



# The Technology Development Plan as a tool for the transition to electric buses in the city of Bogotá D.C.



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This case study is part of a three-part series that analyzes Bogotá's strategy as a Transformative Urban Mobility Initiative (TUMI) E-Bus Mission mentor city, based on an examination of the following aspects of electric buses: technological progress (including details of pilot tests, cycles, and routes); business models (considering innovations that have been widely implemented for managing the procurement of electric buses); and charging infrastructure (including a description of how infrastructure and charging energy were supplied, taking technical and regulatory aspects into account). The technology development plan that is the subject of this case study has been a key tool for achieving the goal of having, as of today, 1,485 electric buses in the city.

**ZEBRA:** The Zero Emission Bus Rapid-deployment Accelerator (ZEBRA) association works to accelerate the deployment of zero-emission buses in Latin American cities, with the ultimate aim of achieving climate goals, improving urban air quality, and raising the overall standard of public transport. ZEBRA is a partnership funded by the ClimateWorks Foundation, led by ICCT and C40 Cities, and supported by CMM-Chile and the World Resources Institute (WRI).

**TUMI E-Bus Mission:** The TUMI E-Bus Mission supports cities in their transition to electric bus deployment. We work closely with 20 Deep Dive Cities in Africa, Asia, and Latin America. National and regional core groups are working to expand our efforts through a network that will include more than 100 cities worldwide by 2022. By 2025, the TUMI E-Bus Mission will inspire and equip cities to acquire more than 100,000 e-buses, thereby reducing CO<sub>2</sub> emissions by more than 15 megatons.





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## INTRODUCTION

Colombia is a country of approximately 52 million people concentrated primarily in large cities, where 77.1% of the population lives.<sup>1</sup> This requires a substantial deployment of urban services, not only in terms of infrastructure for public services, education, and health, but also in terms of mobility. The capital of Colombia is Bogotá D.C., which had a population of approximately 7.2 million as of 2019.<sup>2</sup> Until the end of the 1990s, public transportation services in Bogotá D.C. were operated by private companies along routes designated by the local government, with no government control in terms of schedules, quality, or safety.


The city's public transit system underwent a major change in 1999, with the implementation of a mass transit system managed by a new administrative entity known as TransMilenio S.A. This new Integrated Public Transport System (*Sistema Integrado de Transporte Público*, or SITP) was planned in phases, starting with Phase I, in which exclusive lanes were dedicated on two major “trunk” roads for vehicles with a capacity of 160 passengers, operated by four companies. The system was expanded under Phase II to cover more trunk roads throughout the city and add three new operators. Phase III included the addition of buses with a capacity of 240 passengers and two more operators to the trunk system, and the integration of 13 additional companies in a complementary “zonal” system to operate vehicles capable of carrying 19, 40, 50, and 80 passengers.

These first three phases were characterized primarily by: (i) the unification of fare collection; (ii) the standardization of diesel buses in all of the vehicles in the system, which complied with Euro II, III, IV, and V emission standards; (iii) the standardization of vehicle models; (iv) the definition of schedules and routes; (v) centralized operation by the administrative entity, TransMilenio S.A.; and (vi) concessions with operators that were required to self-finance.

Between 2012 and 2018, based on lessons learned during the first 13 years of service—and on growing concerns about the environmental impact of diesel vehicles, alongside the emergence of new technologies such as natural gas-powered, hybrid, and battery-electric vehicles—TransMilenio S.A. developed

1 Departamento Administrativo Nacional de Estadística, “Serie nacional de población por área, para el periodo 2020-2070,” accessed November 28, 2023, <https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/proyecciones-de-poblacion>.

2 Departamento Administrativo Nacional de Estadística, “Información general: Bogotá,” revised August 30, 2019, [https://sitios.dane.gov.co/cnpv/#!/donde\\_estamos](https://sitios.dane.gov.co/cnpv/#!/donde_estamos).



a program called the Technology Development Plan (*Plan de Ascenso Tecnológico*, or PAT), which sought to evaluate these new technologies through standardized and unified procedures.

The PAT was adopted through Decree 477 of 2013, which described the PAT as “a tool for the environmental management of the Capital District, enabling the gradual replacement of traditional internal combustion technologies with zero- or low-emission technologies on the road, in a process led by the District Secretary of Mobility, District Secretary of Environment, and TransMilenio S.A. as the administrative entity for the SITP.”<sup>3</sup>

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<sup>3</sup> Observatorio Ambiental de Bogotá, “Decreto 477 de 2013 - Adopción del Plan de Ascenso Tecnológico para el Sistema Integrado de Transporte Público,” [https://oab.ambientebogota.gov.co/?post\\_type=dlm\\_download&p=3375](https://oab.ambientebogota.gov.co/?post_type=dlm_download&p=3375).

## **THE STRUCTURE OF THE TECHNOLOGY DEVELOPMENT PLAN (PAT)**

This section describes the scope and objectives of the PAT, and the tests and methods used to evaluate the various vehicle technologies.

### **GOAL OF THE TECHNOLOGY DEVELOPMENT PLAN**

As stated in Decree 477 of 2013, the goal of the PAT is “to improve air quality and reduce the effects of air pollution on public health in the city of Bogotá D.C. through the implementation of zero- or low-emission technologies on SITP routes by means of the future conversion of the fleet, the establishment of operating procedures, and monitoring and follow-up measures.”

### **ESSENTIAL ELEMENTS OF THE TECHNOLOGY DEVELOPMENT PLAN**

According to Decree 477 of 2013, the PAT seeks to pursue its objectives through research and innovation along specific lines of action. The PAT is summarized in Figure 1 below.<sup>4</sup>

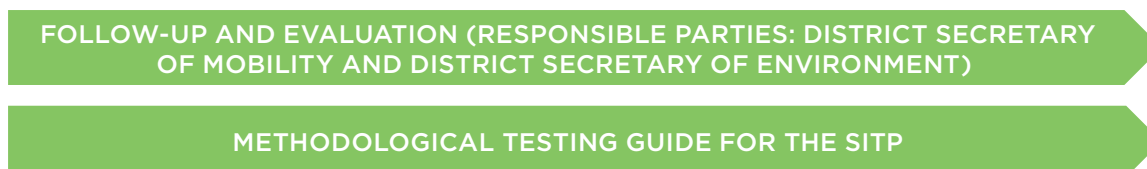
Coordination is carried out by three institutions in the city of Bogotá D.C. The duty of the District Secretary of Mobility is to direct and lead the formulation of policies for the transit system, in order to meet requirements for the movement of passengers and freight in the urban area. The District Secretary of Environment of the City of Bogotá D.C. is responsible for leading the formulation of environmental policies that promote the sustainable use of land and environmental resources, among other things. TransMilenio, for its part, is charged with the administration, organization, and planning of the urban mass transit service for passengers in the Capital District, serving as the manager of the SITP.

The coordination activities headed by these three institutions ensure that the PAT can be designed and implemented within the city’s regulatory framework, as each organization plays an authoritative role in a specific field (mobility, the environment, and management of the city’s mass transit system, respectively). Once the role of each institution is made clear, the implementation of the PAT ensures the achievement of its stated goals.

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<sup>4</sup> This figure was prepared by the authors, based on the contents of Decree 477 of 2013.

Coordinator	Goals / Aims	Methods	Lines of action
<ul style="list-style-type: none"> <li>• District Secretary of Mobility</li> <li>• District Secretary of Environment</li> <li>• TransMilenio S.A.</li> </ul>	<ul style="list-style-type: none"> <li>• Improved air quality</li> <li>• Implementation of zero- and low-emission technologies</li> <li>• Reduced energy consumption (National Resolution 18-0919 of 2010, Ministry of Mines and Energy)</li> </ul>	<ul style="list-style-type: none"> <li>• Future conversion of the fleet</li> <li>• Establishment of operating procedures and monitoring and follow-up measures</li> <li>• Management and coordination of an information database</li> </ul>	<ul style="list-style-type: none"> <li>• Bogotá city laboratory and testing ground for new transportation technologies</li> <li>• Green corridor for Carrera Séptima (Seventh Avenue)</li> <li>• Technological progress in the zonal system</li> <li>• Technological progress in the trunk system</li> </ul>




**Figure 1.** Structure of the Technology Development Plan (Decree 477 of 2013).

As noted above, the PAT aims to improve air quality and reduce the effects of air pollution on public health. As a goal, it seeks to reduce energy consumption, as stated in National Resolution 18-0919 of 2010, issued by the Ministry of Mines and Energy. Accordingly, the PAT specifies that a future conversion of the fleet to zero- and low-emission vehicles must be carried out, and defines associated operating procedures and monitoring and follow-up measures. All of this information must be recorded in a database that serves as a primary source for follow-up and control activities.

The PAT’s lines of action include several elements. The first consists of establishing Bogotá D.C. as a laboratory city. Two others focus on technological development in the zonal and trunk components of the system.

As a laboratory city, Bogotá D.C. has a methodological guide for the evaluation of zero- and low-emission vehicle technologies under the operational and functional conditions of Bogotá’s mass transit system, managed by TransMilenio. All associated information must be stored in a database that is available to the public and is managed by the coordinating team.



The two lines of action related to technological development in the trunk and zonal components share certain features, including: (i) the creation of pioneering routes; (ii) the evaluation of environmental and energy performance; (iii) the legal and financial evaluation of contracts; (iv) the incorporation of the fleet into the pioneering routes; (v) the replacement of used vehicles; (vi) performance evaluation and monitoring, (vii) the structuring of the clean mobility phase for the trunk system; and (viii) the development and execution of the relevant infrastructure.

In short, the structure of the PAT shows that there must be coordination between various institutions or authorities in the city to enable the implementation of plans to decarbonize the fleet of buses that operate within the mass transit system. With clear objectives, and the establishment of goals at the national level, Bogotá D.C. has succeeded under the PAT in developing methods for the technological conversion of the vehicles and has adopted operating procedures and monitoring and follow-up measures. Overall, such efforts highlight the need to: (i) develop methodological guidelines for the evaluation of zero- and low-emission vehicles; (ii) generate a database of relevant information that is available to the public; (iii) identify pioneering routes; (iv) establish clean transit strategies for trunk roads; and (v) implement an appropriate evaluation and monitoring program.



## THE PAT'S PATH TOWARD INCORPORATING ZERO-EMISSION VEHICLES INTO BOGOTÁ'S INTEGRATED PUBLIC TRANSPORT SYSTEM (SITP)

As of 2022, Bogotá D.C. had added 1,485 electric vehicles to its zonal system since beginning to introduce zero-emission vehicles into the fleet in 2020. This section describes the procedure that was developed to achieve that goal.

### CONCEPTUAL FOUNDATIONS OF THE METHODOLOGICAL GUIDE

As noted above, the PAT envisions the development of a methodological guide for testing zero- and low-emission technologies implemented within the SITP. This guide is part of the Bogotá D.C. city laboratory line of action. A summary of such tests appears in Figure 2 below.

<b>Short-term tests</b>	<ul style="list-style-type: none"><li>• Verify compliance with regulatory requirements and the environmental, operational, and energy-related performance of the technology under simulated load conditions.</li></ul>
<b>Long-term tests</b>	<ul style="list-style-type: none"><li>• Monitor the environmental, operational, and energy-related performance of the technology under normal and commercial operating conditions.</li></ul>
<b>Road tests</b>	<ul style="list-style-type: none"><li>• Verify the environmental and operating performance of a vehicle during a driving cycle and/or on a test circuit that is typical of the routes and/or services intended for operation in trunk or zonal areas.</li></ul>
<b>Dynamometer tests</b>	<ul style="list-style-type: none"><li>• Laboratory tests performed on a dynamometer, which must be programmed with the standard driving cycle for Bogotá.</li></ul>
<b>Monitoring and follow-up</b>	<ul style="list-style-type: none"><li>• Monitor the fleet's environmental performance, primarily in terms of emissions and energy efficiency.</li></ul>
<b>Initial acclimatization plan</b>	<ul style="list-style-type: none"><li>• Ensure optimization of energy consumption and minimize adverse environmental effects of the operation of the vehicle fleet.</li></ul>

**Figure 2.** Description of the types of tests provided for in the PAT.<sup>5</sup>

<sup>5</sup> Adapted from TransMilenio and the District Office for Environment, *Guía Metodológica para la Realización de Pruebas de Buses Con Tecnologías Limpias (Version 2.0)* (March 2021).

Short-term tests are more focused on regulatory requirements and on the environmental, operational, and energy-related performance of the technology under a simulated load. They include a group of operational tests, such as starting on hills, acceleration, braking, recovery, maneuverability, and handling. This category also includes a set of energy-efficiency and emissions tests, assessing such factors as energy consumption, performance, and efficiency while in transit, road emissions, noise and comfort, emissions inside the vehicle, and autonomy and energy regeneration while in transit.

All of the tests or trials envisioned by the PAT focus on the study of zero- and low-emission technologies, and on understanding needs for charging infrastructure, the optimization of routes and operating conditions, and strategies for adequately financing the fleets and determining the environmental and public-health benefits of the implementation of clean transport.

### **THE PATH TOWARD INCORPORATING A ZERO-EMISSION FLEET INTO BOGOTÁ'S SITP THROUGH THE PAT**

The road to the electrification of part of the mass transit system in Bogotá D.C. began in 2011, with tests performed within the scope of the Latin American Hybrid and Electric Testing Program.<sup>6</sup> In 2013, the PAT was formalized through Decree 477.<sup>7</sup>

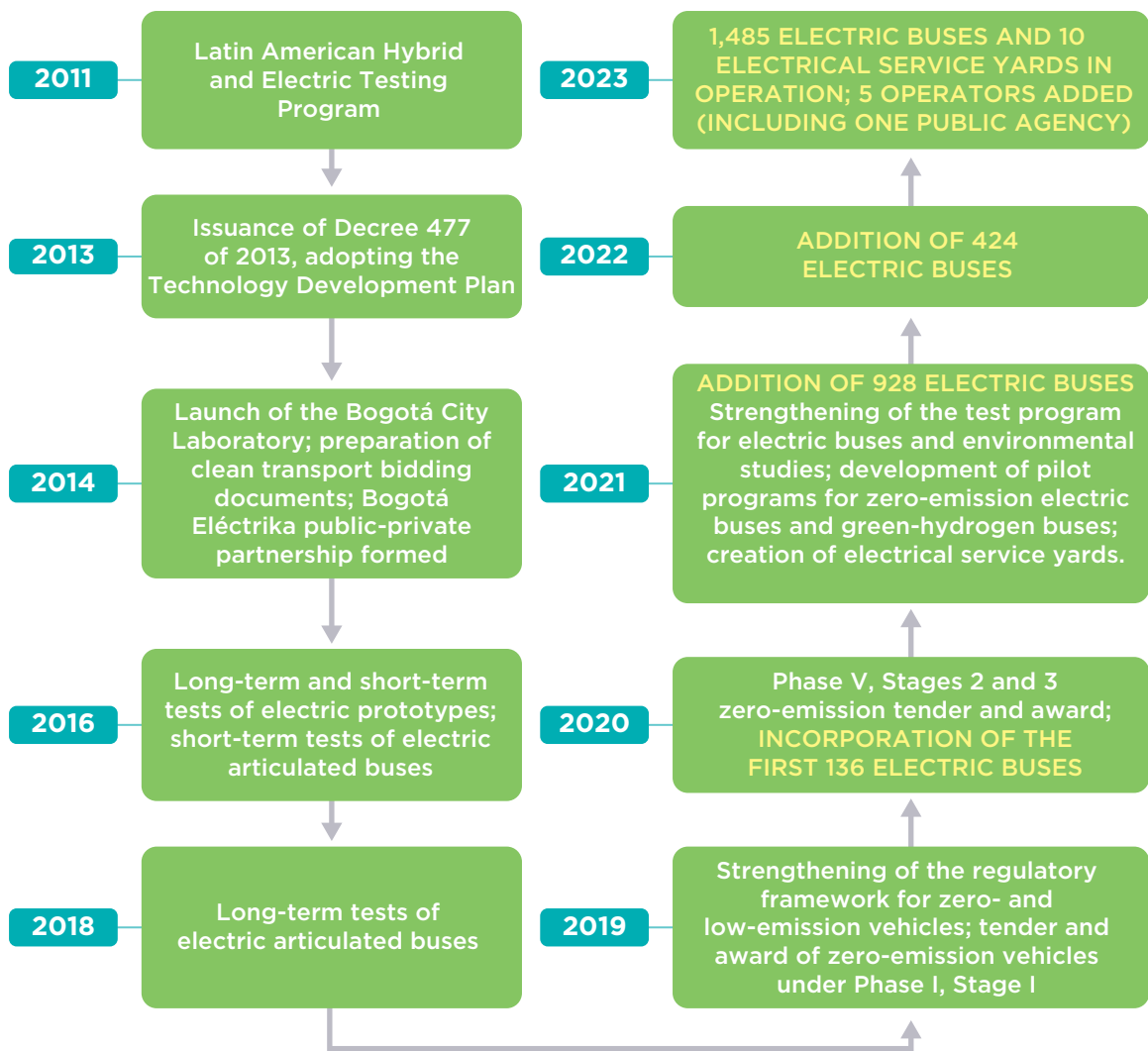
In 2014, the Bogotá D.C. city laboratory went into operation, as did 231 hybrid vehicles in the SITP. Work also began on the design of clean-transit bidding documents, and a public-private partnership called Bogotá Eléctrika was formed to supply electricity for the SITP. In 2016, short- and long-term tests were carried out on a prototype zero-emission vehicle equipped with electric batteries, and short-term tests were performed on a battery-electric articulated bus. Long-term tests of the battery-electric articulated bus were conducted in 2018. In 2019, the regulatory framework for zero- and low-emission vehicles was strengthened, and tenders were prepared for the Phase V, Stage 1 upgrade of the zero-emission zonal fleet. In 2020, bidding proceedings were begun for the Phase V, Stage 2 and 3 upgrades of the zonal fleet through zero- and low-emission tenders, and the SITP's electric fleet went into operation with the deployment of 136 buses.<sup>8</sup>

6 Néstor Roa, "La movilidad sostenible del futuro en las ciudades latinoamericanas," Inter-American Development Bank Movilblog, October 5, 2016, <https://blogs.iadb.org/transporte/es/4159/>.

7 Observatorio Ambiental de Bogotá, "Decreto 477 de 2013 - Adopción del Plan de Ascenso Tecnológico."

8 Mauro Mudu, "Aprendizajes de una Experiencia de Electrificación en el Transporte Público in Bogotá, Colombia" (LEDS LAC, August 2021), <https://www.ledslac.org/wp-content/uploads/2022/01/Caso-de-Estudio-Bogota-2021-09-FINAL-con-logos1-1-1.pdf>.

By 2021, a total of 928 battery-electric buses were incorporated into the zonal system; the electric-bus testing program and environmental studies were strengthened; pilot programs were established for zero-emission electric buses and green-hydrogen buses; and electrical service yards came into operation. Finally, by 2022, a further 424 electric buses were added to the zonal system. Figure 3 below shows this timeline, indicating key milestones that have been reached in the deployment of the zonal electric fleet in the Capital District.



**Figure 3.** The path toward incorporating a zero-emission fleet into Bogotá's SITP through the PAT.

## CONCLUDING REMARKS

Bogotá's success in deploying a zero-emission fleet for the SITP was based on the following factors:

- Bogotá D.C. enjoyed initial support through international cooperation for the launch of pilot programs with low-emission vehicles, and for the financial structuring of possible models for use in bidding proceedings.
- The PAT, proposed by the administrative entity TransMilenio S.A., became a tool with regulatory force for the implementation of zero-emission technologies.
- The PAT defined coordination among the various transportation and environmental authorities in Bogotá D.C., and made the city a laboratory to encourage technological development in both the trunk and zonal transit systems.
- The goals set out in the PAT included improving air quality, reducing the effects of transportation on public health, and reducing energy consumption, corresponding with goals defined at the national level by the Ministry of Mines and Energy.
- The PAT made it possible to structure the bidding proceedings for zero-emission fleets for Phase V (Stages 1, 2, and 3) of the SITP, and to generate inputs for the regulatory frameworks governing those fleets.

## CONTACT

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