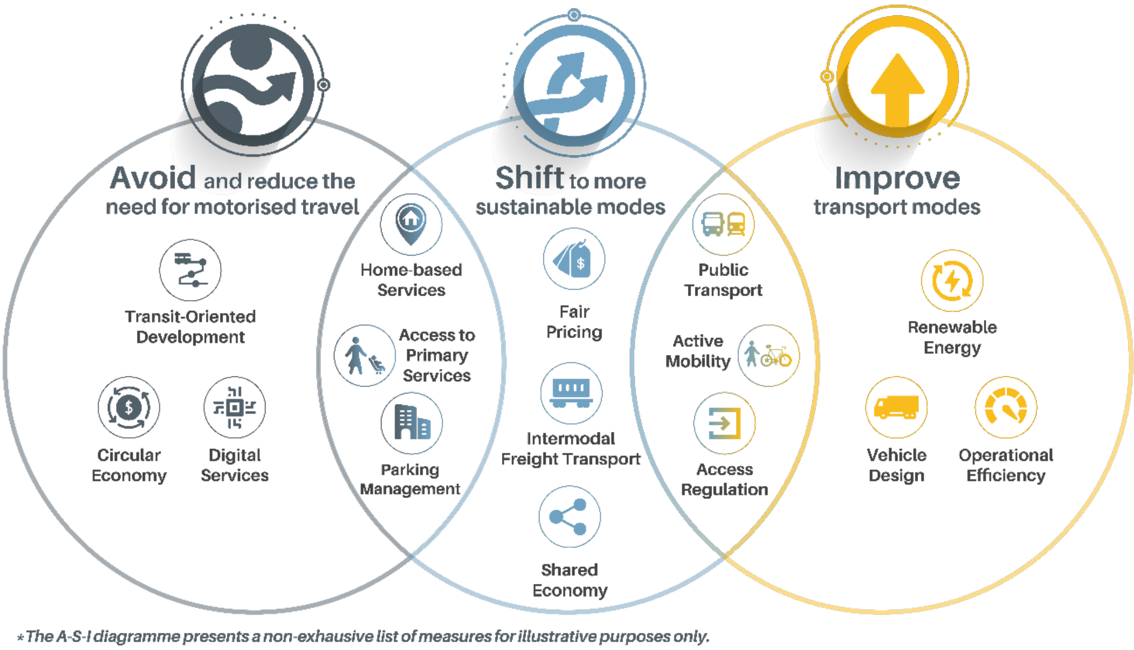
4 Important concepts in sustainable urban mobility planning

The following concepts are relevant when phasing in new transit solutions. These contribute to understand the context in which these are introduced and their link to the three dimensions of sustainable urban mobility.

4.1 The Avoid-Shift-Improve (A-S-I) Framework

Following the three dimensions of sustainability, there are three primary principles to reduce GHG emissions from transport with a focus on the mobility needs of people instead of the infrastructure for private vehicles (Dalkmann & Brannigan, 2010; Bongardt, Stiller, Swart, & Wagner, 2019). This approach is defined as the Avoid-Shift-Improve (A-S-I) Framework and was initially developed in the 1990s in Germany as a means to structure policy measure to reduce the environmental impact of the transport sector and improve life quality in cities. This framework is recognised as a better alternative to the Predict–Provide–Manage Framework as it offers a more holistic approach towards sustainable urban mobility (Bongardt et al., 2019). The A-S-I Framework (Figure 3) is divided into the three following principles according to their hierarchy.

Figure 3: Avoid-Shift-Improve (ASI) Framework



Source: SLoCat (2021).

1. **Avoid**. Transport-oriented and compact development strategies can contribute to the reduction of motorised travel needs and trip lengths. This improves the efficiency of urban mobility systems. Mixed-use urban areas where residential, work and leisure needs are covered reduce the need for travel to other parts of the city, and therefore the use of motorised modes. This is achieved with urban development policies, integrated transport and spatial planning, logistics optimisation and travel demand management.

2. **Shift**. When travel needs cannot be avoided, a shift from the private mobility towards more sustainable modes contributes to reduce energy consumption and pollution. These more environmentally friendly alternatives are active transport (walking and cycling) as the most

effective option, and transit. Although the latter still produces emissions, it still generates less GHG emissions and lower specific energy consumption per passenger per kilometre, especially in transit modes with higher occupancy, such as MRT, LRT and BRT. The Shift principle also includes maintaining the already existing preference for active transport and transit, as it is the case in many Global South cities.

3. **Improve**. Non-petroleum, low carbon fuel and vehicle technologies improve the energy efficiency of transport modes and reduce the emissions of the transport sector. The optimisation of the operational efficiency of transit through the better manage of the transport network increases the attractiveness of transit (Bongardt et al., 2019; SLoCat, 2018, 2019).

A meta-analysis of mitigation measures in NDCs, mitigation studies, and technology needs assessments exposed that 66% of such measures are located within the Improve principle with fuel efficiency and decarbonisation measures. In contrast, 23% and 11% of the measures were Shift- and Avoid-related, with behaviour-based or infrastructure improvements (SLoCaT, 2018). During the first Voluntary National Review (VNR) reporting cycle between 2016 and 2019 (another review mechanism of the 2030 Agenda), from 358 VNRs with reference to the transport sector, 31% and 35% of these were Improve- and Shift-related, with particular interest in electro-mobility, alternative fuels and bus fleet. VNRs categorised as “others” represented 23% with a great emphasis on road infrastructure, especially in emerging economies, for accessibility and connectivity. Only 11% of VNRs were Avoid-related (SLoCat, 2019).

Although all measures contribute to reduce GHG emissions or solve accessibility problems, more Avoid-related measures are needed to reduce private vehicle traffic and reward active transport users who produce less emissions and move more resource-, space- and energy-efficiently. To achieve this, human-centred planning is required to influence the citizens’ behaviour. Measures such as congestion charging and carbon pricing to private vehicles can be useful (SLoCaT, 2019).

4.2 Transport Demand Management (TDM)

Within the Avoid principle of the A-S-I Framework, transport demand management (TDM) involves many strategies and measures that encourage travellers to avoid trips or shift towards more resource-efficient modes. This reduces private vehicle travel demand and associated costs, and redistributes traffic in space or time. TDM also promotes active transport and more compact spatial development. This can be a cost-effective alternative to increasing capacity as limits vehicle traffic to the actual road capacity, and rewards active transport and transit users. The benefits of TDM also include the reduction of environmental impact of transport, improvement of urban public health, strengthening of communities and more prosperous and liveable cities (Hickman, Fremer, Breithaupt, & Saxena, 2011; SLoCaT, 2018). TDM measures can be divided into four categories:

1. Incentives to use efficient modes: road space reallocation away from the private vehicle, such as segregated distance-based pricing (toll roads, congestion, or area-wide charging), parking supply charges and restrictions, and traffic calming. This also includes measures that reward other modes such as bus and bike lanes, wider sidewalks, and pedestrian zones;

2. Smart growth development policies: public realm improvements, transit-oriented development (TOD), social housing and transport policy integration;

3. Implementation programmes: transport management associations, commute trip reduction programmes, school transport management; and

4. Complementary mobility strategies: behavioural change measures, such as flexitime, telework and delivery services, multimodal trip planning, high-occupancy vehicle encouragement (car-sharing schemes), transit information and travel awareness campaigns (Hickman et al., 2011; SLoCaT, 2018).

TDM strategies tend to be most effective when implemented as packages. And, although this approach has caught the interest of policymakers, measures that affect car users, such as street parking and efficient road pricing or comprehensive smart growth policies, are not yet worldwide applied (SLoCaT, 2018).

4.3 Transit-Oriented Development (TOD)

Among the different TDM measures, transit-oriented development (TOD) is a concept used for smart growth development policies. It refers to dense, mixed-use urban development centred around or located near mass-transit facilities, which aims to create vibrant and connected communities and eliminate the need for some motorised trips. TOD approaches include urban compactness, pedestrian- and bicycle-friendly areas, public spaces close to transit stations, and stations designed as community hubs. In this way, high-quality transit (MRT and BRT) significantly contributes to TOD and lead to reduce congestion, urban space requirements, local and global pollution, crashes and noise, while reducing car ownership, and improving more walking, cycling and transit use (SLoCaT, 2018; Thomas et al., 2018). The benefits of TOD in metropolises in emerging economies include climate change mitigation actions. As many urban agglomerations originally developed on the low-lying land of delta regions, compact-city policies contribute to the mitigation of and the adaptation to climate change. TOD also represents an active response against urban sprawl, which is a consequence of the rapid motorisation of LAC and Asian cities (Kidokoro, 2019), and the costs associated to it (investment in road infrastructure, longer motorised trips, consumption of non-urbanised land, etc.).

TODs can be classified into three categories: (1) new TODs around new transit services; (2) high-density TODs, where new transit serves existing, compact, mixed-use areas; and (3) low-density TODs, where the density and mixed-use around transit services increases within suburban areas with low density (Thomas et al., 2018). However, TODs are not always easy to execute, as they require complex, interdependent elements to work together, from urban planning, design and infrastructure, to regulations and finance. It also requires collaboration between different stakeholders, from policymakers, developers and investors, to grassroots organisations and community members (ITDP, 2017). Strategies for the successful implementation of TODs require the following:

1. Cooperation/collaboration between actors, consistent policy and plans, transport/land use long-term vision, and multidisciplinary and experimental implementation approaches;

2. Site-specific tools and instruments for financial gains through private-private, public-private or public-public partnerships, with negotiation and communication that increase the efficiency of the project; and

3. Detailed-oriented, small-scale design, accessibility to transit stations from cycling and walking infrastructure, and the ability to blend into existing urban and historical fabrics (Thomas et al., 2018).

TODs have been implemented in many countries in the Global South. In 2017, China launched its Sustainable Cities Integrated Approach Pilot Project to assist seven major cities integrate TOD principles into future transit and urban plans. In Latin America, Colombia introduced a project with TOD to shift how and where public and private neighbourhood infrastructure investments are made (SLoCaT, 2018). In Mexico, TOD plans are organised according to seven principles: transit, active transport, car and parking management, mixed used, active ground floors, safe and active public spaces and community participation (Vasconcellos, 2019). Local governments can encourage the implementation of TOD through land use laws, integrated active transport and transit systems, housing and spatial plans, and new mobility services near residential developments (SLoCaT, 2018). TOD policies play a major role for the development of transit-oriented cities, as their strategies direct towards urban sustainable development: dense urban areas served by transit systems, and local access to jobs and services (Kidokoro, 2019). Yet, decision-makers and planners need to apply TOD policies according to the local contexts of cities regarding urban form, planning, political, culture, community, financial tools and design aspects (Thomas et al., 2018). To assess TODs, the Institute for Transportation and Development Policy (ITDP, 2017) developed the TOD standard as an accessible reference, with clear definitions and a rapid assessment tool as a basis for the implementation of inclusive TOD. Similar to the principles of the Mexican case, the assessment is based on eight TOD principles: walk, cycle, connect, transit, mix, densify, compact, and shift. Nag, Manoj, Goswami, and Bharule (2019) also add the principles of: ensuring integrity of natural systems and the environment, conserving the built heritage, preserving affordable housing close to the station area, and value generation for financial sustainability.

Nevertheless, TODs face the threat of displacement of landholders or informal occupants of valuable land (Abiad et al., 2019). The attractiveness of transit investments that enhances accessibility can increase housing price in areas surrounding stations and displace original settlers, which can lead to a phenomenon that Dawkins and Moeckel (2016) have identified as transit-induced gentrification. This can prevent low-income sectors, who are the ones in major need of transit, from accessing to transit modes within short distances to their households. To prevent this, all landholders and occupants must receive compensation for the value of their holding and extra costs when relocation of residential occupants or businesses occurs, including if they represent verifiable economic loss (Abiad et al., 2019). On the other hand, TODs with mixed uses have the opportunity to increase access to families from peripheral sectors to areas with higher employment and essential services offer. This can be provided through incentives for social housing in these developments for families, who otherwise would not have the resources to pay high rents (Vasconcellos, 2019). Social housing can also be a way to preserve old low-income tenants after the implementation of TOD projects (Abiad et al., 2019). Nevertheless, there is not enough evidence that low-cost housing policies in areas proximate to transit stations are completely effective (Dawkins & Moeckel, 2016). This would need further and critical studies to find a balance between LVC of TODs and granting direct access to transit to citizens in greater need.

4.4 Multimodal transport planning

TOD is the first step to achieve the integration of a transit mode to the surrounding urban area. Yet, this is just the basis for a complete multimodal transport integration in order to ensure commuter satisfaction and attract more people towards transit use and away from the private vehicle. Multimodal transport planning establishes three levels for complete multimodal integration. The physical integration of different transit modes covers the commuter's need for convenience, easy access and comfort. The second level is the integration of information, through consistent real-travel time information with the different coordinated modes and routes options to assist transit users to plan their journey in advance. This covers the commuter's need to save time. The last level is the fare integration, which not only makes the travel experience more comfortable instead of having separate tickets, but it also makes it affordable for the less privileges sectors. Most integrated fare policies support subsidised fare amounts for longer and multimodal trips (Nag et al., 2019). Multimodal transport planning is common in the Global North, but it still needs development in emerging economies, following the three levels of integration (physical, informational, fare-wise). In addition to the new technologies to provide real-time travel information and buy tickets online, multimodal planning can increase the attractiveness of transit in cities with rapid motorisation growth rates.

There are several approaches to integrate informal buses as feeder to trunk institutional routes: reward schemes, feeder area licencing and through concessions, with successful and unsuccessful cases in Latin America and Asia (Salazar Ferro, Muñoz, & Behrens, 2015). In Mexico City, minibus owners were organised to give up individual buses in return for stock in a new transit company to complement the BRT corridors (VREF et al., 2019). However, the formalisation of the entire informal and paratransit fleet is not always possible, neither is the removal of the service due to the important connecting role it fulfils. A better solution would be to conceive a hybrid approach in which institutional transit is planned, while the informal/ paratransit sector is simultaneously enhanced. New technologies and services can support this approach to improve both systems in a more efficient way (VREF et al., 2019) and promote that both services complement each other to offer the best trip combination for commuters instead of competing against one another along the same routes.

Fare integration plays a key role to eliminate the cost related to changing transit mode during a journey and promoting the most efficient combination of routes to save time, instead of choosing the route with fewest changes to save money. There are two ways to achieve fare integration. One is through combined fares, in which a reduced fare is offered for a multimodal trip (e.g. metro and feeder routes). Through this principle, two operators accept mutual tickets with an agreement for redistribution mechanisms. A second way is through integrated fares, which allow several trip combinations with the same ticket for the same fare, considering tariff zones, time-based tickets and free transfers. This alternative, however, requires more collaborator agreement, usually through operators associations or on a municipal level, to recognise ticket types and redistribute fares according to passenger or vehicle-kilometre travelled. Automated fare collection (AFC) systems are useful to achieve fare integration and develop adaptable ticket tariffs, which can be implemented with real-time information and bus fleet management systems (Brader et al., 2019). PTAs are essential to organise this type of integration.

4.5 Public transport authorities

Coordination and collaboration between different entities and government levels are essential to determine the best transit solution, change the current business model for its provision, get the necessary funds and establish the authority responsible for its implementation (Kumar et al., 2012). The successful implementation of new transit solutions requires high coordination levels between multiple agencies involved in planning, financing, implementing, and operating or regulating several aspects related to transit. Furthermore, it is very likely that new competencies need to be developed (Kumar et al., 2012). This represents a challenge when there is a dispersed institutional framework with transit functions that are widely spread over different agencies (VREF, UITP, & BRT+ CoE, 2019).

To solve this problem, the concept of an autonomous public transport authority (PTA) appeared in European cities in the 1950s to promote high quality transit through metropolitan institutions (Jehanno et al., 2018). PTAs are found in many cities with different sizes and competencies, with examples such as Transport for London (TfL), Land Transport Authorities (LTA) in Singapore or *Iles de France Mobilité* in Paris. They have the autonomy to integrate transit policies with policies that promote active transport and regulate car use, and draw attention to strategic issues such as fleet renovation, intermodal and fare integration, etc. (VREF et al., 2019).

Although there are some PTAs in emerging economies, these still face barriers for their creation as governments are still reluctant to provide institutional power to PTAs because of worries that these would use government revenue to create parallel structures for functions that could be executed internally. As a result, many implementation projects are carried out through a Special Purpose Vehicle (SPV) as a flexible governance mode between different public entities that dissolves once the transit project is completed (VREF et al., 2019).). However, this continues the lack of governance in the transit sector that does not allow the possibility of a full integration of transit and to conceive future plans for the evolution and expansion of transit systems. PTAs can also channel resources towards medium- and long-term goals while offering the guarantee of a stable structure. This also represents a way towards decentralisation with the direct involvement between regional and local governments and national development banks, and the opportunity to get access to loans and funding from international agencies allocated to urban mobility (AFD & MEDDE, 2014).

5 Types of sustainable public transport solutions

After explaining the current situation of Latin American and Asian cities, the challenges of sustainable urban mobility and the approaches to achieve it, this report will present the three types of transit innovations to be studied. These solutions are innovative economically promising in terms of industrialisation and digital prospects, more socially responsible and accessible and environmentally cleaner, and comply with the *Big Push for Sustainable Mobility* approach.

5.1 Bus Rapid Transit (BRT) systems

The basic principle of a BRT system is the priority of buses over a segregated lane to transport many people in the fastest way and avoid traffic congestion. Segregated lanes for buses on freeways exist for a longer period. In 1966, the first dedicated busway appeared in the United States (USA) and Belgium along former tramways. Three years later, the first high-speed busway of 6.5 kilometres appeared in the USA (Mahadevia, Joshi, & Datey, 2013). During the 1970s, the first BRT prototype in Latin America came from Lima, with the introduction of a central segregated lane along a main urban freeway. The prototype inspired policymakers from Curitiba (IEG, 2015), who implemented what is known as the first modern BRT in the world with the *Rede Integrada de Transporte* (Mejía-Dugand, Hjelm, Baas & Ríos, 2013). The system was built along the city's five main corridors in 1972, which encouraged mixed-use and high-density development along those axes (Rodriguez & Vergel Tovar, 2013). BRT was replicated in other Brazilian cities and later on Quito became the first Latin American city outside Brazil to implement it in the 1990s. Yet, it was Bogotá's Transmilenio, opened in 2000, the one that made the system internationally recognised and replicated in other cities in the region (Mejía-Dugand et al., 2013).

The concept of a BRT system is the combination of infrastructure, such as busways, stations and terminals, with organised operation and intelligent technologies that provide a higher-quality service with standard bus operation (Hidalgo & Graftieaux, 2008). Unlike traditional institutional and informal buses, these travel along segregated routes that assure their right-of-way. Within this system, fixed stations and terminals provide more organised boarding and alighting, with fixed routes and frequencies. This structure allows a pre-board fare collection (Ernst, 2005). The integration of BRT to other transit modes, such as feeder services contribute to extend de coverage area of the system (Primatama, 2018).

As institutional transit, BRT is a more reliable system that has improved the image of bus service, with higher speed, frequency, passenger capacity and comfort, comparable qualities with LRT and MRT modes (Deng & Nelson, 2011). Moreover, BRT has become a popular option for local governments as it provides an effective and flexible mass-transit system at a comparatively much more affordable infrastructure cost than that of railways (Mahadevia et al., 2013). For a range between twenty and forty thousand passengers per hour per direction of transit (phpdt), metros and high-level BRTs provide quite similar capacities. However, high-level BRTs have construction costs of five to twenty million USD per kilometre, whereas the construction of metro systems costs from thirty up to 160 million USD per kilometre (Hensher & Golob, 2008). Other benefits are their flexibility, faster construction and expansion.

BRT systems represent more than just mobility investments, as their implementation embodies exceptional opportunities for urban restructuring and growth towards sustainable development. BRT networks can operate as backbones for a compact urban growth with TOD principles of mixed-use and transit and active transport promotion against urban sprawl and its related effects (Cervero & Dai 2014). Good practices of BRT investments linked to good urban planning policies to intensify land use around the corridors are found in Curitiba, but also in Seoul and Guangzhou. In the latter, an appropriate network of connectors to the stations for pedestrians and cyclists has resulted in high-rise commercial developments along the BRT corridor, which has increased real estate prices by 30% during the first two years of BRT operations (Cervero & Dai, 2014). However, within the Latin American context, many peripheral BRT stations are surrounded by informal settlements distant from activity nodes, with large isolated commercial developments similar to US-malls, and lack of public open spaces (Rodriguez & Vergel Tovar, 2013). This shows the need for collaboration between land use and transit authorities, not only to capitalise on transit infrastructure, but also to provide better quality of urban space to peripheral citizens.

According to BRTData (2020), BRT systems are found in 176 cities worldwide, with the largest figures in Latin America with fifty-six cities (32% of cities in the world) and Asia with forty-five (26%). While the first region gathers 1,863 kilometres of BRT corridors (35% of global BRT kilometres), the latter has 1,647 kilometres (31%). Although these figures are comparatively similar, BRT systems in Latin America record almost twenty-one million daily passengers (almost 61% of global ridership). Asian BRT systems carry 9.5 million passengers per day (28%), figure that is still way above those of the remaining regions.

For BRT assessment according to standardised international principles based on passenger experiences, economic benefits and positive environmental impacts, The Institute for Transportation and Development Policy (ITDP, 2016) has created the BRT Standard, which works as a planning tool for policymakers that defines the essential elements of BRT and certifies systems as basic, bronze, silver, or gold within the hierarchy of international best practices. The highest certifications do not imply the high cost of BRT features, but rather the efficiency of the system and the benefits for commuters, the revitalisation of the urban environment and better air quality. The score categories are based on the dedicated right-of-way lane, service planning, infrastructure, stations, communications, access and integration to other transit and active transport modes. Points are reduced due to the lack of maintenance, safety, overcrowding, etc. Examples of gold-standard BRT are found in Belo Horizonte, Brazil and Bogotá, Colombia, and in Yichang, China, and Pimpri-Chinchwad, India (ITDP, 2016).

A major challenge when phasing in BRT systems into already consolidated urban areas is the insertion of corridors and stations onto the streets. Although the construction can be simpler and less costly than railway systems, it requires unique planning for successful outcomes (Kumar et al., 2012). As the exclusive busways require to remove lanes allocated for private mobility, this can lead to the wrong idea that congestion will increase. However, congested areas are the ones in major need to provide right-of-way to transit modes of larger passenger capacity, which otherwise would be stuck in traffic. Nonetheless, this is not always well received by authorities, who continue thinking of enlarging roads in favour of private cars as the best solutions, and neglecting pedestrian areas or expropriating private properties (VREF et al., 2019). Although transit in the Global South accounts for a bigger percentage of daily trips than private vehicles, removing roadway space to cars is still seen as interfering with the *rights* of car owners, who belong to the most privileges sectors (Kumar et al., 2012).

5.2 Metro as Mass-Rapid Transit (MRT)

Metros represent one of the oldest mass-rapid transit (MRT) systems, as they have been running since the second half of the nineteenth century in some European cities. At the end of 2017, there were metros in 182 cities in fifty-six countries, with an average total of 168 million passengers using this service per day (UITP, 2018). The main advantage of metro systems is their passenger capacity, which is the largest of all MRT systems and can carry up to eighty thousand phpdt. LRT can transport up to thirty-five thousand phpdt, while monorail transports eighteen thousand phpdt. In comparison with bus-based systems, BRT is able to transport thirty thousand phpdt, while standard buses only ten thousand (Kumari & Banerjee, 2020). This feature makes metro the most suitable option in densely populated areas with high demand for travel.

A second advantage of metro systems is their right-of-way, which makes them a reliable mode without the interference of road traffic. This increases their attractiveness when they are built underground, as they occupy no road space, while when they are above-ground systems, they only need a corridor of two metres wide on the street level. This does not disturb the flow of traffic on the road. On the contrary, metros are able to carry the same amount of traffic as nine lanes of bus traffic and thirty-three lanes of private cars (Sharma, Dhyani, & Gangopadhyay, 2013). Additional benefits are their smoothing driving, which provides higher comfort, while the carriages and infrastructure offer a modern image for the city (Ranjan, Lal, & Susaeta, 2016). The decision to build a metro as an underground or elevated system highly depends on the high construction costs. Underground systems are more complicated and bear higher risks. One kilometre of underground metro rail costs approximately 2.5 times more than that of elevated sections. Yet, elevated sections can be fifteen times more expensive than the cost per kilometre of a BRT system (Sharma et al., 2013). Another factor for the selection of the type of metro system is the threat of terrorist attacks, as damage in underground systems is estimated to be five times higher than on above-ground sections (Sharma et al., 2013).

Similar to BRT systems, metro systems need to be understood beyond the transport infrastructure itself, but rather considering the opportunities they offer to the urban sphere, such as TODs around metro networks. A successful LVC business model that has been operating for over thirty years is Hong Kong's *Rail+Property* model, in which a major proportion of annual organisational revenues comes from property development and leasing activities year on year. Infrastructure costs for expansion of the MRT network are covered by property-related revenues, which are usually produced from within the same integrated station + real estate development project (offices, retail, and residence combined). Hong Kong's government provides support in the form of land grants and rezoning, while the MRT's corporation acts as master planner for its major projects and partner with private developers (Abiad et al., 2019). Inspired by this business model, Shenzhen has also implemented TOD projects, where the PTA receives a cut of the profits from commercial or residential buildings around the metro network (SLoCaT, 2018).

Metro stations also offer the possibility to integrate different transport modes as they are the common link for modal interchange between metro and bicycles, metro and buses, metro and taxis, and metro and paratransit (Nag et al., 2019). Following the integration planning principles, apart from the physical integration, the informational and fare integration could increase transit ridership and avoid trips in (only) private modes.

Between 2000 and 2017, seventy-five new metros started operations, with forty-four of these located in the Asia-Pacific region, and mainly in China and India. This region holds the greatest amount of metro systems in the world, as they are found in seventy-three cities and they transport almost 27 million passengers annually (almost half of the global ridership). With six of the ten longest metro systems in the world, the extension of the network in the region is 7,218 kilometres (almost 52% of the global metro extension) with 5.2 thousand stations and 53.7 thousand carriages. (UITP, 2018). Examples of integrated transit rail stations are found in Hong Kong, Kyoto, Singapore and Kuala Lumpur (Nag et al., 2019).

In the case of Latin America, nineteen cities have metro systems, the largest amount after Asia-Pacific and Europe regions. The total extension of the metro lines is 943 kilometres with 780 stations and 9 thousand carriages, which is not much in comparison with Europe (2,921 kilometres and 25.8 thousand carriages) and North America (1,544 kilometres and 14.2 thousand carriages). However, Latin America transports almost six thousand passengers annually in metro systems, which is above the annual ridership in North America (3.7 thousand passengers) (UITP, 2018). This confirms the strong reliance on transit in the Latin American region.

5.3 The introduction of e-buses

Buses are the most representative vehicles in transit system, especially in the Global South because of their cost, effectiveness and adaptability (Brader et al., 2019). In 2017, the total municipal bus fleet was estimated for 3 million vehicles, figure that has been on a decline or relatively flat in major markets, such as China, USA or Europe (BNEF, 2018). It is then understandable that cities are looking forward to improving the high quality and safety of bus service and address the environmental challenges it represents, such as congestion and air pollution, through fleet renovation and bus network integration. With China as the exception, most of the global bus fleet is powered by diesel or compressed natural gas (CNG) (Brader et al., 2019). In an effort to solve this situation, electrification of transport has become an opportunity to reduce GHG emissions and local air pollutants. Urban areas are heading the roll-out of electric buses and many local projects complement national programmes. These vehicles hold the necessary driving range to operate as transit and many cities have successfully faced the challenges related to upgrades to grind distribution and power chargers. At the same time, the ongoing decline in battery costs has reduced the gap between electric buses and other bus technologies (IEA, 2020).

Today, there are 500 thousand e-buses in the world, which account for around 16% of the total bus fleet for transit service. It is expected that by 2040, 67% of the global bus fleet will be comprised by e-buses (BNEF, 2020). However, the e-bus deployment has not been equal around the world, but rather focused on a few regions, while others have implemented only small pilot fleet renovations (IEA, 2020). The Chinese government saw the technological innovation potential and has been leading the EV market since the late 1990s when they introduced several types of industrial policies in this sector, while this industry was worldwide still in its infancy. This gave them the opportunity to become a global leader in the EV sector, while at the same time renewing the domestic automobile industry (Li, Zhan, de Jong, & Lukszo. 2016; Wu et al., 2021). The Chinese government also saw in the EV industry the possibility to lower the country's dependency on oil imports and establish a cleaner transport system, which could contribute to reduce health risks in larger cities where air pollution is a major problem (Masiero, Ogasavara, Jussani, & Risso, 2016; Li et al., 2016; BNEF, 2018).

China has adopted a development strategy for EVs or new energy vehicles (NEVs), as they are named in such country, divided into three stages. In 2001, NEVs were named for the first time as a strategic sector and the focus of promotion was narrowed to fuel cell-, electric- and hybrid-vehicles, as well as the key technological components (batteries, electric motors and electric control systems) (Gong, Wang, & Wang. 2013). During the first stage of research and development, the *Ten Cities and Thousand Vehicles* pilot programme (2009-2012) was launched to promote NEVs in the urban transit sector and taxi service in order to market-oriented development in selected key and pilot areas at an early stage. As well, the NEV industry was listed as one of China's strategic emerging industries in the 12th Five-Year Plan (2011-2015). The ultimate goal of the pilot programme was to increase the market share of NEVs in the whole industry to 10% by 2012 (Lumiao & Zhanhui, 2020). The second stage consisted on further development of the NEV market and increasing the amount of pilot cities and city clusters. The final stage, which continues since 2016, aims to improve NEV technology, product safety and reliability on a nationwide level. There is a particular focus on battery technology and their continuous dropping costs. This three-stage approach has supported the industry's transition from a start-up phase to a rapid development phase (Lumiao & Zhanhui, 2020).

The supportive policies and subsidies from the Chinese central government and local authorities combined, which included subsidies for purchasing and operating New Energy Buses, were capable of reducing the capital cost of a New Energy Bus below that of a similar diesel bus, removing the high upfront costs (BNEF, 2018). These supportive policies have been successful to push the market development, create advanced industry chains with a skilled labour force and achieve technological innovations and efficiency gains in the New Energy Bus technology sector. Additional policies are tax reductions and incentives to discourage the traditional buses with conventional combustion engines (Lumiao & Zhanhui, 2020). Moreover, in comparison with American and European cities where operators need to find ways to incorporate NEV technology into existing urban infrastructure, Chinese cities are building entirely new transit networks (BNEF, 2018).

By the end of 2019, more than 400 thousand New Energy Buses were operating in China. In 2018, the share of New Energy Buses (excluding hybrid buses) in the total bus fleet exceeded 50% in ten key regions and provinces for air pollution control and prevention (Beijing, Shanghai, Guangdong, among others). In the nine central provinces, the share of New Energy Buses has reached 40%, while in other provinces, the share has reached 30% (Lumiao & Zhanhui, 2020). At the end of 2017 the fleet of approximately seventeen thousand buses operating in Shenzhen was purely electric (Berlin, Zhang, & Chen, forthcoming). This figure represents a larger amount of e-buses than that of Europe and the Americas combined (IEA, 2020).

While Chinese cities, particularly Shenzhen, have several years of experience in e-buses deployment and fleet renewal, other cities are at relatively early stages (IEA, 2020). An increasing amount of large metropolises is pursuing policies to renovate their transit systems with EVs within the next decade, with full e-buses (battery, fuel cell hydrogen and trolleybus) and plug-in hybrid e-buses (VREF et al, 2019). In Latin America, e-buses are gaining traction. In Colombia, Medellín is integrating sixty-four buses to its BRT system (C40 Cities, ICCT, & Dalberg, 2020), and Bogotá expects 480 vehicles as part of Transmilenio (Graham & Courreges, 2020). Since 2019, Santiago de Chile has become the city with the largest fleet of e-buses outside China with more than 400 vehicles as part of its *Red Metropolitana de Movilidad* (RED), which account for 6% of the fleet. The city aims to electrify it entire bus fleet by 2035 (Galarza, 2020). In 2020, there were already more than 700 e-buses in the city. In both countries, governments are strongly committed to support the electrification of transit through private sector-led business models (Graham & Courreges, 2020).

The deployment of e-buses still faces some challenges regarding the technological and industrial know-how and the high upfront investment cost that these involve. E-buses are less flexible than standard buses, as they depend on different charging alternatives and cannot be incorporated in twenty-four-hour bus routes and there is not enough long-term experience regarding their operation on a commercial scale (BNEF, 2018). This generates doubts among private bus operators who are not familiar with their performance and are concerned about possible increases in electricity rates and demand charges of these vehicles, as well as the need of grid reinforcement and potential power outages due to extreme weather events. The charging infrastructure also requires space for the chargers in the bus depots or public bus stops. Moreover, the lack of standardisation of the charging infrastructure means additional investment when operators buy used e-buses with a different charging standard, which creates dependence on already established e-bus manufacturers (BNEF, 2018).

Programmes to promote new technologies with detailed information about vehicle performance are needed to solve doubts among private operators. Pilots with large bus operators are also recommended to start change for the rest of the market. However, experienced operators also have more advantage over smaller operators to transition towards e-buses, as they have the financial resources to ask manufacturers for bus testing for a long period of operation. Smaller operators will need more incentives to follow the transition of more experience operators (Hoyos Guerrero, Lopez Dodero, & Bianchi Alves, 2018).

This leads to one of the main challenges for the procurement of e-buses: the high upfront investment cost, which slows down the fleet renewal. These vehicles and associated charging infrastructure can still be two- to three-times more capital-intensive than standard diesel buses (Graham & Courreges, 2020). Therefore, many local governments do not have the necessary funds to cover these upfront costs, even with additional support from the central government, (BNEF, 2018). However, upfront capital cost of the assets (vehicle, battery and charging infrastructure) should not be the only focus for procurement of buses, as it has usually been (Graham & Courreges, 2020). E-buses provide potential savings from reduced energy costs per mile and offer a competitive total cost of ownership (TCO), which includes operation, maintenance and other indirect costs over the lifetime of the vehicle, that could be equal or even lower to that of conventional buses (Moon-Miklaucic, Maassen, Li, & Castellanos, 2019; Graham & Courreges, 2020). Because they require less maintenance, e-buses also reduce downtime (BNEF, 2018). These benefits represent an opportunity to attract private operators, especially in regions such as Latin America, where variables related to vehicle performance (fuel and maintenance) can make up over two-thirds of costs over the lifetime of conventional diesel buses (Hoyos Guerrero et al, 2018).

Battery costs and annual operating expenses of e-buses are falling, while their performance and reliability are rapidly improving. Manufacturers are producing lighter, more efficient buses with longer battery life, improvements in battery chemistry and energy storage management, faster charging infrastructure and more reliable performance backed by better warranties (Graham & Courreges, 2020; VREF et al., 2019). Moreover, the e-bus building industry is benefitting from the push towards EVs in the car industry, which is increasing demand for battery supply and improving battery density. BRT systems also optimise e-bus operation, as it can be planned based on the knowledge of mileage, lanes and travelled distances, which can lead to predict energy requirements on board (VREF et al., 2019).

Although TCOs may result more convenient, this is not always the main focus for municipalities when making a purchase decision (BNEF, 2018), while private bus operators who are not familiar with the performance can still see the transition to e-buses as a financial gamble (Hoyos Guerrero et al., 2018), especially when the current models allocate risks to the operators and fleet owners without the financial and technical capacity to absorb them (Graham & Courreges, 2020). This demands to change the procurement model of e-buses from outright purchase to leases payments that offer better risk allocation among stakeholders and involving third-party asset managers, who act as fleet providers (Graham & Courreges, 2020), to focus more on lower total cost of ownership. More flexible procurement enables manufacturers to offer operators the option to lease both vehicles and batteries, reducing technological and financial risks, while lease or loan repayments could be covered with operational cost savings (BNEF, 2018; Moon-Miklaucic et al., 2019).

The model of fleet leasing divides the ownership and operation, in which fleet providers finance, procure, own and maintain the EV-related infrastructure, and provide e-bus fleet to municipalities or private operators under long-term contracts. This concept has been a key component for the operation in other transport industries, and eliminates the upfront investment cost by either local governments or private operators (Graham & Courreges, 2020). In this way, asset managers take up the role as fleet providers and are paid to raise capital, procure e-buses at scale, and keep a reliable and well-charged fleet, while operators fulfil the role to provide bus service. At the same time, distribution of risk provides the opportunity to generate commercial interest from private capital. Therefore, the investment for the transition to zero-emission technology is shared and supported (Graham & Courreges, 2020).

This *unbundled* model, as referred to by Graham and Courreges (2020), also provides a reward between the public and private sector, and can also invite to more stakeholders that are not traditionally involved in transport operation, such as utility companies, which can act as purchasers of vehicles and batteries and lease them to bus operators. The aid of national governments can also support cities to afford the costs related to e-bus deployment (Moon-Miklaucic et al., 2019). This model and the current battery cost declines can incentive municipalities to start an early shift to plan in advance the necessary infrastructure upgrades to eventually support a fully electric bus fleet (BNEF, 2018).

To cover the direct costs of capital and operational expenses, as well as research and development, grants can be provided to reduce the burden on manufacturers and operators. The latter can access available credit guarantees by financial institutions from the public sector. Other financing sources are tax incentives in form of value-added, import, and corporate profit tax breaks (Moon-Miklaucic et al., 2019). Multilateral Development Banks (MDBs) can also provide funding sources for procurement. However, they traditionally focused on acquisition costs without considering additional costs during the lifetime of the vehicle and financial uncertainties related to operation and maintenance (Hoyos Guerrero et al, 2018).

E-bus procurement still faces critical challenges that need to be addressed before new business models that allocate risks and involves third parties are bankable and reach their full potential in emerging economies (Graham & Courreges, 2020). Capacity building is also needed to solve concerns from operators and to address governance and technical problems. It is also important to keep good transparency processes to mitigate corruption risks, while also allowing flexibility and adaptation to commercial practices (Hoyos Guerrero et al., 2018). Once again, e-bus deployment in cities contributes to decentralisation with local procurement practices. It is important to consider that in order to achieve the *true* electrification of transit and reduce carbon emissions, it is necessary to promote as well renewable energy instead of a fossil-fuel dominated grid and improve energy conservation and efficiency (Lumiao & Zhanhui, 2020). The roll-out of e-buses needs to be adapted to the context-specific challenges of each city in relation to the transit network size, ridership, level of sector privatisation and the disposal of funding streams apart from fare revenues (IEA, 2020). Furthermore, the successful promotion of e-buses also depends on the acceleration of the construction of charging infrastructure and increased overall system efficiency (Lumiao & Zhanhui, 2020).

6 Research questions for the study

6.1 General research questions

A diagnosis of the urban mobility situation, an analysis of successful case studies and lessons from policy implications are the first step to move towards a *Big Push for Sustainable Mobility* that impulses the Big Push for Sustainability in Latin America (Vasconcellos, 2019). After presenting the three main urban mobility challenges and the benefits of the introduction of sustainable public transport solutions (BRT, metro and e-buses) in compliance with the three dimensions of sustainability, the three selected solutions will be studied to answer the following three main research questions:

1. What are lessons with regard to **phasing in** new public transport solutions into existing and consolidated urban areas in the Global South in terms of governance and stakeholder management?

2. How to ensure the **accessibility**, **affordability** and **connectivity** of new means of transit in order to provide self-sufficient systems that benefit marginal, low-income citizens, although they may involve **high upfront investments**,?

3. How can industrial policy create **economic co-benefits** and thereby contribute to the success of these new transit systems, leveraging their potential for industrial development, technological learning, new business development and employment generation?

6.2 Specific question per public transport solution

For each specific urban mobility solution, critical detailed questions will be established as it follows.

6.2.1 BRT systems. Paired cases: Jakarta and Bogotá

Bogotá is the city that made the BRT system worldwide recognised and promoted its replication in different contexts, while Jakarta, one of the cities inspired by Bogota's Transmilenio, has implemented the largest BRT system in the world: Transjakarta. Both cities had to deal with vested interests, e.g. by local bus operators, while phasing in a new transit system within very dense and consolidated urban areas. Both case studies are strictly comparable.

1. How are BRT systems implemented within an existing urban fabric with all the vested interests?
2. How is the phasing-in achieved concerning the obstacles, important stakeholders, management of the affected parties, and physical impact in the city?
3. How cost effective is the BRT system and how did the government mobilise the high upfront investments? (When) did the system break even?
4. How is the BRT system self-sustained? Does it require subsidies? Are there other profit alternatives apart from the fare revenue (TOD policies such as property development and retail in stations)?
5. Are BRT tariffs affordable? Do low-income sectors and minorities (e.g. women) benefit from this service? Do routes reach the poor areas of the city? Is there a gender approach?
6. How successful is the BRT within the urban mobility system of the city (daily trips, impact in the modal split, reduction of private mobility, etc.)? Is it integrated to other transport modes (physically and tariff-wise)? How is the first- and last-mile connectivity?
7. Are there any co-benefits in terms of industrial development, technological learning, new business development and employment generation?
8. Has the BRT system contributed to the city's carbon and emission reductions?

6.2.2 Railway systems. Paired cases: Mexico City and Delhi

Mexico City Metro initiated operations fifty years ago and has the tenth highest ridership in the world, while Delhi Metro has the largest network and is by far the busiest one in India. The research focus will again be on the issue of phasing in an existing urban fabric with all the vested interests (as in the BRT case), but a second focus will be on co-benefits in terms of industrial learning and employment generation and TOD policies, because of the lessons that the Delhi case offers. Through the *Make-in-India* initiative, nearly 90% of the current stock of coaches deployed by the company in charge of building and operating the system, the Delhi Metro Rail Corporation (DMRC), is now produced in the country. Moreover, DMRC acquires a substantial part of its revenues from TOD policies, such as property development (housing and commerce) along the metro lines, as well as retail rental in the stations. How and at what cost was this achieved? Both case studies are strictly comparable with a focus on differences in industrial/ procurement policy.

1. How are metro systems implemented within an existing urban fabric with all the vested interests?
2. How do cities decide whether to contract international companies through open tenders or use the introduction to build national technological capabilities? In case of the latter, how do they manage to favour domestic providers, without compromising the possible inferior quality of the infrastructure and need for subsidies?
3. How do cities navigate this trade-off? How do they purchase the moving infrastructure (coaches, etc.), construction works, IT systems, and the overall planning of the system?
4. Are there technology-sharing, local content-requirements etc. involved? Do they have explicit industrial policy objectives, plans, roadmaps?
5. How is the metro system self-sustained? Does it require subsidies? Are there other profit alternatives apart from the fare revenue (TOD policies such as property development and retail in stations)?
6. How successful is the metro within the urban mobility system of the city (daily trips, impact in the modal split, reduction of private mobility, etc.)? Is it integrated to other transport modes (physically and tariff-wise)? How is the first- and last-mile connectivity?
7. Are metro tariffs affordable? Do low-income sectors and minorities (e.g. women) benefit from this service? Do routes reach the poor areas of the city? Is there a gender approach?
8. Has the metro system contributed to the city’s GHG emission reductions?

6.2.3 Introduction of e-buses. Paired cases: São Paulo and Shenzhen

The megacity of Shenzhen started the electrification of transit ten years ago and has become the first city with a fully electrified bus fleet. There are some studies showing why and how this huge electrification was achieved. China had big problems with urban air pollution and decided early to use the technology shift to urban mobility to build a globally competitive auto industry. It has deep pockets to provide subsidies and has invested in knowledge production to have strong capabilities in the EV industry, with a long-term stable policy environment. At first sight, this paid off in terms of competitive advantage (Chinese e-buses are dominating the world market), reduced air pollution and modern transport services. However, the whole system still depends on subsidies. More studies are needed to assess to what extent this early mover advantage will last once e-bus manufacturing and deployment becomes cost-competitive and globally established bus manufacturers enter the market. What lessons can Brazil learn from China? However, Chinese policies cannot be simply emulated, especially because Chinese e-bus companies are already operating in Brazil and other LAC countries, so the challenge is to collaborate with them while trying to build up domestic industrial capabilities. This involves challenges in terms of managing licenses, Chinese inward foreign direct investment (FDI) and technology sharing. Because of the greater advantage of Shenzhen over São Paulo, the comparability of the case studies will be established as lessons from Shenzhen for São Paulo.

1. How do cities achieve the electrification of their bus-fleet financially viable in view of high upfront costs?
2. How did the introduction of industrial policies contribute to China to become a leading exporter and manufacturer of electric buses? Will China’s current early mover advantage last for longer periods, or will it remain just as a temporary artificial subsidy-based boom?

3. What exactly defines the comparative advantage of the Chinese market (technical and industrial know-how, vehicle integration, system management, financial model)?

4. What can Brazil as a second mover do? How does/should it balance the trade-off between keeping bus operating costs and fares low and developing own technological capabilities? Can national bus companies catch up with the already established Chinese companies (BYD, Yutong, etc.), and what are the right policies to learn from and co-invest with these early movers while also building up capabilities for competing with them?

5. How do e-buses integrate within the urban mobility of the city (daily trips, impact in the modal split, reduction of private mobility, etc.)? Are they integrated to other transport modes (physically and tariff-wise)?

6. How is the bus fleet self-sustained? Does it require subsidies? Are there other profit alternatives apart from the fare revenue (TOD policies)?

7. What is the role of cities and local administration to achieve the electrification of their bus fleet? How can they prevent frauds and wrong allocation of subsidies?

7 Closing remarks

This report aimed to introduce the selected transit solutions within the context of sustainable urban mobility and within the framework of the Big Push for Sustainability in order to understand that transit solutions do not only involve the implementation of transport infrastructure, but they rather have implications on an metropolitan scale and with deep economic, social and environmental benefits.

The presented transit solutions can complement each other. E-buses can be used as part of the BRT fleet and feeder to trunk routes, BRT and metro can be part of the same urban transit network, while metro’s coverage area can be extended by a feeder fleet of e-buses. The phasing in of these solutions will need to respond to context-specific needs and benefit the groups in greater need, such a women, low-income sectors, the elderly, and people with especial needs. Their implementation needs to be integrated within the existing transit system, instead of acting as an isolated solution. To do this, mobility patterns and origin-destination travels of citizens must be studied.

It is essential to recognise the need to integrate transit solutions to the urban planning and development of the city to use their potential and benefits in complete harmony with the growth of urban areas. This requires collaboration between different planning entities and third parties that can act as stakeholders (civil society initiatives, the private sector and the academia). Political will is necessary to achieve a holistic development that recognises the importance of sustainable urban mobility. As a good reference, in October 2020, Mexico elevated the right to safe mobility as constitutional and declared it a universal human right (Hidalgo, 2020).

Although transit solutions are significant and necessary, it is also important to evaluate the hierarchy of measures of the A-S-I Framework. More Avoid measures are required, and not only Shift and Improve measures, in order to reduce the need for motorised trips, especially for citizens from low-income neighbourhoods. These measures should include changes in the land use and promotion of jobs and services in peripheral areas in favour of a more equal development for all. Finally, the current effects of the COVID-19 crisis have increased the social gap in Latin America, which remains as one of the most unequal regions in the world (ECLAC, 2020). Therefore, enhancement of the urban mobility towards a sustainable development is more essential than ever.

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