Research Paper

Towards public electric buses in Latin America

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Abstract

Emissions from the transportation sector generate over $ 1 trillion in health damage every year. The growth of that sector has also contributed to expanding greenhouse gas emissions associated with rising sea levels, temperatures, fires, and other impacts on climate change. Urban bus fleets are the primary way of urban mobility for hundreds of millions of citizens in Latin America. However, those fleets are still powered by diesel, an obsolete, and highly polluting technology. In order to tackle the challenges imposed on air quality and climate by diesel engines, cities must embrace an energy and technological transition. E-buses are an excellent solution for promoting cleaner and healthier urban areas while supporting local and national governments to achieve their climate goals. In this context, the expansion of e-bus fleets in Latin American cities is key to the economic and global future. This study aims to review the emerging trend of electric buses' deployment in Latin America within the general framework of the concept of sustainable mobility. The article develops an overview of electric bus technologies available on the Latin American market and a spatial analysis of fleet deployment in Latin America. The analysis of the spatial distribution of e-buses in Latin America indicated that, in terms of the number of vehicles in operation, Chile and Colombia are the regional leaders and Santiago and Bogota are the cities holding the largest electric buses' fleets. The study also indicates key factors to promote the technological transition and the electric buses' deployment in Latin America: regulatory framework, clear and objective strategic planning, cooperation between national and local administration. Moreover, the case study of São Paulo (the largest Brazilian city) highlighted the typical limiting factors: political and regulatory limitations, high battery costs and dependency on infrastructure. Plus, one and half year into the covid19 pandemic led the local public transit system to a critical crisis. Passengers remain at home or they remain fearful of boarding buses and are using alternative transport modes. Consequently, public transit fares have fallen off a cliff. That economic crisis is a new challenge to electric buses' deployment in Latin America. Finally, recommendations are presented to promote bus fleet replacement and to develop a comprehensive sustainable urban mobility strategy.

Keywords

E-buses, Electric buses, Urban bus fleets, Public Transport, Latin America

1. Introduction

Emissions from the transportation sector generate over $ 1 trillion in health damage every year. The sector growth has also contributed to expanding greenhouse gas emissions (GEEs) associated with rising sea levels, temperatures, fires, and other impacts on climate change. Urban bus fleets are the primary mode of urban mobility for hundreds of millions of citizens in Latin America. However, those fleets are still powered by diesel, an obsolete and highly polluting technology. Cities must embrace an energy and

technological transition to tackle air quality and climate challenges. E-buses are an excellent solution for promoting cleaner and healthier urban areas while supporting local and national governments to achieve their climate goals. In this context, the expansion of e-bus fleets in Latin American cities is key to the economic and global future.

This study aims to review the emerging trend of electric buses' deployment in Latin America within the general framework of sustainable mobility. The article also explores challenges São Paulo has faced to transition to urban bus electrification. Finally, the paper develops an overview of electric bus technologies available on the Latin American market and a georeferenced analysis of the fleet deployment.

In 2015, most Latin American countries ratified the Paris agreement – including Brazil and Mexico, the two largest emitters of carbon dioxide in the continent. The agreement lays the foundations to create more resilient communities and economies. It helps mobilize new investment in critical sectors such as clean energy transportation, for example. According to an Inter-American Development Bank analysis, Latin American cities must reach 100% carbon pollution-free transportation by 2050 to achieve their per capita emissions goals.

Responding to Climate Change and emissions to upholding the levels of heat-trapping greenhouse gases in the atmosphere, Latin America holds two competitive advantages concerning other regions of the planet. Firstly, there is a great demand for public transport - behind only China; approximately 85% live in urban centers. Secondly, more than 50% of the energy is made up of renewable sources - performing one of the cleanest energy matrices on the planet.

Following this introduction (as in Section 1), Section 2 presents the material and methods chosen for carrying out each part of the study. Sequentially, Section 3 presents findings and discussion from the sections as mentioned earlier, followed by an assessment evaluation concerning emerging e-bus fleet segments. Finally, Section 4 focuses on São Paulo's Case succeeded by the conclusions presented in Section 5.

2. Material and methods

This section describes methods applied to categorize the raw data into electric buses, evolution estimations, countries and cities currently running e-buses, and manufacturers that stand out in the Latin American scenario.

The main source database is the platform ebusradar.org, which monitors the expansion of electric uses in Latin American cities (Figure 1). The Sustainable Mobility Laboratory (LABMOB) runs the platform under the coordination of the authors. Besides, ebusradar.org counts on C40 Cities, the International Council on Clean Transportation, and the Institute of Energy and Environment (IEMA) partnership.

Figure 1. Countries with electric bus fleets. Source: LABMOB, 2021.

Besides, ebusradar.org georeference electric bus fleets in operation and quantify the CO2 emissions avoided. Whenever possible, as a plus-bonus analysis, the platform displays potential scenarios to prevent premature deaths by improving air quality if all buses go electric instead of running on diesel.

3. Findings and discussions

The Latin American transportation sector is one of the most significant contributors to CO2 emissions from energy consumption. It accounts for 35 percent of such emissions compared with a 24 percent share worldwide (C40 Cities, 2013). But then, several cities have tackled this reality by shifting their bus fleets to upgrade their transport systems and air quality.

Latin America is expected to play a more prominent role in the e-bus segment regarding investments and institutional arrangements over the past five years. Fuelled by public policy and declining battery costs, global electric bus adoption will triple by 2025. Forecast projects expect around 1.3 million e-buses globally by 2040 (Malkov et al., 2020); meanwhile, a predicted number for Latin America is that more than 5,000 vehicles will be rolling out by 2025.

Since then, the electric bus fleet in Latin America has risen exponentially. As of 2017, there were 724 trolleybuses and only seven battery-powered buses running in the entire continent. By 2021, the region scaled up to 2,473 electric buses – 1,573 of which were battery-powered buses and 900 trolleybuses.

3.1. Electric buses in Latin America

Currently (as of July 2021), the fleet of public electric buses in Latin America sums up 2,473 vehicles running. Out of this total, 900 are trolleybuses, and 1573 are powered-battery. Getting into more specific information, we categorized powered-battery vehicles by length and capacity:

- 326 midibuses (8 - 11m),
- 1224 conventional (Padron) buses (12 - 15 meters) and
- 3 articulated buses (> 18 meters).

When observing the evolution since 2017, it is noticeable that battery-powered vehicles outdid the previous prevailing of trolleybuses in fleets. In a 5-year period, as the trolleybus fleet grew by 25%, the battery-powered electric bus grew by 22,000%. In other words, in 2017, only 7 battery-powered buses

were running in Latin America. In contrast, currently, in 2021, the fleet calculates 1,573 vehicles running across the continent (Figure 2).

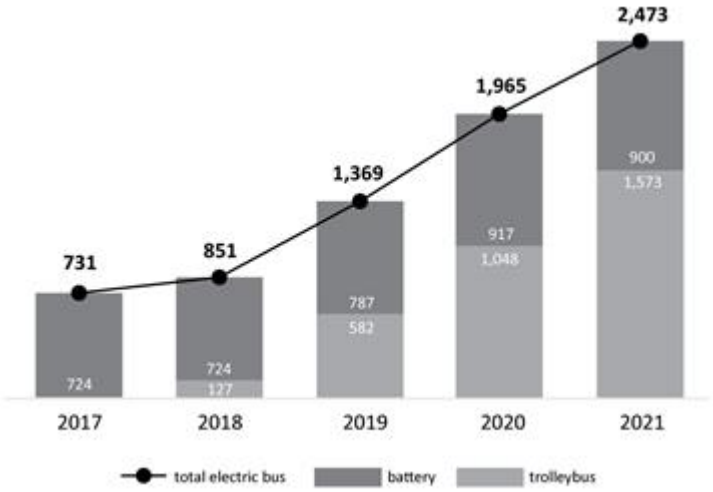

Figure 2. Total of electric buses: evolution. Source: LABMOB, 2021.

This inflection happens from 2019 onwards as technological advancements reach their peak and the manufacturers expand their portfolio. It is also worth mentioning the strengthening of a social-based ecosystem in tackling climate change. Directly, civil society organizations, funders, and city halls joined efforts to influence the electrification policy and expand credit financing lines to acquire e-buses.

3.2. Territorial distribution of electric buses

As mentioned earlier, the primary transportation trend in Latin American cities is to ban fossil-fueled public transport to widespread electrification as a feasible and crucial technology to transition. The distribution of electric buses among Latin American countries is quite uneven. Only five countries – Chile, Colombia, Mexico, Brazil, and Ecuador – concentrate 91% of vehicles (2,263 buses) (Figure 3).

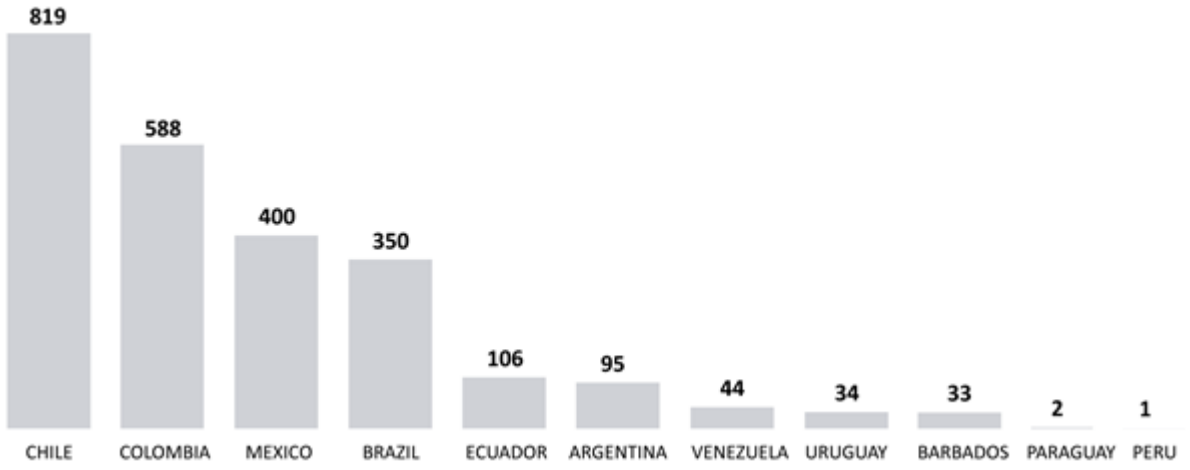

Figure 3. Bus fleet per country. Source: LABMOB, 2021.

Even though there was no substantial progress during the pandemic in 2020, it is clear that Chile is by far the leading Latin American country in deploying electric buses. Chile is home to 33% of electric buses in the continent, of which 819 are running most in Chile's capital Santiago (94%)(Figure 4). The remaining 6% are distributed onto three other cities: Valparaíso, La Reina, and Las Condes.

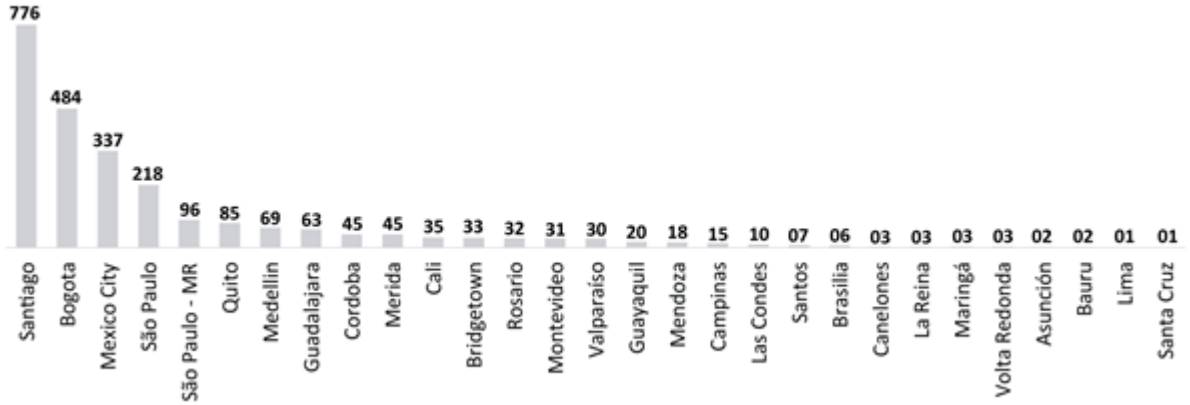

Figure 4. Bus fleet per city. Source: LABMOB, 2021.

Although Colombia hadn't been part of the top-ranking 5 countries with the largest fleets, still, it took a significant step towards electrification in 2021. Colombia's capital Bogotá now runs 484 electric buses, 58% of which are battery-powered Padron buses and 42% battery-powered midi buses. Considering the total fleet regardless of their energy sources, the share of electric vehicles represents only 5.38%. Furthermore, the city is supposed to acquire new vehicles soon. As a result, Colombian ambitions are to rank itself as one of the countries owning the largest electric bus fleets outside China. The introduction of 9 new buses in Cali has also contributed to Colombia's appearance in the 5 countries group with the largest fleets in Latin America.

In Mexico, the main variety from 2020 was embedding 38 new electric buses into Guadalajara's fleet. Even though 38 new e-buses denote only 1.22% of the fleet, they're running onto an all-electric BRT corridor - the first in Mexico. Yet, Mexico City reduced 7 battery-powered electric vehicles from its fleet.

Between 2020 and July 2021, no changes happened in the Brazilian electric fleet. On the other hand, there are currently progressing initiatives worth mentioning. For example, in Rio de Janeiro, a pilot is scheduled to run in 2021-2022. The pilot will assess the performance of three Padron vehicles from different manufacturers, in addition to collecting evidence on efficiency in terms of climate, topography, user demand, and infrastructure. The transition is one of the structuring actions of the "Carbon Neutral City" project, part of the Sustainable Development and Climate Action Plan of the City of Rio de Janeiro, launched in 2021. Rio is also one of the cities committed with C40 Cities to become Emissions Neutral by 2050 to deliver on their share of the Paris Agreement.

Another city that is carrying out a pilot to include electric buses into its fleet is Salvador, now in September 2021 (G1, 2021). Curitiba and São José dos Campos are about to kick off electric buses into their buses-only lanes more advanced than Rio and Salvador (Curitiba, 2020; Quatro Rodas, 2021). São José dos Campos stands out for expanding its fleet with 12 articulated buses (22m) thus December 2021. In Curitiba, 54 electric buses are planned, mixing Padron and articulated battery-powered vehicles. It is also worth adding that the state of Paraná is running the first national pilot test on an intercity scale, connecting the capital Curitiba to the city of Ponta Grossa by electric bus.

Until 2020, Argentina used to be ranked as the five Latin-American countries owning the largest fleet of electric buses. Yet, Argentina left this ranking due to removing battery-powered vehicles ran in Buenos Aires and 10 trolleybuses in Mendoza.

Regarding Ecuador, Santa Cruz Island included one battery-powered electric bus into its fleet. Thus, despite the shy progress, Ecuador is now the fifth country with the most electric-assisted buses in Latin America as of July 2021.

The fleet of electric vehicles in Bridgetown, the capital of Barbados, is equivalent to 11.66% of the city's total buses. Therefore, it is the most representative sample of all cities monitored by ebusradar.org, besides the largest fleet of electric buses in the Caribbean.

The evolution of the electric vehicle fleet in Latin America represented an approximate growth of 158% in emissions savings over the last five years (2017-2021). Therefore, it is estimated that the current number of vehicles avoids 254.7 kt of CO2 per year.

3.3. Manufacturers

The provision of zero-emission bus models has long been a barrier to expanding electric buses fleets in Latin American countries due to the scarcity of national manufacturers. To help reduce costs and overcome import taxes, the Chinese manufacturing company headquartered in Shenzhen BYD established its first Latin American factory in Campinas, Brazil. As a result, China has come to be a globally leading electric bus seller and has enhanced vehicular technologies through developing, upscaling, and cost reduction of electric batteries and drivetrains.

European manufacturers such as MAN and Volvo dominate the Latin American bus market with diesel bus technology. On the other hand, Chinese manufacturers such as BYD, Yutong, and Foton are the largest new electric bus products in Latin America (Figure 5). Increasing market competition and portfolio is key to widespread the number of vehicles in the systems. Along the way, e-buses manufacturers have drawn attention to adapting their vehicles to the Latin American market regulations, affecting economic evaluations in decision-making. Over the past years, technologies have been tested all over Latin America, and local supply has expanded in most markets.

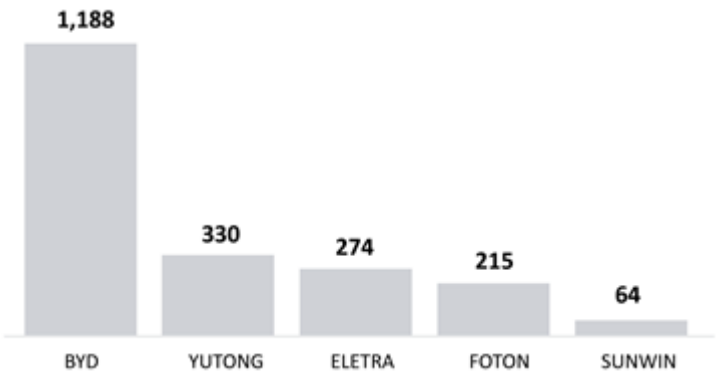

Figure 5. Top 5 Manufacturers responsible for the electric fleet in Latin America. Source: LABMOB, 2021.

BYD is the world's largest producer of full-size purely electric buses. It is also the world's largest manufacturer of rechargeable batteries. Considering active fleets in Latin America, BYD is responsible for 45% of electric vehicles in use. Comparatively, to 2020, the use of BYD vehicles grew 53% across the continent. Specifically, 81% of vehicles manufactured by BYD are in use in Santiago (Chile) and Bogotá (Colombia).

Besides, BYD provides 64 e-buses to Metroplús, Medellin's BRT system. In addition to Chile and Colombia, the vehicles traded are also running in Brazil, Ecuador, Costa Rica, Uruguay, and Argentina. In Brazil, BYD was a pioneer in manufacturing 100% battery-powered electric buses. In its country of origin, China, and in others where it operates, BYD usually offers complete vehicles with chassis and bodywork. Oppositely, BYD offers 100% electric bus chassis in the Brazilian market, as bodies remain in charge of local partners and manufacturers.

The largest trolleybus fleet in Latin America is in Mexico City, with 336 vehicles, 58% of which are manufactured by Yutong. In comparison, the second-largest fleet circulates in São Paulo, with all 201 vehicles. Electra produced the first entirely Brazilian trolleybuses in 1980. Currently, Electra operates exclusively within Brazil, with fleets spread in São Paulo and the metropolitan area. All Electra vehicles operating in Brazil are produced in its factory located in São Bernardo dos Campos, state of São Paulo.

In addition to trolleybuses, Yutong also delivers battery-powered vehicles to cities. Its fleet represents the second-largest among the manufacturers, with operations mapped in Mexico, Chile, Uruguay, and Colombia. Yutong is one of the most technologically advanced manufacturing based on medium and large-sized buses worldwide. It was responsible for creating a complete 5-meter – 25-meter bus line-up. To date, Yutong is the main trolley bus supplier in Mexico City.

Zhongtong has standardized a 7.8-meter bus model for Medellin and has approved e-buses for the Chilean market. Sunwin and Foton have participated in the bidding process in Bogotá and Medellin, Colombia. They are exploring the market but without any transactions yet.

4. São Paulo case

The city of São Paulo holds the third-largest urban bus fleet in the world - behind the Chinese cities of Beijing and Shenzhen. Currently, São Paulo has a fleet of 14 thousand urban buses. It carries an average of 10 million passengers per day, traveling 3 million kilometers daily (SPTrans, 2020). The bus fleet comprises diesel buses (14,160 buses), making up 98.48% of the total fleet. On the other hand, only 1.52% of the fleet consists of electric buses - 17 of which are battery-powered and 201 trolleybuses, as shown before.

Despite the small share of electric buses, the city of São Paulo still is the leading city running electric buses among Brazilian cities. Brazil has 247 electric buses plus that operate in additional seven cities (Bauru, Brasília, Campinas, Maringá, Salvador, Santos, São Paulo and Volta Redonda).

São Paulo also stands out on bus electrification policy. In 2018, the city passed and enacted its first Climate Law (Municipal Law 16,802) (São Paulo, 2018) to cut 50% of the emission of greenhouse gases down and 90% of particulate material in 20 years. According to the text law, to achieve the goals defined in this law, the city of São Paulo encourages the renewal of the urban bus fleet using electric vehicles.

It is the first Brazilian municipal civil mark with an adaptive perspective to electromobility. The law inflects the bus service concession process with clear goals for reducing pollutants between 10 and 20 years.

The law determines that the choice of alternative fuels and energy sources must always be made upon the advice of the municipal technical authorities. Always in the light of consistent scientific information, indicating the possibility of maximizing the reductions in fossil emissions throughout the entire life cycle of the fuel/energy to be used, within costs acceptable to the budget. Yet, the law prioritizes the expansion of the trolleybus fleet instead of battery-powered buses.

Therefore, São Paulo has been lately at the forefront when it comes to sustainable transportation in Brazil. Previously, the city had introduced Transportation Demand Management measures. A traffic restriction program allows vehicles whose license numbers end with certain digits to drive on particular weekdays. Although it helped the city reduce congestion, it didn't necessarily result in a modal shift as many households own more than one car, which makes many drivers deceive restrictions.

The process of speeding up bus electrification in São Paulo comes with the hope that a cleaner, faster, and trustful mode of transportation can shift the car-oriented city's travel behavior. Besides, congestion and traffic pricing might be considered in a medium-term period to fulfill São Paulo's goals on reducing CO2 emissions according to the Climate Law.

Given this context, we highlight five critical challenges for strengthening the electric bus ecosystem in São Paulo and Brazil.

First, challenges to consolidate electromobility-oriented policies must be overcome by bringing stakeholders together. A harmonic ecosystem can reconcile stakeholders' interests towards a collective, unique goal of making bus transportation cleaner.

Despite the Climate Law being ruled at a municipal level, a national electrification policy is needed to address more precise goals and strategies. Besides, a national electromobility policy can provide efficient instruments, such as financial and industrial incentives (especially to import components, such as batteries). Then, an electromobility national policy is crucial to boost electric buses and change travel behavior in São Paulo and other cities.

The second point is the high initial costs of acquiring e-buses and providing charging infrastructure. Fossil fuels are still subsidized mainly by the Brazilian government, constraining bidding processes from buying new buses. As bids prioritize the lowest cost to the detriment of newly-rare technologies, acquiring e-buses is seen as risky (especially for municipalities regardless of their size or GDP).

The consequence is the delay in the electrification process comparatively to North Global cities, for example. There is also a need to develop managing capabilities to address feasible and competitive business models when signing contract concessions with operations. Contract models and their governance are critical to the technological transition of urban buses.

The third point is the standard of concession contracts and governance that create obstacles to electrical transformation. As a result, there is a low incentive for technological innovation and user experience improvement. On the other hand, successful experiences indicate the advantages of operating models that assume the sharing of risks through public-private partnerships.

Currently, Brazilian contracts put mostly the private sector at risk on trading e-buses. Moreover, it leads to creating an ill-favored environment for private investors. Therefore, the solution recommended by benchmarking worldwide is to split purchase risks between different agents. For example, as city halls own e-buses and periodically enhance their technologies, other companies and agents could manage fleets and garages without having ownership charges.

The fourth point is the absence of an innovation and business environment that encourages diverse actors to enter the public electric transport ecosystem. A favorable environment must promote the entrance of new actors, such as energy companies. Besides, the lack of large-scale projects in the Brazilian context makes operators skeptical about electric fleets' financial sustainability and operationalization. Then, encouraging public-private partnerships enable a safer business environment, thus letting investors engage in the technological transition process towards electric buses in São Paulo and Brazil.

5. Conclusions

The spatial distribution of e-buses in Latin America points out that Chile and Colombia are the regional-leader countries, as Santiago and Bogota own the largest electric buses' fleets running nowadays.

The study also indicates critical factors to promote the technological transition and the electric buses' deployment in Latin America: regulatory framework, transparent and objective strategic planning, cooperation between national and local administration, public-private partnerships, etc.

The data indicate that among the electric bus categories considered in the study, the predominant ones are Padron e-buses, equivalent to 50% of the total fleet. The trolleybuses represent 36% of the total. In

addition, the 326 midi and 3 articulated vehicles complete the fleet of 2,473 in use in Latin American countries monitored by ebusradar.org Platform.

Chinese manufacturers are the most present in the technologies used in the current Latin fleet. They try to facilitate technological updates by reducing costs on electric appliances. Bus manufacturers are encouraged to draw attention to current regulations and adapt their products to the Latin American market directives, affecting economic evaluations of bus operations. BYD is the foremost manufacturer responsible for producing the most conventional battery-powered vehicles (12-15m) available in the continent's fleet. Trolleybuses are manufactured by different manufacturers, including Electra, Yutong, and others in Brazil, Mexico, Argentina, and Ecuador. Increasing market competition and product availability is critical to expanding the number of vehicles in the systems.

Moreover, the case study highlights why São Paulo stands out in the Brazilian electromobility context, despite political and regulatory limitations. This agenda can gain ground by developing a national policy to address more explicit goals and achievable transition horizons. Plus, one and half years into the covid19 pandemic led the local public transit system to an acute crisis. As a result, passengers remain at home or are fearful of boarding buses and are using alternative transport modes.

Consequently, public transit fares have fallen off a cliff. That economic crisis is a new challenge to electric buses' deployment in Latin America. Finally, recommendations are presented to promote a bus fleet replacement and develop a comprehensive sustainable urban mobility strategy.

Latin America has a promising market for electric buses. There have been significant advances to increase electric urban buses quantitatively. Innovative local initiatives that promote a favorable environment for the expansion of the transition to electrification - the case of Santiago and Bogotá - are also worth mentioning.

There are innovative initiatives for the transition to urban bus electrification in Latin America that have been successful. These initiatives certainly deserve public managers' attention. They are split into two main dimensions: (a) new regulations and (b) commercial models that can facilitate trading electric vehicles and establish financial and fiscal incentives to increase demand.

But despite these advances, the transition to urban bus electrification is still plodding in Latin America compared to China and Asia. Therefore, national governments must take the initiative and implement systemic policies that accelerate growth.

6. Acknowledges

This research has been developed by the Sustainable Mobility Laboratory (LABMOB), from the Federal University of Rio de Janeiro (UFRJ), in partnership with the Zero Emission Bus Rapid-Deployment Accelerator (ZEBRA), co-led by C40 Cities (C40) and the International Council on Clean Transportation (ICCT), counts on the collaboration of the Energy and Environment Institute (IEMA) and supports by the Climate and Society Institute (ICS).

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