

# Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City

---

# 2020

A photograph showing several people boarding a green and white bus. The bus has "ALCALDIA DE PANAMA" and a coat of arms on its side. The image is overlaid with a blue semi-transparent filter.

## **Deliverable 3.3 Sustainable Public Transport Mobility Plan**

Prepared for the United Nations  
Industrial Development Organization  
and the Climate Technology Centre  
& Network



This document was commissioned to LOGIOS, LLC by the CTCN via the United Nations Industrial Development Organization (UNIDO), as part of contract 3000057328. Research, interviews, data collection, analysis, and documentation under this project were conducted by LOGIOS, LLC. Reference herein, direct or indirect, to any specific commercial product or service does not necessarily constitute or imply its endorsement by LOGIOS, UNIDO, or CTCN.

LOGIOS, LLC is a company dedicated to clean energy innovation, integration and implementation ([www.logios.global](http://www.logios.global)).

Cover photograph: Electric bus in Casco Viejo, Panama City, Panama (2018). © LOGIOS.

(Page intentionally left blank.)

## Acknowledgments

The work documented in this report would not have been possible without the invaluable assistance of many stakeholders in Panama, including the Ministerio de Ambiente (MiAmbiente), the Secretaría de Energía, Transporte Masivo de Panamá (MiBus), Alcaldía de Panamá, and others. The continued and diligent assistance of Mr. Ramiro Salinas Revollo and Mr. Federico Villatico, with the Climate Technology Centre & Network (CTCN), is greatly appreciated.

(Page intentionally left blank.)

# Table of Contents

<b>LIST OF FIGURES</b> .....	<b>8</b>
<b>LIST OF TABLES</b> .....	<b>10</b>
<b>EXECUTIVE SUMMARY</b> .....	<b>12</b>
<b>INTRODUCTION</b> .....	<b>12</b>
<b>RISK MANAGEMENT APPROACH</b> .....	<b>12</b>
FINANCIAL RISKS .....	13
RELIABILITY RISKS .....	13
ENVIRONMENTAL PERFORMANCE RISKS.....	14
RISK AND PERFORMANCE METRICS.....	14
<b>OVERALL PLAN FOR BUS ROUTE ELECTRIFICATION</b> .....	<b>14</b>
CRITICAL CONCEPTS TO APPROACH FURTHER BUS ROUTE ELECTRIFICATION.....	15
PHASE 1: INITIAL DEPLOYMENT OF ELECTRIC BUSES .....	16
PHASE 2: REPLACEMENT OF RETIRING BUSES WITH ELECTRIC BUSES .....	17
BUS ROUTE PLANNING .....	20
<b>ELECTRICITY SUPPLY ANALYSIS</b> .....	<b>21</b>
<b>APPROACHING CHANGE</b> .....	<b>22</b>
<b>1. INTRODUCTION</b> .....	<b>23</b>
1.1 BACKGROUND .....	25
1.2 PLAN ORGANIZATION .....	26
<b>2. RISK MANAGEMENT APPROACH</b> .....	<b>26</b>
2.1 FINANCIAL RISKS .....	28
2.2 RELIABILITY RISKS .....	29
2.3 ENVIRONMENTAL PERFORMANCE RISKS .....	31
2.4 RISK AND PERFORMANCE METRICS .....	31
2.5 RISK TOLERANCE MAPPING.....	34
<b>3. OVERALL PLAN FOR BUS ROUTE ELECTRIFICATION</b> .....	<b>39</b>
3.1 CRITICAL CONCEPTS TO APPROACH FURTHER BUS ROUTE ELECTRIFICATION.....	39
THE USE OF A SYSTEMS APPROACH.....	40
THINK IN TERMS OF TRANSFORMATION — NOT JUST INNOVATION.....	40
TO FOSTER A ZERO-EMISSION CULTURE — EMBRACE NEW WAYS OF DOING THINGS .....	40
CREATE A MIBUS ZERO-EMISSION LAB.....	40
EMPOWER A MIBUS ELECTRIC BUS CHAMPION .....	41
<b>3.2 PHASE 1: INITIAL DEPLOYMENT OF ELECTRIC BUSES</b> .....	<b>41</b>
FOCUS ON LEARNING AND EXPERIMENTATION .....	51

3.3	PHASE 2: REPLACEMENT OF RETIRING BUSES WITH ELECTRIC BUSES .....	53
3.4	FLEET TRANSITION SCENARIOS .....	60
3.5	BUS ROUTE PLANNING.....	61
<b>4.</b>	<b><u>ELECTRICITY SUPPLY ANALYSIS.....</u></b>	<b>64</b>
4.1	ELECTRICITY SUPPLY COSTS.....	64
	IMPLICATIONS OF BUS DEPLOYMENT CHOICES ON ELECTRICITY DEMAND .....	64
	EVALUATING AND FORECASTING ELECTRICITY SUPPLY OPTIONS .....	65
	INTEGRATED ANALYSIS OF ELECTRICITY DEMAND AND SUPPLY.....	67
<b>4.2</b>	<b>UTILITY ENGAGEMENT .....</b>	<b>68</b>
	BENEFITS .....	68
	UTILITY MOTIVATIONS FOR STRATEGIC PARTNERSHIPS .....	69
	DEVELOPING A PRODUCTIVE UTILITY ENGAGEMENT STRATEGY .....	70
<b>5.</b>	<b><u>ELECTRIC BUSES AS PART OF AN INTEGRATED PLAN FOR SUSTAINABLE MOBILITY</u></b>	<b><u>71</u></b>
5.1	A NEW ERA.....	71
5.2	MONITORING AND EVALUATION.....	71
5.3	FINANCING .....	74
5.4	INTERMODAL INFRASTRUCTURE AND LAST MILE TRANSPORT SOLUTIONS .....	77
5.5	ACCESSIBILITY AND PRICING POLICY .....	84
5.6	TRANSPORT WITH GENDER PERSPECTIVE .....	88
5.7	NEW TECHNOLOGY FOR NEW USER REQUIREMENTS.....	89
5.8	APPROACHING CHANGE.....	90

## List of Figures

FIGURE 1. TEST ELECTRIC BUS AVAILABILITY AGAINST MILES OF OPERATION DURING TEST PERIOD (DATA SOURCE: NREL) .....	30
FIGURE 2. CANDIDATE ROUTES FOR THE INITIAL DEPLOYMENT OF ELECTRIC BUSES. (SOURCE: LOGIOS) .....	42
FIGURE 3. ROUTE C850, SELECTED BY MIBUS FOR THE INITIAL DEPLOYMENT OF ELECTRIC BUSES. (SOURCE: LOGIOS) .....	42
FIGURE 4. ROUTE C888, SELECTED BY MIBUS FOR THE INITIAL DEPLOYMENT OF ELECTRIC BUSES. (SOURCE: LOGIOS) .....	43
FIGURE 5. ROUTE C898, SELECTED BY MIBUS FOR THE INITIAL DEPLOYMENT OF ELECTRIC BUSES. (SOURCE: LOGIOS) .....	43
FIGURE 6. ROUTE C938, SELECTED BY MIBUS FOR THE INITIAL DEPLOYMENT OF ELECTRIC BUSES. (SOURCE: LOGIOS) .....	44
FIGURE 7. ROUTE C968, SELECTED BY MIBUS FOR THE INITIAL DEPLOYMENT OF ELECTRIC BUSES. (SOURCE: LOGIOS) .....	44
FIGURE 8. ROUTE C982, SELECTED BY MIBUS FOR THE INITIAL DEPLOYMENT OF ELECTRIC BUSES. (SOURCE: LOGIOS) .....	45
FIGURE 9. ROUTES E489-I AND E489-R, SELECTED BY MIBUS FOR THE INITIAL DEPLOYMENT OF ELECTRIC BUSES. (SOURCE: LOGIOS) .....	45
FIGURE 10. HISTOGRAM OF TOTAL KILOMETERS LOGGED TO THE ENTIRE FLEET OF MIBUS (DATA SOURCE: MIBUS) .....	53
FIGURE 11. HISTOGRAM OF TOTAL KILOMETERS LOGGED TO THE GRAN VIALE FLEET OF MIBUS (DATA SOURCE: MIBUS) .....	54
FIGURE 12. CUMULATIVE DISTRIBUTION OF TOTAL KILOMETERS LOGGED TO THE GRAN VIALE FLEET OF MIBUS (DATA SOURCE: MIBUS) .....	54
FIGURE 13. HISTOGRAM OF TOTAL KILOMETERS LOGGED TO THE TORINO FLEET OF MIBUS (DATA SOURCE: MIBUS) .....	55
FIGURE 14. CUMULATIVE DISTRIBUTION OF TOTAL KILOMETERS LOGGED TO THE TORINO FLEET OF MIBUS (DATA SOURCE: MIBUS) .....	55
FIGURE 15. NUMBER OF UNITS REACHING THE RETIREMENT OR OVERHAUL LIMIT PER SEMESTER, UNDER CURRENT DISTRIBUTION OF ANNUAL MILEAGE .....	56
FIGURE 16. NUMBER OF UNITS REACHING THE RETIREMENT OR OVERHAUL LIMIT PER SEMESTER, ASSUMING HOMOGENIZATIONS OF ANNUAL MILEAGE .....	57
FIGURE 17. COUNT (COLUMNS) AND CUMULATIVE (CIRCLES) DISTRIBUTION OF VEHICLES SCHEDULED FOR RETIREMENT .....	57
FIGURE 18. NUMBER OF UNITS SCHEDULED FOR RETIREMENT (COLUMNS), FRACTION OF THE FLEET SCHEDULED FOR RETIREMENT, AND FRACTION OF THE FLEET THAT COULD TURN ELECTRIC ASSUMING A LOGISTIC PROGRESSION .....	58
FIGURE 19. POSSIBLE PROGRESSION OF NUMBERS OF ELECTRIC BUSES INTEGRATED IN THE FLEET AND OF NUMBERS OF UNITS OVERHAULED .....	60
FIGURE 20. SIMPLIFIED DECISION CHART FOR THE SELECTION OF BUS ROUTES FOR ELECTRIC BUS DEPLOYMENT .....	63

FIGURE 21. THE “DUCK CURVE” (IMAGE SOURCE: CALIFORNIA INDEPENDENT SYSTEM OPERATOR)..... 66

FIGURE 22. SAMPLE OF SUPPLY AND DEMAND VARIABLES TO INCLUDE IN OPTIMIZATION PROBLEM FOR INTEGRATED ANALYSIS (IMAGE: LOGIOS) ..... 68

FIGURE 23. PERSONAL VEHICLES SALES IN PANAMA (SOURCE: INTERNATIONAL ORGANIZATION OF MOTOR VEHICLE MANUFACTURERS) ..... 74

FIGURE 24. PERSONAL VEHICLES IN USE IN PANAMA (SOURCE: INTERNATIONAL ORGANIZATION OF MOTOR VEHICLE MANUFACTURERS) ..... 74

FIGURE 25. CLASSICAL STRUCTURE OF A TWO-LANE BRT (SOURCE: NACTO, 2018) ..... 79

FIGURE 27. APPROXIMATE COVERAGE OF ROUTE C938 (SOURCE: LOGIOS) ..... 85

## List of Tables

TABLE 1. EXAMPLE PERFORMANCE METRICS MATRIX.....	33
TABLE 2. SAMPLE OF COMMERCIAL ELECTRIC BUS MODELS (SOURCE: LOGIOS RESEARCH)..	34
TABLE 3. ROUTES SCHEDULED FOR INITIAL DEPLOYMENT OF ELECTRIC BUSES, TRIPS SERVED AND DAILY DISTANCES. ....	46
TABLE 4. REPORTED RESULTS OF TESTS OF ELECTRIC BUS K9-FE, BY ROUTE.....	51

(Page intentionally left blank.)

## Executive Summary

---

### Introduction

This document lays out a high-level sustainable mobility plan for public transport in Panama City. The National Strategy for Electric Mobility (NSEM) set the following goal for public transport fleets: 15 to 35 percent of the buses in fleets under concession will be electric by 2030. These figures are meant as minimum aspirations – a public transportation system in which, 10 years from now, 17 out of 20 buses remain carbon intensive, would not be representative of Panama City true potential to move toward sustainable transportation. A solid and consistent plan, geared toward attracting investments in clean transportation systems, providing zero-emission technologies with a leveled competitive field that accounts for externalities, combined with sustained technology innovation can put Panama City into a steeper pathway of transformation.

While the emphasis of this technical assistance is on the technology transformation of the fleet of Transporte Masivo de Panamá, MiBus, a sustainable public transport plan should clearly have a broader focus. A central premise is then that starting to move MiBus's fleet in the direction of zero emissions, however necessary, is only one step in the journey of Panama's transportation system toward sustainability. Furthermore, consistent with the 2030 Agenda for Sustainable Development, a true quest for sustainability requires progress along multiple, interrelated dimensions.

### Risk Management Approach

In the transport sector, disruptive technologies are creating opportunities for transformative business models and new mobility choices. Innovation is critical to organizations such as MiBus, and urban centers such as Panama City, to remain competitive. Innovation has associated risks and the technology transformation of a transit fleet is no exception. Management must embrace the possibility of technology/experiment failure, increase risk tolerance, and adopt a longer-term stance on success.

The risk management discussion included here focuses on three broad categories: financial risks, reliability risks, and environmental performance risks.

## Financial risks

The risks associated with expenditures involved in the integration of electric buses to a transit fleet were discussed in a separate report.<sup>1</sup> The relationship between driving cycle and efficiency and economics is particularly important for all-electric vehicles, including heavy duty vehicles such as transit buses. The choice of route and driver behavior are important factors to improve efficiency and economics of electric bus operation. Training drivers to adjust driving behavior to maximize efficiency is critical to increase financial returns on electric bus investment.

A risk associated with the integration of new advanced technologies is that products and components can be modified and even dropped from production. This should be accounted for in the procurement contracts that MiBus signs with suppliers. How to internalize these risks should be matter of discussion between MiBus and the broader set of stakeholders.

## Reliability risks

MiBus should identify the risks associated with the reliability of vehicle performance, electricity supply vis-à-vis alternatives, and resilience to extreme weather events. It is expected that electric vehicle platforms will have lower maintenance events. This is certainly the expectation, as the technology further evolves into maturity. While there may still be some perceived risk of the reliability electric bus drivetrain and energy storage systems, methodic tests in fleets in service operation have shown that these systems can perform reliably.

Availability is defined as the ratio of the number of days that the unit is available for pull-out to the number of days that it was planned for operation. A typical level of availability adopted by transit agencies is 85%. On service data for electric buses at Foothill Transit shows that all buses were available at least 85% of the time, with an average availability of 93%.

---

<sup>1</sup> LOGIOS (2019) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 2.3 <https://www.ctc-n.org/technical-assistance/projects/accelerating-transition-sustainable-mobility-and-low-carbon-emissions>

## Environmental performance risks

While battery electric buses, by definition, will eliminate mobile emissions and thus will improve the quality of urban air, the climate benefits of battery electric buses will be dependent predominantly on the carbon intensity of the electricity they consume and the strategies adopted to integrate their charging with renewable sources of energy. An analysis of the range of emission reductions that are expected over the multi-year period of battery electric bus deployments was included in a separate report of this technical assistance.<sup>2</sup>

## Risk and performance metrics

The implementation of a risk management framework, particularly risk governance and measurement, needs clear metrics. These metrics would establish the criteria to evaluate the overall performance of battery electric buses and the boundaries of what are considered acceptable risks during all stages of their deployment. Given the systemic nature of the innovation process that MiBus would undergo, metrics should be holistic. In other words, MiBus should consider establishing metrics that consider a variety of factors in addition to technology performance.

## Overall Plan for Bus Route Electrification

One of the goals proposed in the Panama National Strategy of Electric Mobility is technology transition for public transport bus fleets, such that 15% - 35% of the units in concession-based operations be electric buses by 2030. Prospective directions for the progressive electrification of MiBus's routes are described, aiming at *higher* penetrations than those proposed in the National Strategy.

---

<sup>2</sup> LOGIOS (2019) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 2.2. <https://www.ctc-n.org/content/d22report-recommendation-most-appropriate-technology-panama>

## Critical concepts to approach further bus route electrification

### *The use of a systems approach*

Integrating battery electric buses into MiBus's fleet requires a stronger integration of the processes of planning, procurement, implementation, operations, and management. These processes and related decisions affect and depend on each other.

### *Think in terms of transformation – not just innovation*

It is critical for MiBus's management to recognize that battery electric buses represent a new paradigm. Innovation processes are not mere substitutions of technologies — they require institutional and behavioral change as well.

### *To foster a zero-emission culture – embrace new ways of doing things*

MiBus should recognize and embrace the need to do things differently. This may include route assignment, driving behavior, risk management, and other practices in the organization. Building a zero-emission culture can be important; successful transformations need also support from the bottom up.

### *Create a MiBus zero-emission lab*

MiBus is, in many ways, blazing trail. While a number of cities in Latin America have started integrating battery electric buses, MiBus will face some unique challenges. A low-risk electrification process must be built upon the foundation of solid information about interconnected elements, such as bus performance, charging strategies, electricity and power access rates, cultural changes, and so forth.

To acquire this information, there is no real alternative to analysis and experimentation. MiBus should consider implementing a zero-emission lab for the testing of ideas.

### *Empower a MiBus electric bus champion*

Institutional change can be greatly facilitated by champions; examples abound in the history of electric transportation policy. MiBus should consider designating a motivated person to lead the internal coordination and identify and address obstacles to electric bus integration.

## Phase 1: Initial deployment of electric buses

For the first phase of deployment, Panama is planning a procurement of a number of electric buses, to be assigned prospectively to routes C850, C888, C898, C938, C968, and E489, which are currently served by 46 conventional diesel Euro III buses. Figure ES 1 shows the geographical distribution of these routes. The number of electric buses in the first deployment cohort was still undetermined at the time of this writing, although there was a tentative floor of 35 units. It was estimated that this base cohort would be composed of smaller 9-meter buses that would complement, not replace, diesel buses currently in service. There are no clear plans for further deployments beyond this initial one. This report in part serves as guidance in this respect.



Figure ES 1. Candidate routes for the initial deployment of electric buses. (Source: LOGIOS)

The first stage of deployments should focus on learning and experimentation. As part of the present technical assistance, MiBus is receiving detailed technical evaluations of the performance of generic electric buses of different charging technologies, for operational conditions specific to the routes selected by MiBus. Regardless, the tender for the buses should include clear requirements of information relative to performance of the particular models being offered. The validation of this information should be part of the evaluation program. MiBus should establish

data collection procedures that are accurate and independent of the supplier, in order to avoid potential conflicts of interest.

While MiBus has already decided the routes for initial deployment, it has not yet decided on the *portfolio of technologies* that may be best suited to serve these routes. A separate report is concerned with a technical evaluation of routes and technology, intended to support MiBus's decision making in this area. The selection of bus technology, particularly the charging technology, will have direct and profound implications on the planning and deployment process.

## Phase 2: Replacement of retiring buses with electric buses

MiBus started operations in the year 2010 with a fleet of buses Volvo/Gran Viale diesel Euro III. This fleet includes 2,136 units in service today. The distribution of kilometers traveled by buses in the entire fleet is shown in Figure ES 2.

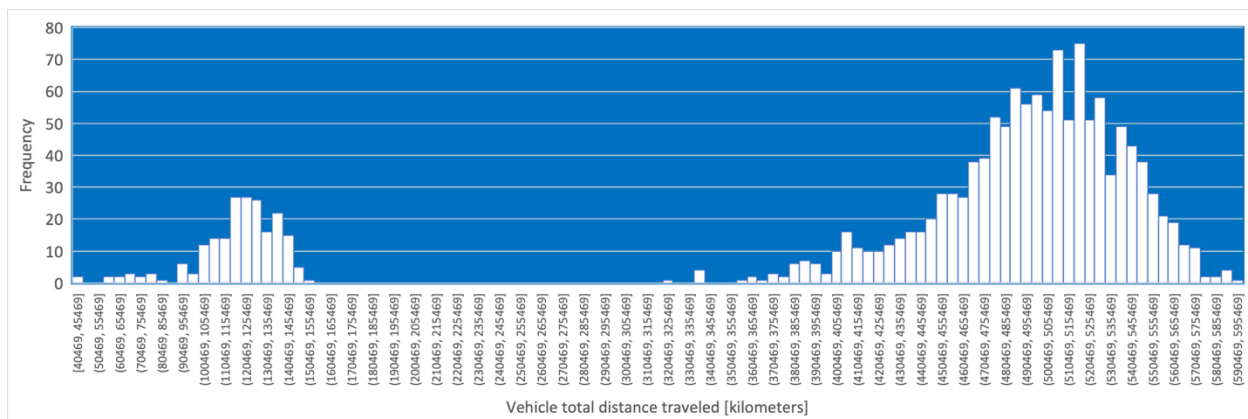


Figure ES 2. Histogram of total kilometers logged to the entire fleet of MiBus (data source: MiBus).

The mileage of the Gran Viale fleet, based on last data received for this analysis, had a geometric mean of 494,233 kilometers, with a standard deviation of 43,417 kilometers. The geometric mean of the mileage of the Torino stands, based on latest data, at 117,121 kilometers, with a standard deviation of 20,191 kilometers.

MiBus generally uses a vehicle useful life reference of 650,000 miles. At that point, MiBus faces the decision of retiring the unit or performing a complete overhaul. Figure ES 3 shows that MiBus is facing a steep fleet renovation schedule, with a peak of 250 units in the fifth semester. As the

semester count starts with the second semester of 2020, this peak is fast approaching and scheduled to happen in mid 2022.

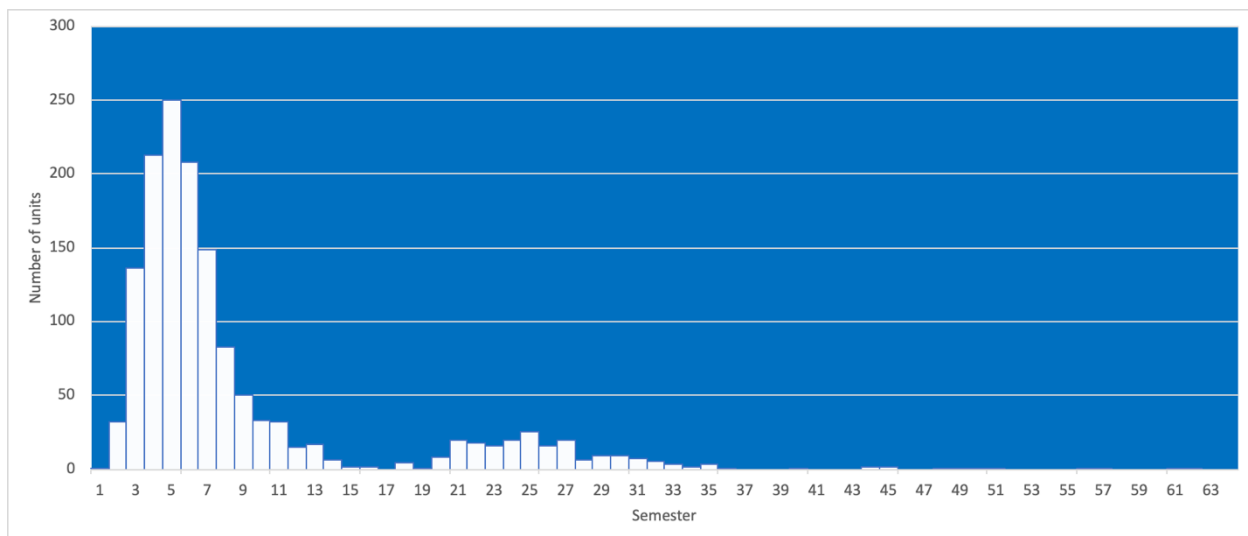


Figure ES 3. Number of units reaching the retirement or overhaul limit per semester, under current distribution of annual mileage.

While slight further adjustments could be planned, the overall conclusion from these data is that it is late for MiBus to plan a gradual transition of all retiring vehicles to zero-emission units. Panama is thus confronted with a decision about the schedule of technology transformation for its public transport fleet. The central question facing Panama is: *How many of the buses reaching retirement age could be replaced with electric buses?* To support Panama on its decision-making process, a fleet renovation strategy is considered below.

An electric bus procurement schedule could be approximated by a mathematical function, which could be used to support decisions by MiBus and the government of Panama. Typically, and based on historical cases, mathematical functions could be logarithmic, inverse exponential, and logistic. Logistic functions (S-shaped) are better at incorporating early stages with slower rates of adoption. In view of the timelines facing MiBus, it is more productive to focus the analysis in the short- to medium-term. Figure ES 4 shows the distribution of units scheduled for retirement, the fraction of the fleet represented by these numbers, and a logistic curve that describes a *potential* progression of the fraction of the fleet that turns electric over time. For the purpose of analysis, the logistic curve is designed so that it approximately meets a hypothetical phase 1 deployment condition of 35 buses, starting in semester 3. The shape of the logistic curve can be changed, to reflect different possible deployment scenarios.

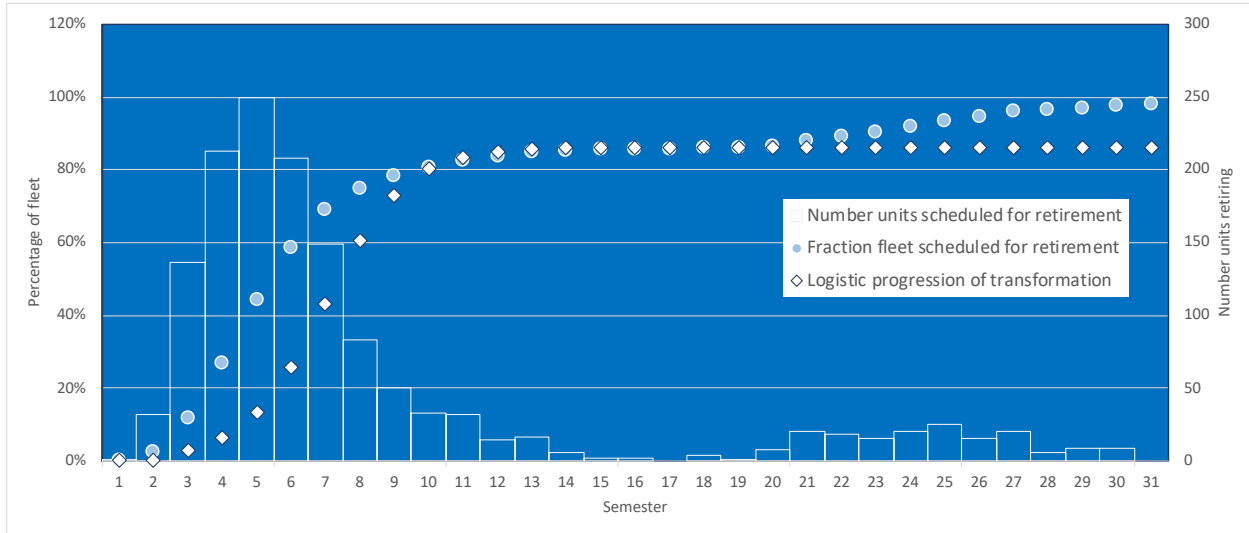


Figure ES 4. Number of units scheduled for retirement (columns), fraction of the fleet scheduled for retirement, and fraction of the fleet that could turn electric assuming a logistic progression.

Figure ES 5 shows the progression of units that are overhauled and the number of electric buses that are integrated in the fleet over time. This scenario would carry an estimated price tag of over USD 13M for the replacement of the engines included in the overhaul of the diesel Euro III buses. The rate of fleet transformation is fairly rapid nevertheless, with 1,125 electric buses incorporated in a period of five years. This is the type of tradeoffs that MiBus will need to optimize, having a fleet quickly approaching retirement age.

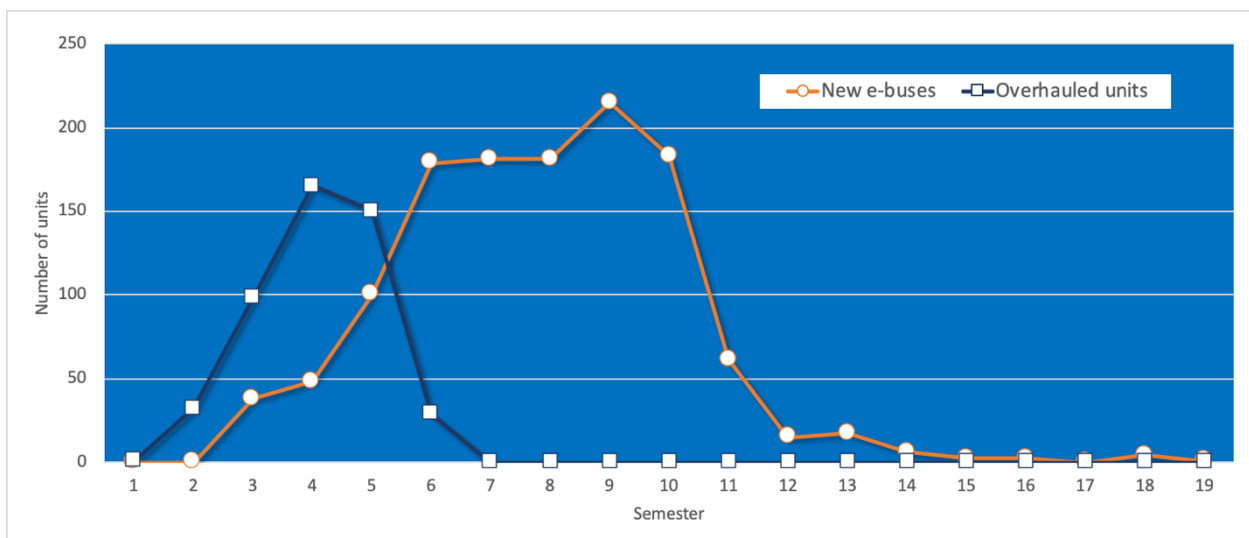


Figure ES 5. Possible progression of numbers of electric buses integrated in the fleet and of numbers of units overhauled.

## Bus route planning

Separate reports in this technical assistance have shown that vehicle efficiencies can vary widely depending on the operational conditions, and that technical viability and financial competitiveness depend on choosing the right system of technology assets.<sup>3 4</sup> The notion of using one single configuration of electric bus to serve a system of different routes is impractical.<sup>5</sup> Adequate consideration of this fact is key for financial efficiency and the maximization of social and environmental impact.

The planning of electric bus deployment needs to recognize local factors, and thus no do-it-yourself recipe can be proposed that applies to all cases. For the purpose of providing general guidance, a simplified decision chart is proposed in Figure ES 6, highlighting key aspects and sequential steps in the identification of routes for the deployment of electric buses.

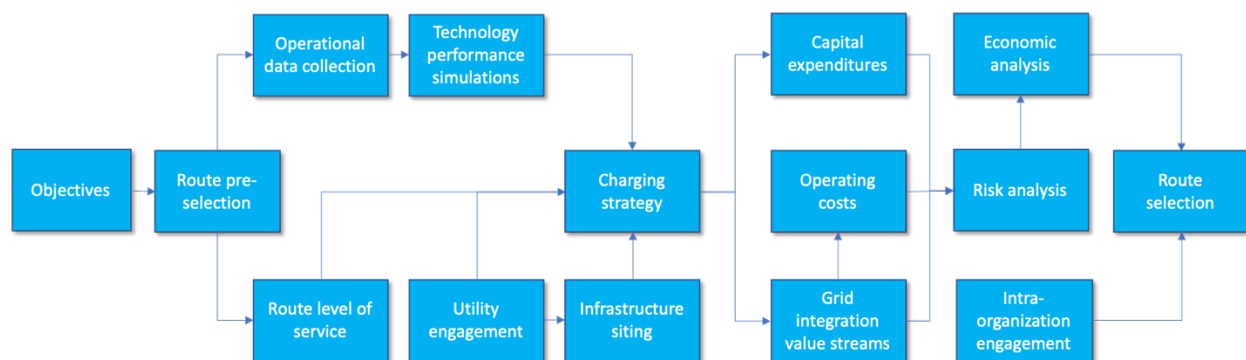


Figure ES 6. Simplified decision chart for the selection of bus routes for electric bus deployment

<sup>3</sup> LOGIOS (2020) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 3.2.

<sup>4</sup> LOGIOS (2019) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 2.3 <https://www.ctc-n.org/technical-assistance/projects/accelerating-transition-sustainable-mobility-and-low-carbon-emissions>

<sup>5</sup> Unless all routes are similar and selected for the purpose of fitting well the particular bus configuration.

## Electricity Supply Analysis

This section identifies strategies to help MiBus maximize predictability and cost-effectiveness of electricity supply rates for electric buses and consistent with environmental goals. Electric utility engagement is a central part of the planning of electricity supply; this section also lays out principles to guide MiBus's communication with local electric utilities.

In order to review the costs of electricity supply, it is helpful to consider separately supply factors that are driven by the power demand of the fleet of electric buses from supply factors that exist in MiBus's local power markets. MiBus has important choices to make, both in the demand and supply sides.

MiBus's load curve<sup>6</sup> by location can have a significant effect on its supply costs. The charging strategy<sup>7</sup> adopted by MiBus will impact:

- Monthly peak demand charges;
- Capacity-related costs and renewable energy transactions;
- Time-of-use energy charges;
- Total energy charges.

Electric buses should be thought of as distributed energy resources (DER). MiBus's charging strategies will also determine the *locational value* that ZEBs can access as DER. Perhaps this value cannot be internalized in Panama's present utility markets, but this may change in the future.

An understanding of Panama's electricity markets, both from wholesale and retail perspectives is important to plan and manage electric bus energy supply and attain economic and environmental objectives. As Panama increases its renewable power installed capacity, it will start

---

<sup>6</sup> Load curve refers to the variation of demand over time.

<sup>7</sup> A charging strategy can be defined as the set of integrated practices adopted in order to supply electrical energy to the buses. It is analyzed for the case of MiBus in a separate report: LOGIOS (2020) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 3.2.

encountering net differences between generation and demand, primarily due to solar deployments; a phenomenon known as the “duck curve”. The development of a duck curve would imply that MiBus’s charging strategy would tilt toward mid-day charging events, while steering away from early evening charging.

In addition to receiving bundled electricity service from utilities, MiBus should explore opportunities to increase the share of renewable power in its supply. In particular, long-term transactions for renewable power delivered at charging sites are a practical alternative in this regard.

The structure of utility distribution rates will be an important factor in the operating costs of electric buses, independently of the strategies adopted to generation sourcing. MiBus should develop a careful charging strategy to address this and other challenges. Effective charging strategies are as complex as essential to implement.<sup>8</sup>

## Approaching change

Transformations, especially those linked to systems as complex as transportation, take time. Time is necessary to study, propose, prototype, do impact evaluations and, above all, communicate. This is particularly true for the kind of transformations that are necessary to move urban transportation systems to long-term sustainability. No change in the transportation system will be successful if there is no in-depth communication campaign in which the new policies are explicitly established, communicated, discussed and put into context. People are usually averse to change, especially those that involve something as everyday as how to move around the city. The policy's target population must be convinced that sustainable mobility is a new positive standard in which governments will make every effort to improve the transportation system taking into account the aspects previously established. At the same time, users of the transportation system will demand, rightly so, adequate travel conditions, as discussed in this report. Understanding possible areas of concern among the public is essential to provide consistent responses and to create a feedback process that will continually improve the system.

---

<sup>8</sup> Charging strategies are discussed in the separate report LOGIOS (2020) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 3.2.

## 1. Introduction

---

This document lays out a high-level sustainable mobility plan for public transport in Panama City. The National Strategy for Electric Mobility (NSEM) set the following goal for public transport fleets: 15 to 35 percent of the buses in fleets under concession will be electric by 2030. These figures are meant as minimum aspirations – a public transportation system in which, 10 years from now, 17 out of 20 buses remain carbon intensive, would not be representative of Panama City true potential to move toward sustainable transportation. A solid and consistent plan, geared toward attracting investments in clean transportation systems, providing zero-emission technologies with a leveled competitive field that accounts for externalities, combined with sustained technology innovation can put Panama City into a steeper pathway of transformation.

While the emphasis of this technical assistance is on the technology transformation of the fleet of Transporte Masivo de Panamá, MiBus, a sustainable public transport plan should clearly have a broader focus. A central premise is then that starting to move MiBus's fleet in the direction of zero emissions, however necessary, is only one step in the journey of Panama's transportation system toward sustainability. Furthermore, consistent with the 2030 Agenda for Sustainable Development, a true quest for sustainability requires progress along multiple, interrelated dimensions.

The United Nations Secretary-General, recognizing the central role that transport plays in the context of sustainable development, established a High-Level Advisory Group on Sustainable Transport in the year 2014. The work of the Advisory Group was eventually documented in a report entitled *Mobilizing Sustainable Transport for Development*, which included a series of policy recommendations.<sup>9</sup> As stated in that report, *[T]ransport is not an end in itself but rather a means*

---

<sup>9</sup> Mobilizing Sustainable Transport for Development: Analysis and Policy Recommendations from the United Nations Secretary-General's High-Level Advisory Group on Sustainable Transport. Available at: <https://sustainabledevelopment.un.org/content/documents/2375Mobilizing%20Sustainable%20Transport.pdf>

allowing people to access what they need: jobs, markets, and goods, social interaction, education and a full range of other services contributing to healthy and fulfilled lives.<sup>10</sup> Further, the report proposes the following definition of sustainable transport:

Sustainable transport is the provision of services and infrastructure for the mobility of people and goods—advancing economic and social development to benefit today’s and future generations—in a manner that is safe, affordable, accessible, efficient, and resilient, while minimizing carbon and other emissions and environmental impacts.<sup>11</sup>

Perhaps implicit in this statement, though worthy of highlighting, a sustainable transport needs to provide these services in an inclusive and equitable manner. It can be argued that sustainable transport should also provide services and infrastructure for the *substitution* of mobility, thus encompassing the access to information and communication technologies (ICT) for the remote access to work, services, etc. A sustainable mobility plan is necessarily concerned with providing services that are physically accessible to the elderly and persons with disabilities, preserving the personal safety of women, and particularly conscious of the challenges of vulnerable populations such as rural and lower-income communities.

Transport is central to several of the Sustainable Development Goals (SDG) included in the 2030 Agenda for Sustainable Development, including the following:

- Food security,
- Health,
- Energy,
- Economic growth,
- Infrastructure, and
- Cities and human settlements

As the core of the present technical assistance is related to road public transport, it is relevant to speak to the *first mile-last mile* problem.

A strategic framework for the development of a sustainable transportation system, could follow

---

<sup>10</sup> Ibid.

<sup>11</sup> Ibid, pp.10.

the guidelines of the Declaration of Bogota. This declaration, signed by nine countries in Latin America, proposed the framework known as *Avoid – Shift – Improve*.<sup>12</sup> The successful design and implementation of policies, plans, and business models consistent with the *Avoid – Shift – Improve* strategic framework or any other framework, always depends on the local institutional framework. One key area of attention is the integration of transport and land use. While this is the area that has received the most attention in the planning literature, still important questions remain unclear and implementation challenges remain high. The High-Level Advisory Group on Sustainable Transport emphasized that transport and land use must be integrated to deliver urban areas with higher and equitable accessibility.

## 1.1 Background

Zero emission buses are attractive because they offer numerous benefits to MiBus and the broader community of Panama City. These benefits include:

- **Zero emission of local criteria pollutants.** Battery electric buses have no tailpipe emissions. The Panama City air basin faces major challenges relative to urban air quality and associated health risks to the local population. Large reductions are needed, for example, in the emissions of particulate matter that contribute to health problems such as increased risks of heart attacks and aggravated asthma.
- **Low greenhouse gas emissions.** Battery electric buses produce zero tailpipe greenhouse gas (GHG) emissions. Upstream emissions associated with battery electric buses depend on the marginal impact of the additional load from the charge of onboard batteries on the electricity generation mix. Battery electric buses will result in significantly lower lifecycle GHG emissions as compared to conventional compressed natural gas (CNG) buses, with a much bigger difference in this respect relative to diesel buses. If renewable electricity generation is used, GHG emissions will be effectively zero.
- **Lower noise pollution.** Battery electric buses operate much more quietly than buses powered by an internal combustion engine. Studies suggest that electric buses can generate reductions in noise levels of up to 14 dB(A), particularly in segments of low speed,

---

<sup>12</sup> Bogota Declaration: Sustainable Transport Objectives. Available at [https://sustainabledevelopment.un.org/content/documents/1605Bogota%20Declaration\\_discussed%20\\_ENG.pdf](https://sustainabledevelopment.un.org/content/documents/1605Bogota%20Declaration_discussed%20_ENG.pdf)

common in large urban areas.<sup>13</sup> This will be particularly beneficial in the densely populated areas of MiBus's service territory.

- **Mitigation of operating costs.** As shown in an earlier report, electric buses will help reduce operating costs of bus fleets in Panama City.<sup>14</sup> The extent of these reductions are tightly connected with the quality of the planning.
- **Lower fuel cost volatility.** Electricity prices tend to be more stable and predictable than fossil fuel prices, particularly when the regulatory environment makes it possible to secure energy supply via long-term contracts.

## 1.2 Plan Organization

The remainder of this plan is organized in four sections, as follows:

- Section 2 discusses risk management approaches.
- Section 3 discusses the overall planning of route electrification.
- Section 4 discusses energy supply for the electric bus fleet.
- Section 5 discusses the integration of bus electrification into a sustainable mobility plan.

## 2. Risk Management Approach

---

The development of an electric bus plan can start with the development of a framework for MiBus to identify and manage risks associated with the transition to this technology. In the transport sector, disruptive technologies are creating opportunities for transformative business models and new mobility choices. Innovation is critical to organizations such as MiBus, and urban centers such as Panama City, to remain competitive. Innovation has associated risks and the technology transformation of a transit fleet is no exception.

---

<sup>13</sup> Laib, F., A. Braun, and W. Rid (2019) Modeling noise reductions using electric buses in urban traffic: A case study from Stuttgart, Germany. *Transportation Research Procedia* **37**: 377-384.

<sup>14</sup> LOGIOS (2019) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 2.3 <https://www.ctc-n.org/technical-assistance/projects/accelerating-transition-sustainable-mobility-and-low-carbon-emissions>

Sometimes overlooked, organization culture is a critical factor in determining the outcome of innovation processes. In general terms, all pertinent layers of the organization must be open to changing practices. Electric transportation is a different paradigm and does not accept the same approach to fleet management as conventional vehicles. Management must embrace the possibility of technology/experiment failure, increase risk tolerance, and adopt a longer-term stance on success.

Transit agencies, such as MiBus, are accustomed to dealing with risk, but the integration of battery electric units may have different risk matrices associated to them. The integration of electric vehicles creates opportunities for the operations and finance sides of the organization to communicate and understand how overall risks associated with this technology compare with those associated with incumbent conventional technologies.

A risk management framework can be defined with the following elements, which are commonly used in investment risk management:

1. Governance of risks
2. Identification of risks
3. Measurement of risks
4. Strategy to mitigate risks
5. Reporting and monitoring of risks

Risk governance refers to the assignment of responsibilities across MiBus on decision-making involving risk. This may include approval of risks, reporting on progress, risk measurement, etc. In the context of electric buses, this will mean, for example, that MiBus will enter the process of electric bus adoption with an understanding of acceptable risks, that performance over time is regularly measured against these accepted boundaries, etc.

As indicated above, innovation is an inherent part of growth, and risk is an inherent part of innovation. In the context of an electric bus integration plan, it is not necessary for the identification of risks to enumerate *all* possible risks, but rather to focus on a critical set. The risk management discussion included here focuses on three broad categories: financial risks, reliability risks, and environmental performance risks. Each is discussed separately.

## 2.1 Financial risks

The risks associated with expenditures involved in the integration of electric buses to a transit fleet were discussed in a separate report.<sup>15</sup> General concepts are included below for context.

Driving cycles have a large influence on the efficiency and economics of any vehicle, regardless of its fuel platform. The relationship between driving cycle and efficiency and economics is particularly important for all-electric vehicles, including heavy duty vehicles such as transit buses. The drive cycle is determined by the three-dimensional coordinates along a given route and its first and second derivatives, which give speed and acceleration, respectively. Thus, the choice of route and driver behavior are important factors to improve efficiency and economics of electric bus operation. Training drivers to adjust driving behavior to maximize efficiency through smoother acceleration, braking mindful of regeneration gains, and efficient use of auxiliary loads such as air conditioning, is critical to increase financial returns on electric bus investment. For example, increasing efficiency will not only result in lower costs of operation per mile, but it will also help reduce the frequency of charging cycles, which in turn help extend the life of the batteries, which increases the net present return on these assets.

Electric vehicle platforms are often associated with lower maintenance costs because they have a small number of mechanical moving parts, compared with internal combustion platforms. The operating costs of electric buses relative to other platforms were discussed in a separate report.<sup>16</sup> Even if certain maintenance events are expected to be less frequent, many of the maintenance items scheduled for conventional units also apply to electric buses.

A risk associated with the integration of new advanced technologies is that products and components can be modified and even dropped from production. This should be accounted for in the procurement contracts that MiBus signs with suppliers. How to internalize these risks should

---

<sup>15</sup> LOGIOS (2019) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 2.3 <https://www.ctc-n.org/technical-assistance/projects/accelerating-transition-sustainable-mobility-and-low-carbon-emissions>

<sup>16</sup> Ibid.

be matter of discussion between MiBus and the broader set of stakeholders.

## 2.2 Reliability risks

MiBus should identify the risks associated with the reliability of vehicle performance, electricity supply vis-à-vis alternatives, and resilience to extreme weather events. It is expected that electric vehicle platforms will have lower maintenance events. This is certainly the expectation, as the technology further evolves into maturity. While there may still be some perceived risk of the reliability electric bus drivetrain and energy storage systems, methodic tests in fleets in service operation have shown that these systems can perform reliably.

Availability is defined as the ratio of the number of days that the unit is available for pull-out to the number of days that it was planned for operation. A typical level of availability adopted by transit agencies is 85%. On service data for electric buses at Foothill Transit shows that all buses were available at least 85% of the time, with an average availability of 93%.<sup>17</sup> Figure 1 shows a scatterplot of availability against the total miles of operation for each electric bus that took part in the Foothill Transit test, except for an outlier. This chart also suggests that reliability did not change significantly with unit usage. If anything, a slight upward trend in availability can be identified which could, hypothetically, be simply related to the OEM schedule of bus maintenance.

---

<sup>17</sup> This excludes one outlier that spent more time out of service because of an accident and issues with the air conditioning system.

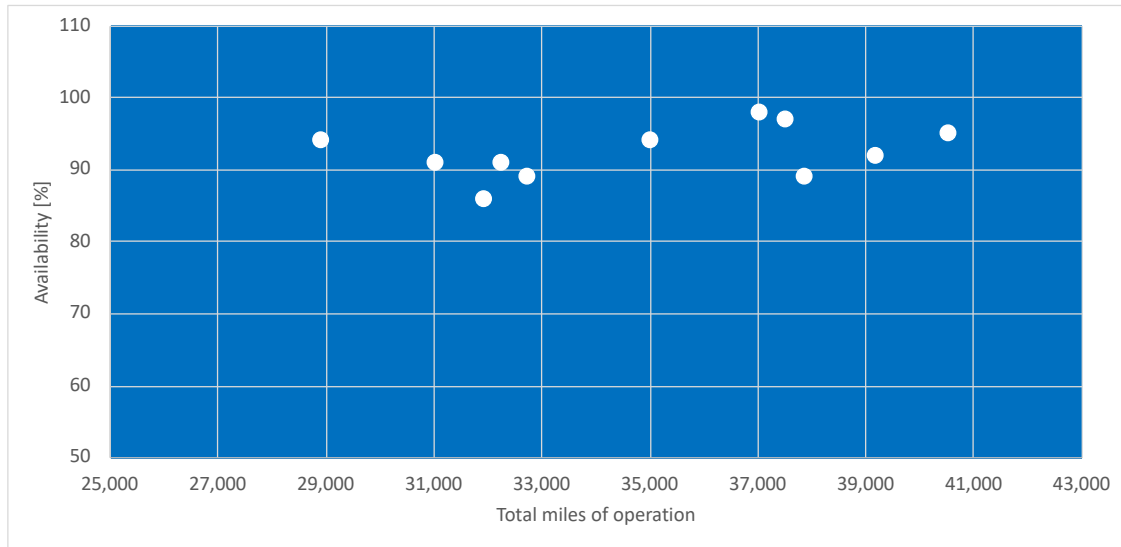


Figure 1. Test electric bus availability against miles of operation during test period (data source: NREL)

On the aggregate, the Foothill Transit battery electric buses had 4,600 planned workdays and were unavailable for 10% of the time (456 days). Most of this unavailability (6.5%) was due to general unit maintenance. The energy storage system, electric drive, and charging system were responsible for the battery electric buses to be unavailable 0.9%, 2.2%, and 0.1% of the days, respectively. General maintenance caused a higher average unavailability on the battery electric bus units than on the baseline CNG units, which had a value of 4.0%.

Another way to measure reliability is in terms of miles between roadcalls (MBRC). Consistent with the results shown above, energy storage systems were not an important source of roadcalls, and in fact the MBRC related to issues with the ESS was measured at over 133,000 during the test period.

Another potential reliability issue is related to the risk of power supply disruptions (outages). To mitigate this type of risk, MiBus could consider a combination of the following factors:

- **Duration** (maintaining charging capability for the requisite length of time during outages)
- **Reliability** (assuring seamless backup power and increasing redundancy)
- **Flexibility** (adapting to changing requirements over the course of an outage)
- **Maintainability** (the ease of keeping solutions on-line given the skills of MiBus staff and contractors)

- **Coverage** (expanding the amount of charging infrastructure backed-up during an outage)
- **Cost** (achieving the best, long-term financial value per kW of charging capability protected)

Questions related to power supply will be addressed in more detail in a later section.

## 2.3 Environmental performance risks

Achieving environmental impact, such as eliminating urban criteria pollutant emissions and reducing lifecycle greenhouse gas emissions from the operation of buses, is the main driver for the conversion of MiBus's fleet to zero emission units. While battery electric buses, by definition, will eliminate mobile emissions and thus will improve the quality of urban air, the climate benefits of battery electric buses will be dependent predominantly on the carbon intensity of the electricity they consume and the strategies adopted to integrate their charging with renewable sources of energy.

An analysis of the range of emission reductions that are expected over the multi-year period of battery electric bus deployments was included in a separate report of this technical assistance.<sup>18</sup>

## 2.4 Risk and performance metrics

The implementation of a risk management framework, particularly risk governance and measurement, needs clear metrics. These metrics would establish the criteria to evaluate the overall performance of battery electric buses and the boundaries of what are considered acceptable risks during all stages of their deployment. Given the systemic nature of the innovation process that MiBus would undergo, metrics should be holistic. In other words, MiBus should consider establishing metrics that consider a variety of factors in addition to technology performance. The performance of battery electric buses will clearly be a function of the state of technology, but it will also be a function of MiBus's strategic choices for deployment. For example,

---

<sup>18</sup> LOGIOS (2019) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 2.2. <https://www.ctc-n.org/content/d22report-recommendation-most-appropriate-technology-panama>

performance will be affected by the choice of routes, complementary measures that Panama City could adopt to improve operational conditions, the level of training given to staff, the agreements negotiated with the local utilities, etc.

Metrics should be dynamic and foresighted

It is standard practice to measure the performance of early-stage technologies on dynamic metrics, establishing requirements for performance that change over time. To adopt a dynamic metric, MiBus should use foresight about progress on all aspects that contribute to battery electric bus performance. This includes projections of technology performance and economics progress, staff training program implementation, construction schedules (e.g. depot upgrades, charging equipment planning and installation), etc. Responsibilities for developing this foresight should be established as part of risk governance, which could be internal or external to MiBus, and would involve close communication with industry, utilities, and other stakeholders.

MiBus should consider adopting a battery electric bus assessment program. This would entail the implementation of risk measurement, risk mitigation strategy, and risk monitoring and reporting elements of the risk management framework.

Developing holistic metrics

Three main types of risks were identified: financial, reliability, and environmental risks. For each of these, MiBus should first consider specific metrics (i.e. how to measure these risks), and then establish tolerances for each (i.e. acceptable boundaries), against which the performance of battery electric bus deployments will be evaluated. Additionally, MiBus could consider adopting rates at which these tolerances will be tightened over time. Table 1 shows an example performance metrics matrix. MiBus should adopt these or other metrics and decide on initial and longer-term values of tolerance.

Table 1. Example performance metrics matrix

Risk	Metrics (example)	Measurement
<b>Financial</b>	Per-mile operation costs (net of revenues from grid services)	\$ __/mile
	Per-mile vehicle maintenance costs	\$ __/mile
	Per-mile infrastructure maintenance costs	\$ __/mile
	Change in farebox revenue	__%
<b>Reliability</b>	Drivetrain-related unavailability	__%
	Other unavailability	__%
	Customer satisfaction	__%
<b>Environmental</b>	Per-mile average lifecycle carbon emissions	__g/mile
	Per-mile minimum lifecycle carbon emissions	__g/mile
	Annual reductions in emissions of criteria pollutants	__ton/year

Once measurements are obtained, MiBus should evaluate how much of these can be attributed to technology, and how much to institutional factors (route choices, staff experience, experimentation, etc.).

Two suggested good practices are the following:

- a. Evaluate variations in risks across routes. This may reveal characteristics of routes that are conducive to the deployment of battery electric buses.
- b. Evaluate metrics on an annual basis, whenever possible. battery electric buses are likely to have different seasonal effects in performance when compared to conventional drivetrains, particularly due to the different impacts that HVAC systems have on vehicle efficiencies.

## 2.5 Risk tolerance mapping

Finally, MiBus should identify groups, sectors, routes, or divisions that may provide better conditions for the experimentation with and evaluation of the new technology in earlier stages of deployment. This analysis can be important to inform the battery electric bus phase-in strategy. The wider the range of commercial bus models, the higher the probability that the best technology fit for a given route can be found. Table 2 shows a sample of commercial models.

Table 2. Sample of commercial electric bus models (Source: LOGIOS research)

Make	Model	Charge	Battery [kWh]	Length [m]	Weight [kg]	Origin
<b>Alexander Dennis Limited (ADL)</b>	ADL Enviro400VE	Fast	61	10.3	18000	UK
<b>Alexander Dennis Limited (ADL)</b>	BYD ADL Enviro200EV	Overnight	324	12	18600	UK/China
<b>Alexander Dennis Limited (ADL)</b>	BYD ADL Enviro200EV II	Overnight	324	10.8	18600	UK/China
<b>Bluebus</b>	Bluebus	Overnight	240	12	20000	France
<b>BOZANKAYA A.S.</b>	Sileo S10	Overnight	200	10.7	18000	Turkey

Make	Model	Charge	Battery [kWh]	Length [m]	Weight [kg]	Origin
<b>BOZANKAYA A.S.</b>	Sileo S12	Overnight	200/230	12.7	18000	Turkey
<b>BOZANKAYA A.S.</b>	Sileo S18	Overnight	300	18	28000	Turkey
<b>BYD</b>	12m China	Overnight	324	12	18000	China
<b>BYD</b>	12m Overseas	Overnight	324	12	19000	China
<b>BYD</b>	BYD Double Decker	Overnight		10.2/12	<20000	China
<b>BYD</b>	18m Articulated	Overnight	547.5	18	28000	China
<b>BYD</b>	12m coach	Overnight	324	12	19000	China
<b>CAETANOBUS – FABRICO DE AUTOCARROS E CARROÇARIAS, S. A.</b>	eCobus	Fast	85	14	20000	Portugal
<b>CARROSSERIE HESS AG</b>	TOSA BGT-N2D	Ultra-Fast	70	18,74	29000	Switzerland
<b>EBUSCO B.V.</b>	2.1 HV LF-311-HV-2/3	Overnight	311	12	12000	Netherlands
<b>EBUSCO B.V.</b>	18M HV LF-414-HV-3/4	Overnight	414	18	19500	Netherlands
<b>GreenPower</b>	EV250	Overnight	210	9.4		USA
<b>GreenPower</b>	EV350	Overnight	320	12.2		USA

Make	Model	Charge	Battery [kWh]	Length [m]	Weight [kg]	Origin
<b>GreenPower</b>	EV400	Overnight	320	13.7		USA
<b>GreenPower</b>	EV550 (2-Decker)	Overnight	478	12.2		USA
<b>HEULIEZ BUS</b>	GX 337 ELEC	Overnight	349	12.0	20000	France
<b>HEULIEZ BUS</b>	BUS GX437 ELEC	Fast	106	18	30000	France
<b>HUNAN CRRC TIMES ELECTRIC VEHICLE CO., L</b>	CRRC C12	Semi-Fast	201	12	18000	China
<b>HYBRICON BUS SYSTEM AB</b>	Arctic Whisper HAW 18 LE 4W	Ultra-Fast	40/120	18	28000	Sweden
<b>HYBRICON BUS SYSTEM AB</b>	City bus HCB 12 LF	Fast	38/265	12	18000	Sweden
<b>IRIZAR S. C</b>	i2e	Overnight	376	12	20000	Spain
<b>IRIZAR S. C</b>	i2e 18m	Dual	120/180	19	28000	Spain
<b>LINKKER</b>	12+	Fast	55/63.5	12.8	16000	Finland
<b>OPTARE</b>	Solo EV	Semi-Fast	138	9.2/9.9	11300	UK
<b>OPTARE</b>	MiBuscity EV	Semi-Fast	138	10.8	12960	UK
<b>OPTARE</b>	Versa EV	Semi-Fast	138	10.4/11.1	12480	UK
<b>OPTARE</b>	MiBusdecker EV	Overnight	200	10.5	-	UK

Make	Model	Charge	Battery [kWh]	Length [m]	Weight [kg]	Origin
<b>RAMPINI CARLO SPA</b>	E12	Overnight	180	12	19000	Italy
<b>SAFRA</b>	Midibus	Overnight	132	10.5	19000	France
<b>SAFRA</b>	Standard	Overnight	132	12	20000	France
<b>ŠKODA ELECTRIC A.S.</b>	Perun HE	Overnight	230	12	18600	Czech Rep.
<b>ŠKODA ELECTRIC A.S.</b>	Perun HP	Ultra-Fast	80	12	18000	Czech Rep.
<b>SOLARIS</b>	Urbino 8.9 LE electric	Semi-Fast	160	9	15500	Poland
<b>SOLARIS</b>	Urbino 12	Semi-Fast	240	12	18000	Poland
<b>SOLARIS</b>	Urbino 18	Semi-Fast	240	18	29000	Poland
<b>SOR LIBCHAVY, SPOL. S R.O.</b>	SOR EBN 11	Fast	172	11.1	16500	Czech Rep.
<b>SOR LIBCHAVY, SPOL. S R.O.</b>	SOR EBN 10,5	Overnight	172	10.4	16500	Czech Rep.
<b>TEMSA GLOBAL SANAYI VE TICARET A.S.</b>	MD9 electric	Semi-Fast	200	9.3	14000	Turkey
<b>TEMSA GLOBAL SANAYI VE TICARET A.S.</b>	Avenue EV	Ultra-Fast	75	12	19000	Turkey
<b>URSUS BUS S.A.</b>	Ekovolt	Fast	120	12	18000	Poland

Make	Model	Charge	Battery [kWh]	Length [m]	Weight [kg]	Origin
<b>URSUS BUS S.A.</b>	City Smile	Overnight	175	8.5	16000	Poland
<b>URSUS BUS S.A.</b>	City Smile	Fast	210	9.95	18000	Poland
<b>URSUS BUS S.A.</b>	City Smile	Overnight	175	12	18000	Poland
<b>URSUS BUS S.A.</b>	City Smile	Ultra-Fast	105	12	18000	Poland
<b>URSUS BUS S.A.</b>	City Smile	Ultra-Fast	105	18	28000	Poland
<b>VAN HOOL</b>	Exqui.City	Dual	215	18.6	28000	Belgium
<b>VDL BUS &amp; COACH</b>	Citea LLE-99	Dual	180	9.95	14400	Netherlands
<b>VDL BUS &amp; COACH</b>	Citea SLF-120	Dual	63/240	12	19500	Netherlands
<b>VDL BUS &amp; COACH</b>	Citea SLFA-180	Dual	63/180	18	29000	Netherlands
<b>VOLVO BUS CORPORATION</b>	7900 Electric	Ultra-Fast	76	12	11700	Sweden

## 3. Overall Plan for Bus Route Electrification

---

The Autoridad del Tránsito y Transporte Terrestre (ATTT, Ground Transportation and Traffic Authority), with Concession Contract 21-10, gave Transporte Masivo de Panamá (MiBus) the right to design, supply, and operate the system of public transport in the districts of Panama and San Miguelito. The concession included 83 routes, both trunca and transversal, for a period of 15 years, starting on 2010.

According to the original *Pliego de Cargos*, MiBus has to replace buses during the concession (Section 5.3.1) and submit to ATTT a fleet modernization program. Such program was to include:

- Financing parameters, including capital needs, investment plan, and cost of the buses;
- Phased-out fleet, including vehicle type/s, model, and number of units; and
- Phased-in fleet, including make, model, year, technology, size, number of units, and integration plan.

One of the goals proposed in the Panama National Strategy of Electric Mobility is technology transition for public transport bus fleets, such that 15% - 35% of the units in concession-based operations be electric buses by 2030. This section describes prospective directions for the progressive electrification of MiBus's routes, aiming at *higher* penetrations than those proposed in the National Strategy. The presentation is organized around the description of critical concepts, the discussion of the first phase of deployment, and finally the proposed directions for longer-term deployments.

### 3.1 Critical concepts to approach further bus route electrification

Based on the experience of LOGIOS and consultations with stakeholders, as well as MiBus staff, several concepts are proposed to help MiBus implement a technology renovation plan toward a zero-emission fleet. These concepts are described next.

## **The use of a systems approach**

MiBus is already a complex system. The operation of a large electric fleet will constitute a new subsystem within MiBus. This subsystem will be composed of interrelated technical and institutional elements that will grow organically over time.

To MiBus this means, primarily, that integrating battery electric buses into its fleet requires a stronger integration of the processes of planning, procurement, implementation, operations, and management. These processes and related decisions affect and depend on each other. As an example, procurement decisions, without due consideration to technology evaluation and planning, risk management, or other elements, will lead to inefficiencies and may result in disappointments with the technology, or worse outcomes.

## **Think in terms of transformation – not just innovation**

The transition to a zero-emission fleet is an innovation and transformation process. It is critical for MiBus's management to recognize that battery electric buses represent a new paradigm. Innovation processes are not mere substitutions of technologies — they require institutional and behavioral change as well. This transformation is not unique to MiBus or to fleet electrification; it is part of the much larger transformation that the global economy is undergoing in the quest for sustainability and a more livable planet for all.

## **To foster a zero-emission culture – embrace new ways of doing things**

As a new paradigm, the successful integration of battery electric buses into the operations of a fleet needs to be accompanied by adjustments in practices. Attempts to force this technology fit into business-as-usual practices will likely be met with negative impacts on MiBus's operations. MiBus can instead recognize and embrace the need to do things differently. This may include route assignment, driving behavior, risk management, and other practices in the organization. Building a zero-emission culture can be important; successful transformations need also support from the bottom up.

## **Create a MiBus zero-emission lab**

MiBus is, in many ways, blazing trail. While a number of cities in Latin America have started integrating battery electric buses, MiBus will face some unique challenges. A low-risk

electrification process must be built upon the foundation of solid information about interconnected elements, such as bus performance, charging strategies, electricity and power access rates, cultural changes, and so forth. Accelerating this transition without this foundation will likely be counterproductive, as can discredit the technology in the eyes of operators, drivers, and end users.

To acquire this information, there is no real alternative to analysis and experimentation. MiBus should consider implementing a zero-emission lab for the testing of ideas, which could include:

- Selection of deployment routes: This should be mindful of contemporary state of the commercial technology. Simulations of technology performance should be a central part of this.
- Collect and analyze data: This should be done in collaboration with a third party.
- Evaluation and reporting: Clearly reporting results and presenting preliminary recommendations, to inform next testing and procurement cycles.

### **Empower a MiBus electric bus champion**

Institutional change can be greatly facilitated by champions; examples abound in the history of electric transportation policy. MiBus should consider designating a motivated person to lead the internal coordination and identify and address obstacles to electric bus integration.

## **3.2 Phase 1: Initial deployment of electric buses**

For the initial deployment of battery electric buses, MiBus has independently identified a set of six routes, namely C850, C888, C898, C938, C968, and E489.<sup>19</sup>

Figure 2 shows the geographical distribution of these routes, while Figure 3 through Figure 9 show each of the routes individually.

---

<sup>19</sup> A dashboard with statistical information on these routes can be accessed at <https://logios.shinyapps.io/BusesElectricosPanama/>



Figure 2. Candidate routes for the initial deployment of electric buses. (Source: LOGIOS)

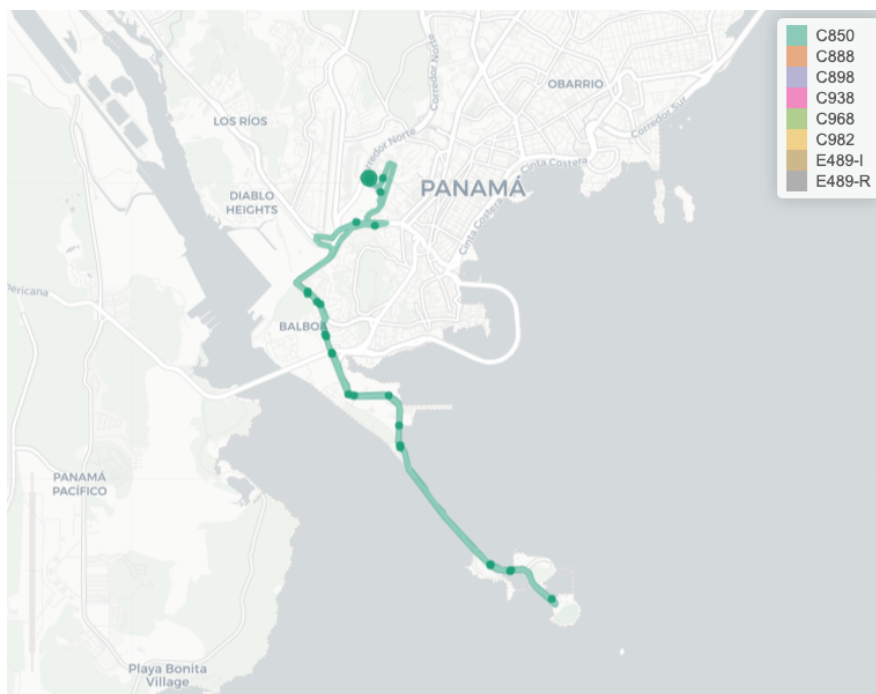


Figure 3. Route C850, selected by MiBus for the initial deployment of electric buses. (Source: LOGIOS)



Figure 4. Route C888, selected by MiBus for the initial deployment of electric buses. (Source: LOGIOS)

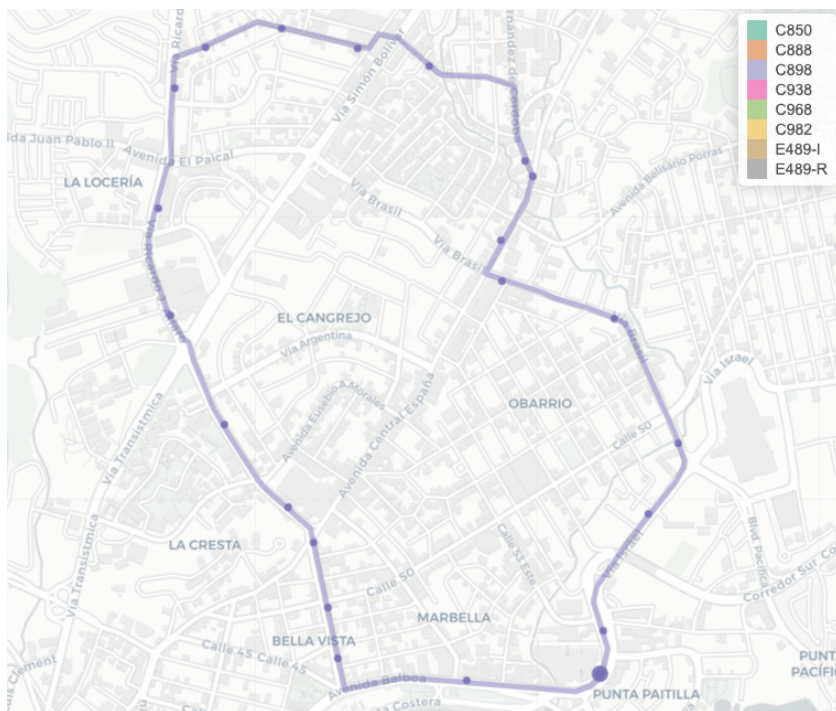


Figure 5. Route C898, selected by MiBus for the initial deployment of electric buses. (Source: LOGIOS)



Figure 6. Route C938, selected by MiBus for the initial deployment of electric buses. (Source: LOGIOS)



Figure 7. Route C968, selected by MiBus for the initial deployment of electric buses. (Source: LOGIOS)

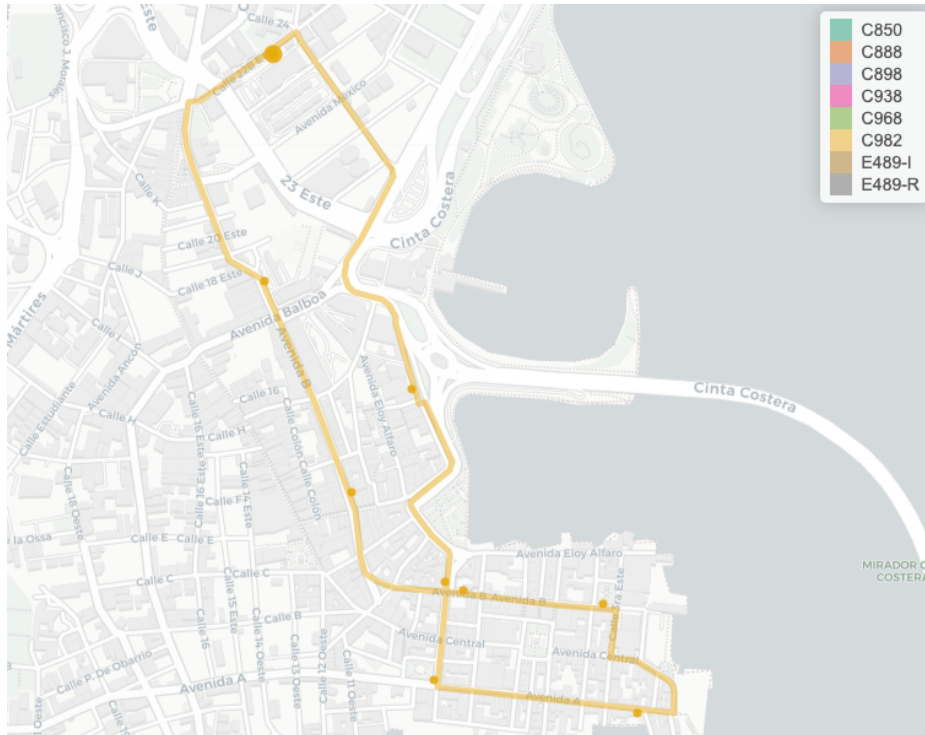


Figure 8. Route C982, selected by MiBus for the initial deployment of electric buses. (Source: LOGIOS)



Figure 9. Routes E489-I and E489-R, selected by MiBus for the initial deployment of electric buses. (Source: LOGIOS)

Table 3 shows the trips served by these routes and the daily geographical distance of these services. All these routes, except for E489, are close-loop routes, which means that they start and end in the same terminal.<sup>20</sup>

Table 3. Routes scheduled for initial deployment of electric buses, trips served and daily distances.<sup>21</sup>

Route & bus	Number trips	Daily distance[km]
C850	44	980.144
1W0001U	12	267.312
1W0002U	14	311.864
1W0003U	12	267.312
1W0004U	6	133.656
C888	53	208.078
2LE0A0H	10	39.26
2LE0BBH	8	31.408
2LE0DCH	6	23.556
2LE0DKH	4	15.704
2LE0FTH	3	11.778
2LE0HAH	8	31.408
2LE0HUH	4	15.704

<sup>20</sup> Route E489 is now being redesigned as a loop route, although that change does not affect operations in any way.

<sup>21</sup> Routes C888 and C938 are inter-lined at the time of this writing. The table shows only the distances that buses cover for these routes, though not the total of their daily distance.

Route & bus	Number trips	Daily distance[km]
2LE0KOH	1	3.926
2LE0NWH	3	11.778
2LE0PHH	3	11.778
2LE0PXH	3	11.778
C898	40	345.04
0I3001H	19	163.894
0I3002H	21	181.146
C938	43	889.842
2LE0A0H	1	20.694
2LE0ALH	1	20.694
2LE0DCH	4	82.776
2LE0DKH	2	41.388
2LE0F5H	2	41.388
2LE0FTH	4	82.776
2LE0GBH	2	41.388
2LE0HAH	3	62.082
2LE0HUH	2	41.388
2LE0JMH	1	20.694
2LE0KIH	4	82.776
2LE0KOH	1	20.694

Route & bus	Number trips	Daily distance[km]
2LE0LWH	3	62.082
2LE0M4H	3	62.082
2LE0NWH	4	82.776
2LE0OJH	4	82.776
2LE0PXH	2	41.388
C968	78	470.106
0MY001H	23	138.621
0MY002H	19	114.513
0MY003H	19	114.513
0MY004H	17	102.459
E489-I	74	421.43
0S2001D	23	130.985
0S2002D	21	119.595
0S2003D	22	125.29
0S2004D	8	45.56
E489-R	74	476.19
0S2001D	22	141.57
0S2002D	22	141.57
0S2003D	22	141.57
0S2004D	8	51.48

Route & bus	Number trips	Daily distance[km]
Total general	406	3,790.83

For the first phase of deployment, Panama is planning a procurement of a number of electric buses, to be assigned to these routes, which are currently served by 46 conventional diesel Euro III buses. The number of electric buses in the first deployment cohort was still undetermined at the time of this writing, although there was a tentative floor of 35 units. It was estimated that this base cohort would be composed of smaller 9-meter buses that would complement, not replace, diesel buses currently in service. Electric buses beyond the baseline of 35 could be a mix of sizes, although this was still undetermined. There are no clear plans for further deployments beyond this initial one. This report in part serves as guidance in this respect.

To date, MiBus has tested two electric bus models, namely a 9-meter BYD K7 and a 12-meter BYD K9FE. Both models are designed for overnight charging. A detailed technical evaluation of the tests of the former, operating in Panama City’s historic *Casco Antiguo* was presented in an earlier report. The BYD K9 was tested in several routes, for periods ranging from four to 21 days, between August 14, 2019 and March 12, 2020. These tests were conducted independently by MiBus, who reported results, some of which are summarized in

Table 4. From this set of tested routes, four are among the routes selected for initial deployment: C850, C888, C898, and C968. It is important to note that the efficiencies were estimated in a relatively crude way and they may reflect specific operation conditions during tests, and not be necessarily representative of efficiencies that might be found during actual operation on the routes. Estimation of efficiencies for the routes currently planned for deployment are discussed in depth in a separate report.<sup>22</sup>

---

<sup>22</sup> LOGIOS (2020) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 3.2.

Table 4. Reported results of tests of electric bus K9-FE, by route

Route	Distance (km)	Stops	Speed A.M. (km/h)	Speed P.M. (km/h)	Efficiency (kWh/km)
C640-I (Panamá Viejo – Albrook)	15.9	33	13.5	13.7	1.49
C640-R (Albrook – Panamá Viejo)	17.4	31	18.2	17.6	
M181-I (Los Andes – Albrook)	14.6	25	11.9	14.1	1.69
M181-R (Albrook – Los Andes)	14.6	25	18.3	7.5	
C850 (Albrook – Amador)	22.3	25	21	19.7	1.12
T176 (24 de Dic. - San Isidro)	41.5	16	33.8	28.7	1.02
E616 (Brisas del Golf)	15.4	39	15.5	14.9	1.58
S482-I (Tocumen – 5 de Mayo)	31.9	29	35.5	30.3	1.46
S482-R (5 de Mayo - Tocumen)	31.8	28	41	30.3	
K181-I (Los Andes – Albrook)	13.2	19	13	17.5	1.44
K181-R (Albrook – Los Andes)	12.8	19	15.5	9.2	
N025-I (Chilibre – Los Andes)	26.6	57	23.4	25.1	1.23
N025-R (Los Andes – Chilibre)	26.5	56	n.a.	21.7	
C888 (Iglesia del Carmen - El Cangrejo)	3.9	12	10.4	11.7	1.44
C898 (Paitilla - Plaza Edison)	8.6	21	11.5	8.1	1.48
C968 (Vía Argentina - Punta Pacífica)	6	12	13	8.9	1.58

## Focus on learning and experimentation

The first stage of deployments should focus on learning and experimentation. MiBus and partners should pursue the evaluation of as many parameters as possible, to inform future larger procurements of additional electric buses. These parameters should be understood as *extending beyond the technology*, and into all areas of the technology innovation system, such as all areas of operation of MiBus, and pertinent planning, policy, and regulatory areas. As shown in earlier

reports, the viability and efficiency, both technical and economic, of electric bus technology systems are tightly connected with operational conditions, regulatory conditions for the access to electric power, and others. Therefore, pilots should not be limited to the evaluation of a technology; they should rather be evaluations of packages of technology and interventions.

As part of the present technical assistance, MiBus will receive detailed technical evaluations of the performance of generic electric buses of different charging technologies, for operational conditions specific to the routes selected by MiBus. Regardless, the tender for the buses should include clear requirements of information relative to performance of the particular models being offered. The validation of this information should be part of the evaluation program. MiBus should establish data collection procedures that are accurate and independent of the supplier, in order to avoid potential conflicts of interest. The evaluation could involve the use of metrics such as those suggested in the risk management analysis, or variants thereof, and could be informed with data collected during the first year of operation of these buses.

Because the deployment is planned on a variety of operational conditions, the result of the evaluation will likely not be of the pass-fail type, but rather will be contingent on such operational conditions. The evaluation will give a score to each of the bus-route assignments according to the established metrics. Metrics should be developed and agreed upon *prior* to the testing and evaluation of the new electric buses, so as to enable objective evaluations. Importantly, these metrics are meant for the evaluation of one technology, not for comparisons across technologies. If metrics were to be used for the evaluation of electric buses vis-à-vis another technology, it is important that dynamic and learning effects (for example, operational adjustments) be accounted for, to help the newer technology to face a leveled competitive playing field. If metrics do not adequately account for these factors, the scores will have to be interpreted in light of additional information.

While MiBus has already decided the routes for initial deployment, it has not yet decided on the *portfolio of technologies* that may be best suited to serve these routes. A separate report is concerned with a technical evaluation of routes and technology, intended to support MiBus's decision making in this area. The selection of bus technology, particularly the charging technology, will have direct and profound implications on the planning and deployment process. Specifically, the choice of buses designed for slower overnight charging events will require a deeper assessment of the upgrades needed in the patios. For example, each charging station typically involves a concrete pad of variable length and approximately two meters wide, covered by a

canopy. In the extreme that all 35 units were located in the same patio, the power requirements at the site would be in the order of several megawatt, for which a transformer or substation will be likely needed. As discussed in detail below, MiBus would be well served by engaging the local electric utility as early in the process as feasible.

### 3.3 Phase 2: Replacement of retiring buses with electric buses

MiBus started operations in the year 2010 with a fleet of buses Volvo/Gran Viale diesel Euro III. This fleet includes 2,136 units in service today. An expansion of the fleet serving MiBus routes was announced in 2017. As part of this expansion, and following a third-party technical evaluation, 203 low-entry Volvo/MarcoPolo Torino buses were procured in a USD 36M direct contract with Volvo Do Brasil, approved by the Cabinet Council (Consejo de Gabinete). In addition to these buses, a tender for the provision of 70 new buses was implemented. Five proposals were received from local and international consortia, although eventually none of the proponents fulfilled the requirements, and the tender was declared void.

The distribution of kilometers traveled by buses in the entire fleet is shown in Figure 10. The bimodal type of distribution, with a clear difference in the mean travel distance logged to the two fleet segments, responds to the procurement schedule just described.

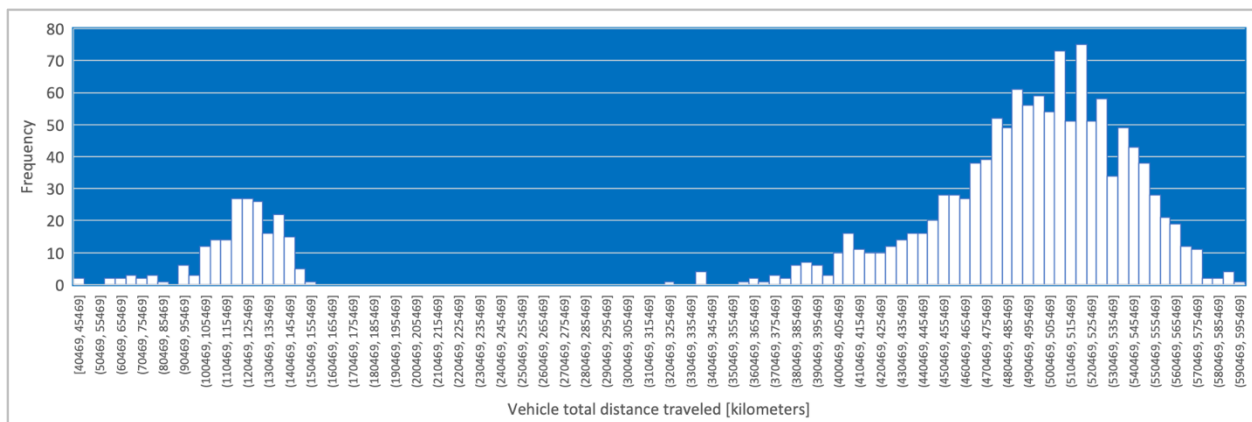


Figure 10. Histogram of total kilometers traveled to the entire fleet of MiBus (data source: MiBus).

A closer detail of the distribution of kilometers traveled by Gran Viale units is shown in Figure 11, while the cumulative distribution of kilometers across units is shown in Figure 12. The mileage of the Gran Viale fleet, based on last data received for this analysis, had a geometric mean of 494,233 kilometers, with a standard deviation of 43,417 kilometers. The histogram of logged

kilometers for the Torino fleet is shown in Figure 13, with the corresponding cumulative distribution shown in Figure 14. The geometric mean of the mileage of the Torino stands, based on latest data, at 117,121 kilometers, with a standard deviation of 20,191 kilometers.

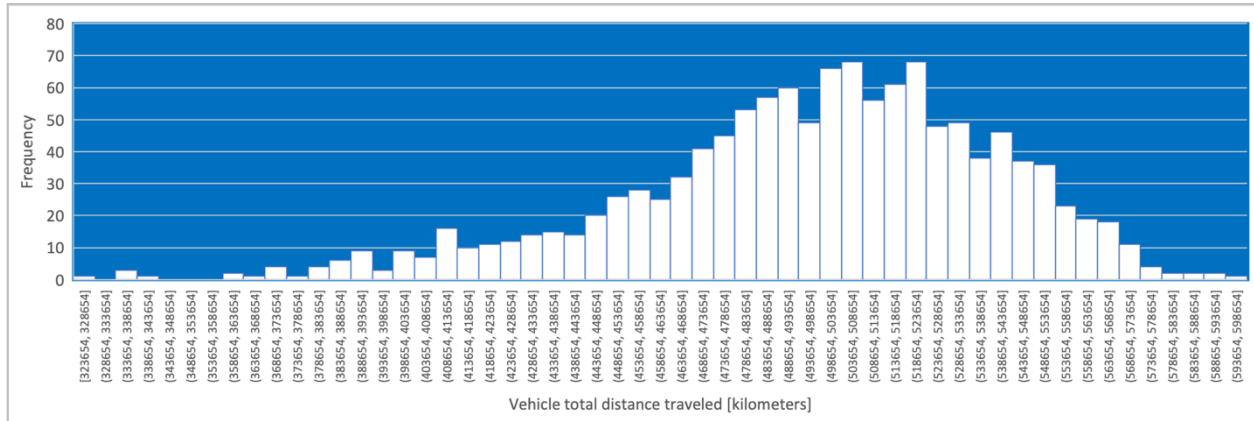


Figure 11. Histogram of total kilometers logged to the Gran Viale fleet of MiBus (data source: MiBus).

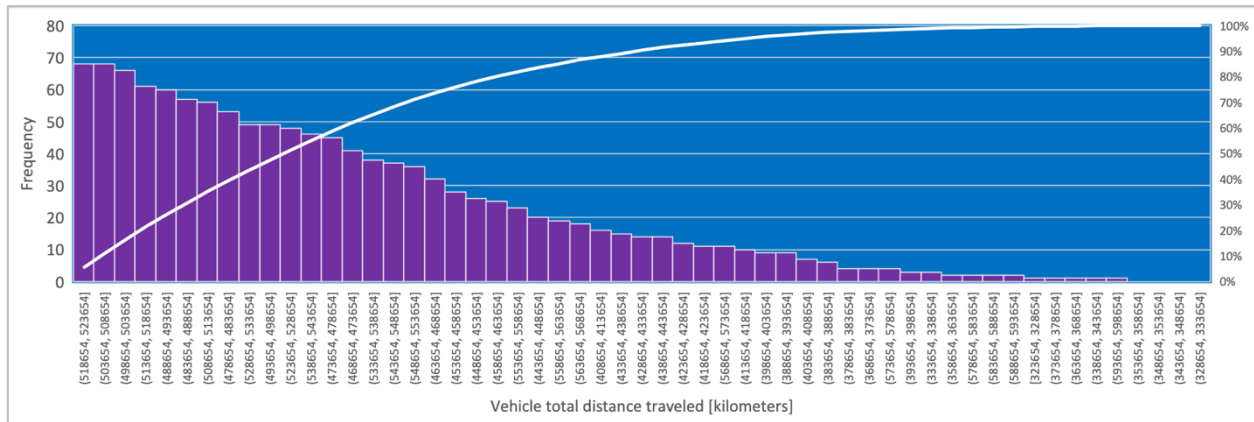


Figure 12. Cumulative distribution of total kilometers logged to the Gran Viale fleet of MiBus (data source: MiBus).

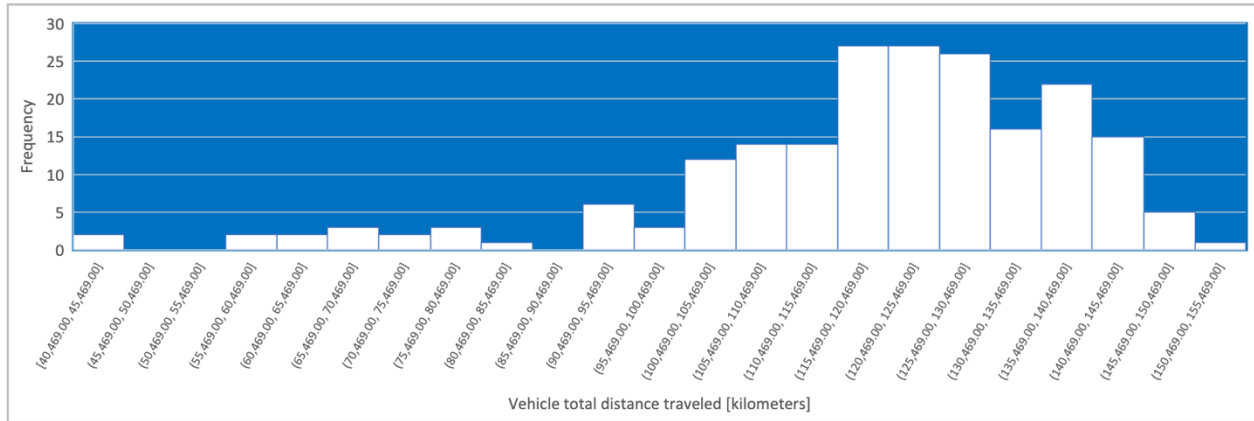


Figure 13. Histogram of total kilometers logged to the Torino fleet of MiBus (data source: MiBus).

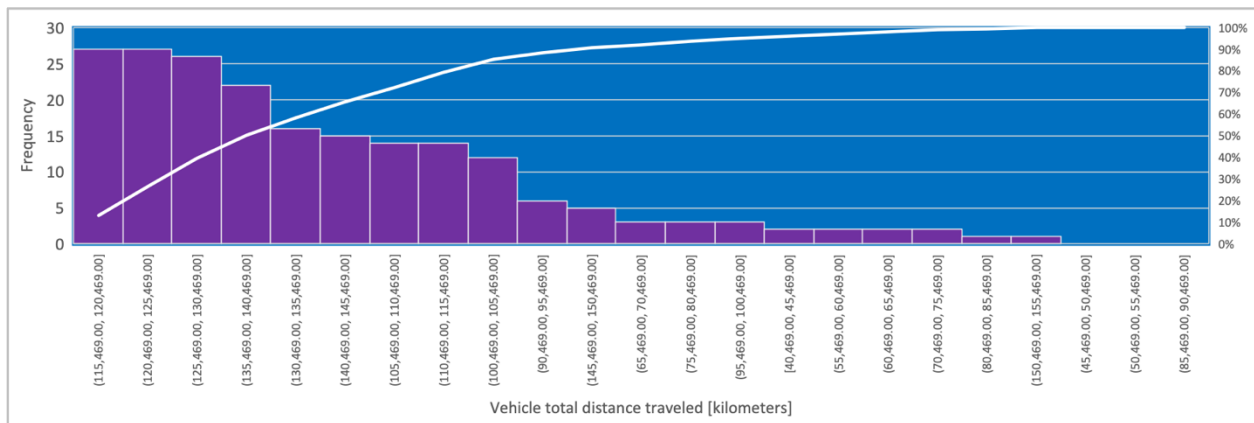


Figure 14. Cumulative distribution of total kilometers logged to the Torino fleet of MiBus (data source: MiBus).

MiBus generally uses a vehicle useful life reference of 650,000 miles. At this point, MiBus faces the decision of retiring the unit or performing a complete overhaul. Taking the current mileage distribution across units in the fleet, and estimating vehicle annual mileage based on these data, a projection of the retirement time for each unit in the fleet can be made. The results are shown in

Figure 15. The figure shows that MiBus is facing a steep fleet renovation schedule, with a peak of 250 units in the fifth semester, preceded by groups of 213, 136, and 32 buses in the fourth, third, and second semesters, respectively. As the semester count starts with the second semester of 2020, this peak is fast approaching and scheduled to happen in mid 2022.

The start of the process of fleet renovation is well timed with the opportunity to integrate electric buses. However, the schedule for the potential phasing in of new units is too aggressive to be entirely accommodated with a radical change in technology. For this reason, a possible adjustment of the schedule was investigated. Units were algorithmically assigned different annual mileages for the future, with the goal of homogenizing mileage across units. This adjustment resulted in the retirement/overhaul schedule shown in Figure 16. In this scenario, a first retirement of units, consisting of a batch of 64, could be deferred until the first half of 2022, although it would be immediately followed by the retirement of 479 units, about one third of the entire fleet, in the second semester of 2022.

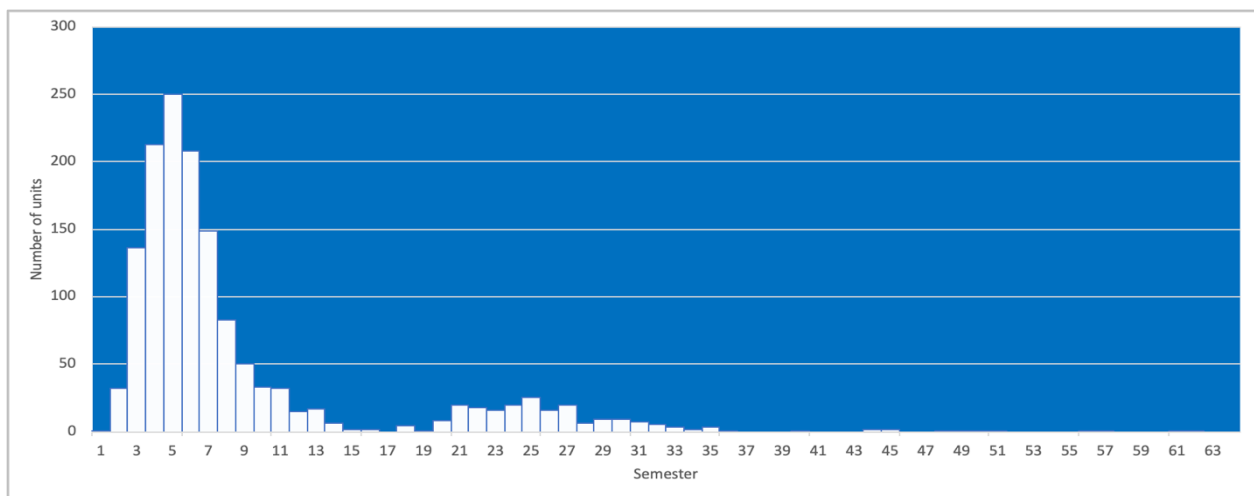


Figure 15. Number of units reaching the retirement or overhaul limit per semester, under current distribution of annual mileage.

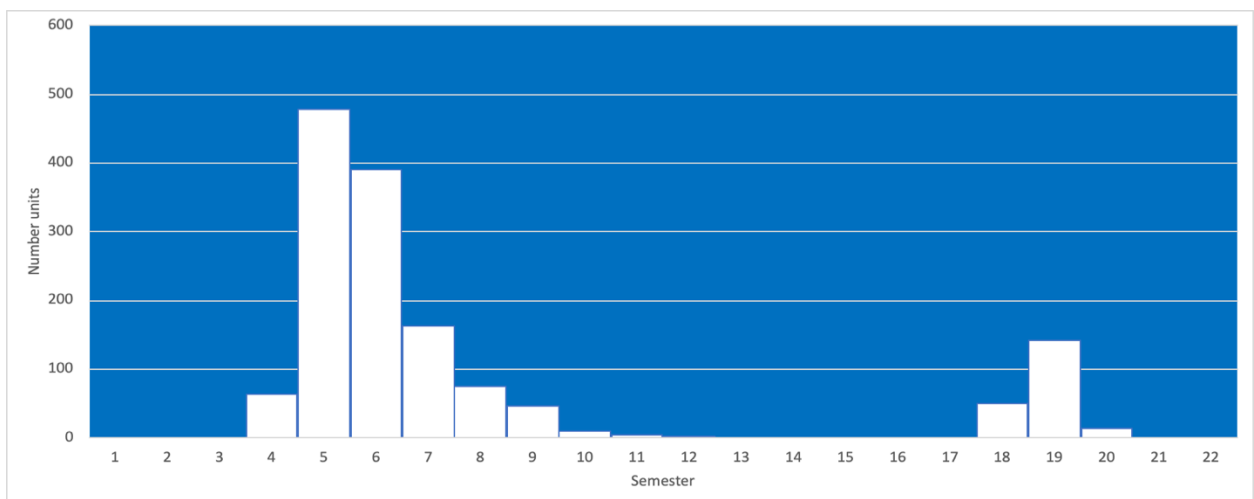


Figure 16. Number of units reaching the retirement or overhaul limit per semester, assuming homogenizations of annual mileage.

While slight further adjustments could be planned, the overall conclusion from these data is that it is late for MiBus to plan a gradual transition of all retiring vehicles to zero-emission units. Panama is thus confronted with a decision about the schedule of technology transformation for its public transport fleet. The central question facing Panama is: *How many of the buses reaching retirement age could be replaced with electric buses?* To support Panama on its decision-making process, a fleet renovation strategy is considered below.

Figure 17 shows the schedule of retiring units estimated under current conditions, along with the cumulative fraction of the fleet to be retired, per semester. The retirement schedule is bimodal, with modes in the fifth and 25<sup>th</sup> semesters, mainly reflecting the two procurement batches: a larger one for Gran Viale units and the second one for Torino units. The bimodality translates into an inflection point in the cumulative distribution of retirements, which can be observed around the 20<sup>th</sup> semester in Figure 17. The essence of the renovation strategy is deciding how many of the conventional buses reaching their useful life in the short term should be replaced with electric buses, and how many of the buses could be subject to a complete overhaul to extend their service life. An answer to this question could be obtained via mathematical optimization, although this approach runs the risk of leaving a number of factors unaccounted for.

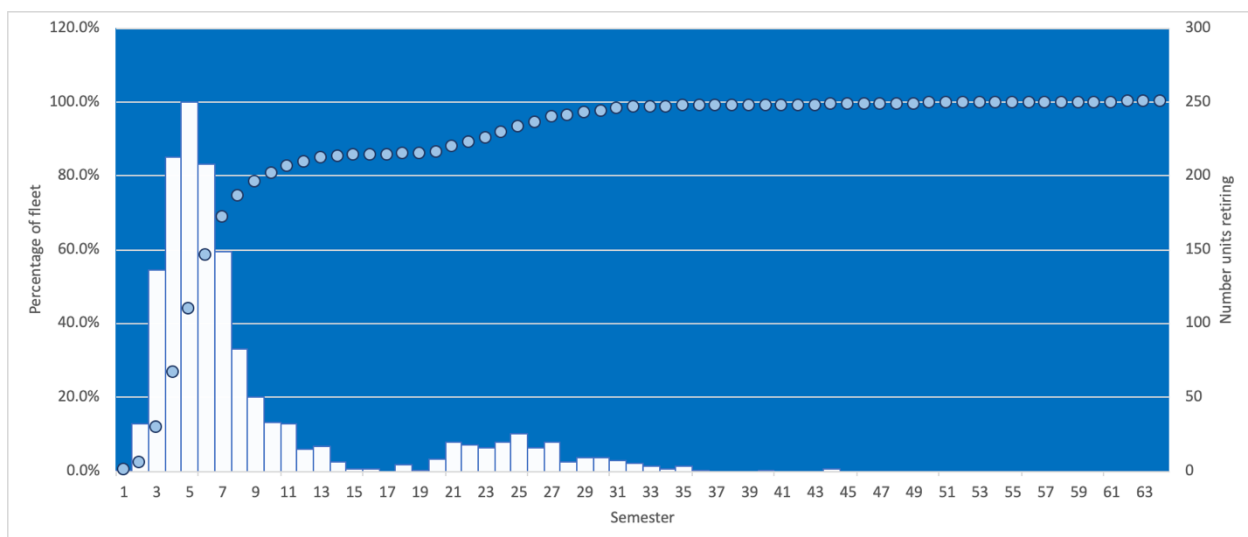


Figure 17. Count (columns) and cumulative (circles) distribution of vehicles scheduled for

retirement.

An electric bus procurement schedule could be approximated by a mathematical function, which could be used to support decisions by MiBus and the government of Panama. Typically, and based on historical cases, mathematical functions could be logarithmic, inverse exponential, and logistic. For example, an inverse exponential function of time and a parameter  $\beta$  was tested, taking  $\beta=0.12$  and  $\beta=0.15$  (the bigger  $\beta$ , the more aggressive the procurement schedule). These two cases described realistic scenarios, although they failed to properly incorporate the initial phase of deployment. Logistic functions (S-shaped) are better at incorporating early stages with slower rates of adoption, were then tested. A combination of logistic and exponential could also be used, given the shape of the schedule for retiring units (Figure 17); a logistic progression for the short- and medium-term and exponential for the long-term.

In view of the timelines facing MiBus, it is more productive to focus the analysis in the short- to medium-term. Figure 18 shows the distribution of units scheduled for retirement, the fraction of the fleet represented by these numbers, and a logistic curve that describes a *potential* progression of the fraction of the fleet that turns electric over time. As discussed above, MiBus and the government of Panama are in the process of deciding the size and characteristics of the first cohort of electric buses, as well as the exact time of deployment.

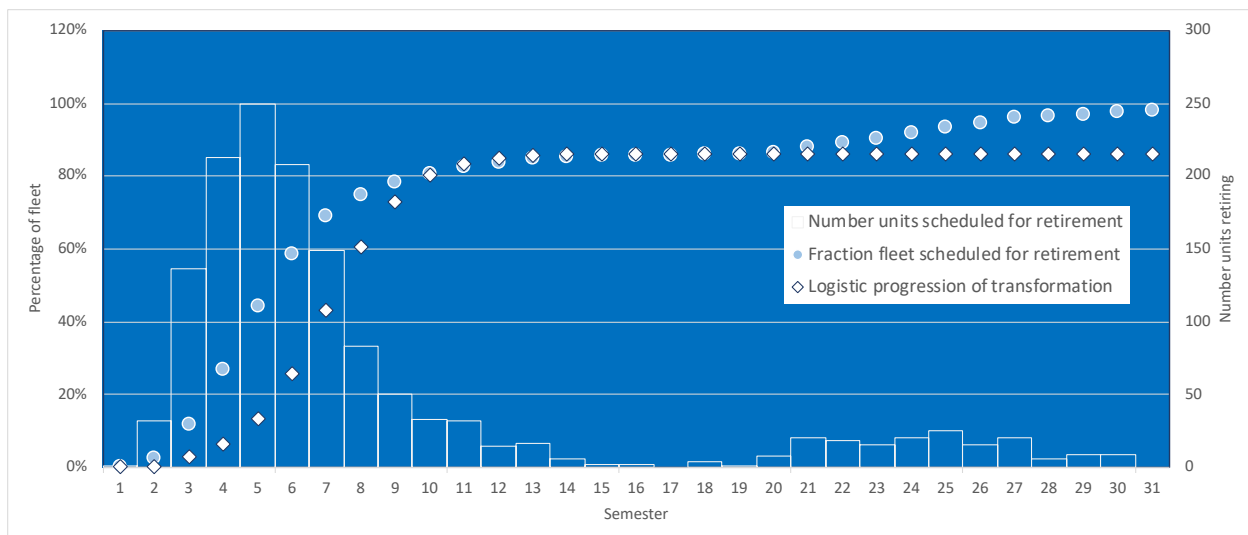


Figure 18. Number of units scheduled for retirement (columns), fraction of the fleet scheduled for retirement, and fraction of the fleet that could turn electric assuming a logistic progression.

For the purpose of analysis, the logistic curve is designed so that it approximately meets a hypothetical phase 1 deployment condition of 35 buses, starting in semester 3. The shape of the logistic curve can be changed, to reflect different possible deployment scenarios.

Keeping buses in active service beyond the 650,000 miles limit requires a complete overhaul. Therefore, the capital expense of keeping vehicles in service is approximated as

$$C^{ov} = \sum_{t=1}^T c^{ov} \times No_t$$

The replacement of a diesel engine is estimated at USD 28,000.<sup>23</sup> Referring back to Figure 18, the difference between the number of buses that are scheduled for retirement and the number of electric buses integrated to the fleet, represents the number of buses that are overhauled (instead of being retired). Because overhauled buses stay in service for an additional period of time, they will be replaced with electric buses at a later stage. These dynamics complicate the algorithms of fleet transformation.

Figure 19 shows the progression of units that are overhauled and the number of electric buses that are integrated in the fleet over time, assuming the base retirement schedule shown in Figure 17. For this particular example, it was assumed that overhauls extend the useful life of the vehicles an additional five years, and that the maximum share of the fleet that is transformed to electric during this period is 86 percent (equivalent in number of buses to the number of Gran Viale units currently in service). This scenario would carry an estimated price tag of over USD 13M for the replacement of the engines included in the overhaul of the diesel Euro III buses. The rate of fleet transformation is fairly rapid nevertheless, with 1,125 electric buses incorporated in a period of five years. This is the type of tradeoffs that MiBus will need to optimize, having a fleet quickly approaching retirement age.

---

<sup>23</sup> Communication with MiBus.

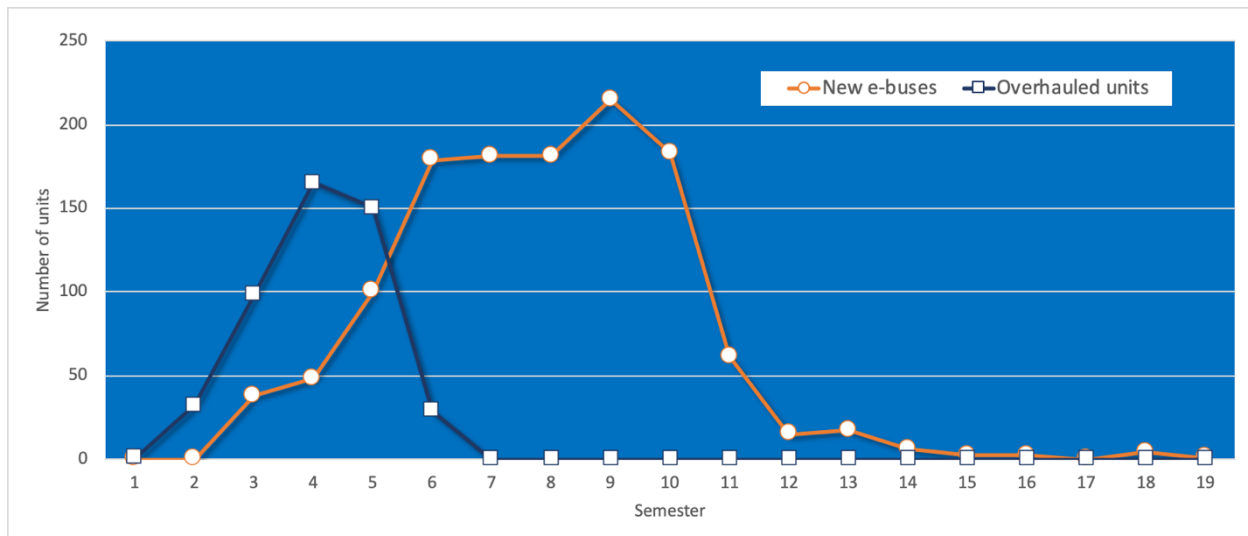


Figure 19. Possible progression of numbers of electric buses integrated in the fleet and of numbers of units overhauled.

### 3.4 Fleet transition scenarios

A central input to determine the different viable scenarios of electric vehicle integration is the age distribution for MiBus’s fleet. Assuming that units are scheduled for retirement (or overhaul) when they reach 650,000 kilometers of service, MiBus will face the most challenging decisions over the next 3-4 years, as shown in the analysis above. This can also be viewed as an opportunity to strengthen partnerships, accelerate planning, create stronger regulatory environments, developing financing mechanisms, and other steps, to enhance the viability to replace as many of the retiring buses with electric buses as practicable. In a broad sense, these discussions imply that, if the short-term retirement of units is coordinated with the integration of electric buses, MiBus may be able to exceed the goals set in the National Strategy of Electric Mobility. This will be contingent upon Panama being able to forge strong partnerships across stakeholders and engaging the right technical support.

The technology transition scenarios discussed herein are agnostic about the configuration of the electric buses to be integrated, including their charging technology. It should be kept in mind, however, that technology strategy is part of the fleet transformation plan. Some bus operators have a preference for battery electric buses capable of completing a daily duty cycle between charging episodes. Such preference may often be grounded on limited information about

technology options, uncertainties around the deployment of very high-power overhead charging infrastructure in urban areas, the potential complexities of adapting operations assigning units to match routes, and other reasons. A separate report discusses in depth the considerations around different vehicle configurations and charging technologies. From an operational and homologation perspective, an issue that has come up in a number of locations is that of weight. Overnight charging vehicles carry heavier batteries, which may bring the gross vehicle weight beyond tolerable limits for the local road infrastructure.

As discussed above, MiBus selected a set of routes for the first phase of deployment. MiBus and Panama should proactively conduct a careful selection of the routes where electric buses will be deployed in the short- and medium-term. The present technical assistance will inform MiBus and Panama about key variables to take into account for the development of such selections. The selection plan should include technical evaluations of the system of all routes, as well as other considerations, such as Panama’s priorities (environmental, political, etc.), the progress with regulatory reforms and leveling the playing field for electric vehicles, availability of financing, the selection of financing models, and such. This technical assistance showed that, because of the local climate and the extensive use of bus air conditioning units, average operational speed is an important predictor of bus efficiency (regardless of the technology of the bus). However, vehicle efficiency depends on the complex interaction of factors that are different from route to route, and these have to be correctly analyzed to arrive at informed, solid procurement decisions.

### 3.5 Bus route planning

Separate reports in this technical assistance have shown that vehicle efficiencies can vary widely depending on the operational conditions, and that technical viability and financial competitiveness depend on choosing the right system of technology assets.<sup>24</sup> <sup>25</sup> Thus, the development of a general approach to the selection of routes for the deployment of electric buses, presented in this section, builds upon the understanding that electric buses are assigned to specific sets of routes, matching vehicle configurations with the operational and energy requirements of the routes. The

---

<sup>24</sup> LOGIOS (2020) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 3.2.

<sup>25</sup> LOGIOS (2019) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 2.3 <https://www.ctc-n.org/technical-assistance/projects/accelerating-transition-sustainable-mobility-and-low-carbon-emissions>

notion of using one single configuration of electric bus to serve a system of different routes is impractical.<sup>26</sup> Adequate consideration of this fact is key for financial efficiency and the maximization of social and environmental impact.

The planning will start with the specification of objectives. The electrification of a public transport fleet typically has an underlying environmental motivation, and just as typically complementary motivations are present. The specification of motivations will help relevant stakeholders identify the routes for deployment and the methods used to identify them. From a purely technical and economic standpoint, this might be best approached as an optimization problem, for which technical assistance may be needed.

To enable effective evaluation, MiBus should consider assigning buses in the short term to a diversity of routes. The notion of electrifying an entire route has benefits, although it may be more appropriate for later deployments. In the early stage, it is important for MiBus to maximize opportunities for controlled experimentation and learning. The process of identification of bus-route combinations should take into consideration a diversity of factors, which could include the following:

- Prioritize duty-cycles that are mindful of the relatively early stage of the technology;
- Maintaining or upgrading current levels of service;
- Evaluation of information provided by manufacturers and electric utilities;
- Cost efficiency;
- Diversity of routes in terms of topography, level of service, and duty cycle;
- Diversity of unit configuration, particularly in terms of onboard energy storage systems and associated charging strategies;
- Costs and benefits related to the alternatives for siting charging infrastructure;
- Diversity of served populations.

The planning of electric bus deployment needs to recognize local factors, and thus no do-it-yourself recipe can be proposed that applies to all cases. For the purpose of proving general guidance, a simplified decision chart is proposed in Figure 20, highlighting key aspects and sequential steps in the identification of routes for the deployment of electric buses. To preserve

---

<sup>26</sup> Unless all routes are similar and selected for the purpose of fitting well the particular bus configuration.

the communication value of the chart for broader audiences, possible iterations between decision blocks are not included.

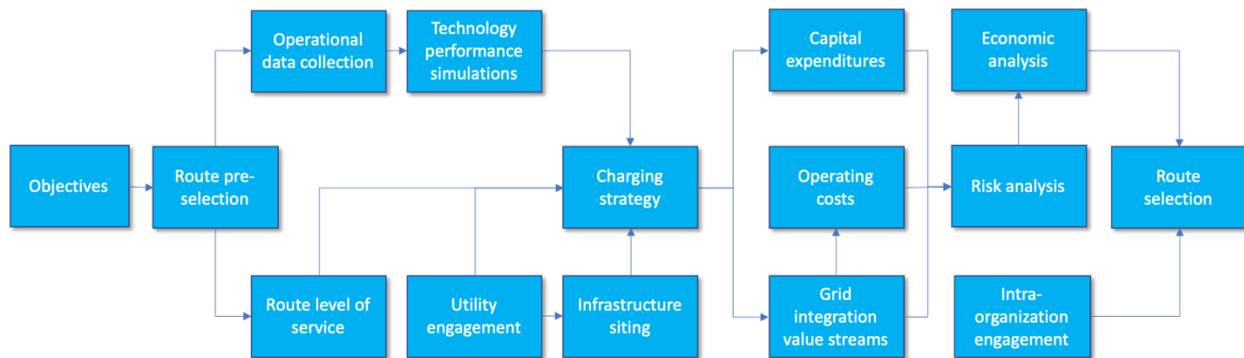


Figure 20. Simplified decision chart for the selection of bus routes for electric bus deployment

## 4. Electricity Supply Analysis

---

This section identifies strategies to help MiBus maximize predictability and cost-effectiveness of electricity supply rates for electric buses and consistent with environmental goals. Electric utility engagement is a central part of the planning of electricity supply; this section also lays out principles to guide MiBus's communication with local electric utilities.<sup>27</sup>

### 4.1 Electricity supply costs

In order to review the costs of electricity supply, it is helpful to consider separately supply factors that are driven by the power demand of the fleet of electric buses from supply factors that exist in MiBus's local power markets. MiBus has important choices to make, both in the demand and supply sides. Thus, demand and supply choices are discussed separately first, to then follow with a discussion on the integration of demand and supply considerations.

#### Implications of bus deployment choices on electricity demand

MiBus's load curve<sup>28</sup> by location can have a significant effect on its supply costs. For this reason, it is important to analyze it first, to then evaluate supply choices. That is because the charging strategy<sup>29</sup> adopted by MiBus will impact:

- Monthly peak demand charges
- Capacity-related costs and renewable energy transactions that MiBus may pursue;
- Time-of-use energy charges, which in Panama are mostly reflected in on-peak and off-peak tariffs, but could later evolve into more granular tariff systems
- Total energy charges, which depend on the efficiency of the buses, the requirements of

---

<sup>27</sup> Energy supply reliability (i.e., availability) is another important component of an electrification plan and is addressed primarily in the section on risk management.

<sup>28</sup> Load curve refers to the variation of demand over time.

<sup>29</sup> A charging strategy can be defined as the set of integrated practices adopted in order to supply electrical energy to the buses. It is analyzed for the case of MiBus in a separate report: LOGIOS (2020) Accelerating the Transition to Sustainable Mobility and Low Carbon Emissions in Panama City: Deliverable 3.2.

the routes on which they are deployed, and the efficiency of the charging infrastructure.

Electric buses should be thought of as distributed energy resources (DER). MiBus's charging strategies will also determine the *locational value* that ZEBs can access as DER. Perhaps this value cannot be internalized in Panama's present utility markets, but this may change in the future, creating opportunities for MiBus to participate in power markets, thus generating positive cash flows.

Taken together, there are several financial opportunities and risks associated with power supply for electric buses. MiBus's overall approach to electric bus planning is described in this report, while duty cycles and charging strategy are considered in a separate report. Information on fixed assets (vehicle and charging infrastructure), operational conditions, and in-route and depot charging locations are interdependent and will all be important to evaluate MiBus's electricity supply options, and choosing how to deploy, operate, and maintain assets.

## Evaluating and forecasting electricity supply options

An understanding of Panama's electricity markets, both from wholesale and retail perspectives is important to plan and manage electric bus energy supply and attain economic and environmental objectives.

### *Wholesale power market*

The purpose of this section is not to produce an in-depth description of wholesale power markets in Panama, but rather to highlight some of the issues. Wholesale markets can be complex, with considerable price volatility on annual and daily time scales. As Panama increases its renewable power installed capacity, it will start encountering net differences between generation and demand, primarily due to solar deployments; a phenomenon known as the "duck curve" (see example in Figure 16).<sup>30</sup>

A clear implication of the duck curve is that wholesale power costs are lower the greater the net

---

<sup>30</sup> This particular curve describes an example day in California.

difference between renewable generation and demand. This implies that, as Panama's solar capacity increases, MiBus's charging strategy would tilt toward mid-day charging events, while steering away from early evening charging.

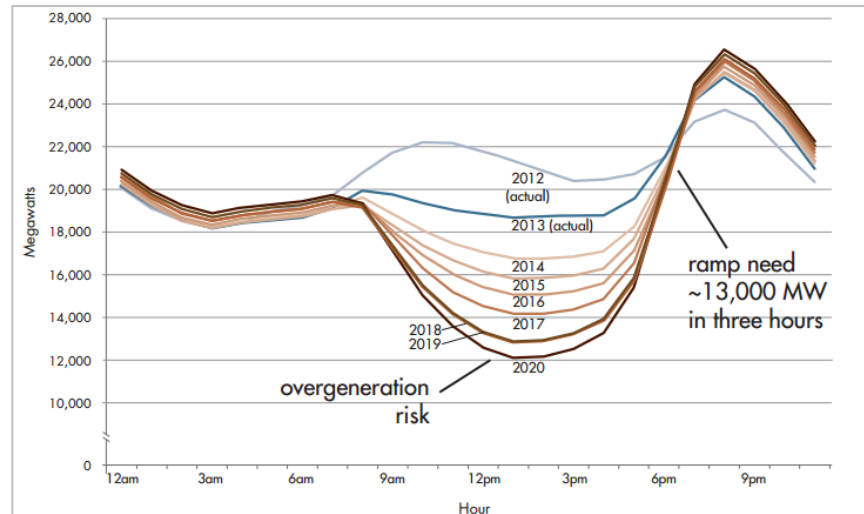


Figure 21. The “duck curve” (Image source: California Independent System Operator)

Projections of wholesale power costs are an important input for the medium- and longer-term planning of electric bus integration. This is because the wholesale portion of bundled utility electric bills is more volatile than the portion related to distribution.

To the extent that electric buses in Panama can be operated as assets integrated with the power grid, participation in revenue-generating demand management becomes possible. With the right price signals in place, participation in demand response and ancillary markets create win-win situations for both electricity system operator and fleet operator. These activities are best managed by a third-party partner.

### *Renewable energy options*

In addition to receiving bundled (generation, transmission, and distribution) electricity service from its utilities, MiBus should explore opportunities to increase the share of renewable power in its supply. In particular, long-term transactions for renewable power delivered at charging sites are a practical alternative in this regard.

MiBus should explore the availability of incentives for load shifting to accompany the growth in power generation, particularly with an eye in renewables. As mentioned above, shifting load to hours when excess of solar power starts to develop can help Panama attain its carbon mitigation goals. As long-term transactions, they also tend to have fixed prices, generally with annual price adjustment factors, that offer near price certainty for terms of over a decade on the non-distribution portions of the electricity bills. All these ideas should be part of the initial experimentation and learning process to be undertaken by MiBus *and all other relevant actors* in the first phase of deployment.

### *Utility distribution rates*

The structure of utility distribution rates will be an important factor in the operating costs of electric buses, independently of the strategies adopted to generation sourcing. MiBus should develop a careful charging strategy to address this and other challenges. Electric buses will have advantages relative to other MiBus electric loads (e.g. buildings): (a) the timing of power draws is more amenable to shaping, and (b) the location of their charging can be planned and varied strategically. Effective charging strategies are complex to implement. For example, even a one-time failure that resulted in over-clustering of charging could result in a spike in demand charges for that month.

## **Integrated analysis of electricity demand and supply**

To exploit the flexibility of electric bus loads, it is essential to conduct an analysis that pools factors related to supply and demand. A number of strategic decision points will arise from such analysis. As an example, MiBus should evaluate the level and structure of distribution rates available for different distribution utilities to inform their charging infrastructure siting and charging timing decisions. Integrated analyses can be approached as an optimization problem. The schematic in Figure 22 illustrates supply and demand variables to such problem.

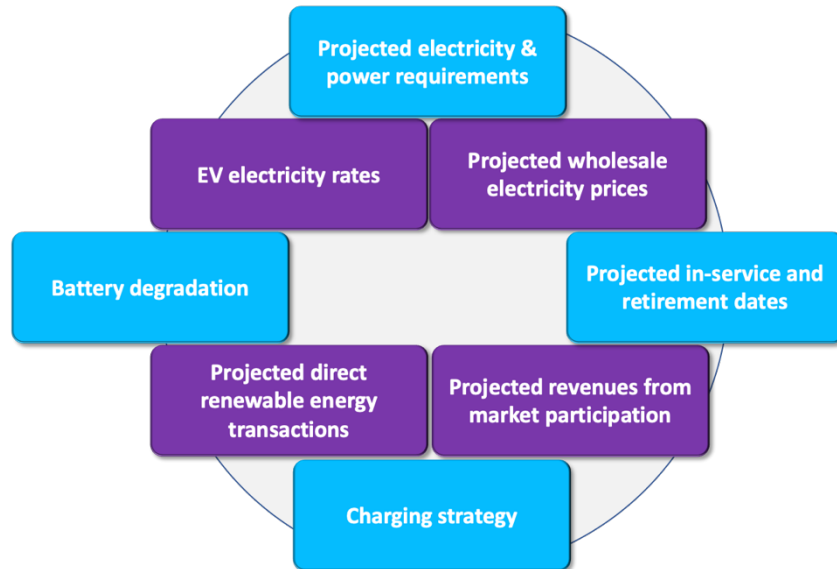


Figure 22. Sample of supply and demand variables to include in optimization problem for integrated analysis (Image: LOGIOS)

## 4.2 Utility engagement

As MiBus initiates the planning of fleet transformation, it is recommended that it develops a partnership with the local utilities. This section describes benefits and approaches to such partnerships.

### Benefits

Engaging the local utility/ies early in the planning process would be beneficial to MiBus. The key benefits are highlighted below.

#### *Cost reductions*

By working closely with the local utilities, MiBus will develop a deeper understanding of prospective monthly electric bills and learn strategies to manage them. Many of the drivers of the cost of access to electrical energy can be influenced by MiBus decisions (charging location, charging time, etc.).

### *Enhancing reliability*

Utility engagement can help MiBus identify practices to improve the reliability of service. For example, electric utilities can help identify clustering of charging events which might cause grid problems. Electric utilities can also support MiBus identify risks for power outages and available strategies to manage these risks.

### *Accelerating deployment*

Proactive engagement with the electric utilities will help streamline vehicle and charging infrastructure deployments. Utilities will inform MiBus about the incremental load that can be readily accommodated at different locations and whether and what types of upgrades of the distribution system are needed.

### *Creating organizational efficiencies within Metro*

Sometimes overlooked, one benefit of utility engagement relates the creation of organizational efficiency. The establishment of a continued communications bridge with utilities can greatly reduce time-consuming uncertainties to MiBus's staff. Time savings, derived from greater certainty in viability of asset deployment, mitigations of risks on power reliability, and the receipt of custom rate and other special analyses for MiBus, can be shared by internal divisions/groups, from planning, to finance, to operations.

## **Utility motivations for strategic partnerships**

As mentioned above, partnerships between MiBus and utilities are mutually beneficial. Electric utilities interested in working with MiBus for a variety of reasons, including:

- The potential for significant incremental revenue that the utilities can apply to their largely fixed-cost operations;
- An opportunity for learning and capacity building, that can be applied to future efforts to electrify the transportation sector; and
- The opportunity to inform the growth of these new loads, so that they help alleviate (instead of potentially exacerbate) some of the challenges derived from the growth in solar installed capacity.

## Developing a productive utility engagement strategy

The principles of an effective utility engagement strategy include:

- Lead time
- Specificity
- Optionality

### *Lead time*

Utility grid planning and ratemaking cycles typically take years. Thus, engaging the utility as early as possible may be critical. MiBus is recommended to initiate communications with local utilities as soon as possible in anticipation of the first phase of electric bus deployments. The first phase is to be centered on learning and experimentation and thus offers a fertile laboratory for both MiBus and utilities to develop deployment strategies, a data collection plan, and program evaluation. While the first phase deployments are unlikely to create negative impacts on the grid, scaling deployments are likely to require grid upgrades, or change the energy rates available to MiBus. Thus, the first phase should inform the planning of subsequent phases. It is critical to understand the value of this collaboration because early deployments may not be representative of the experience at scale if, for example, it focused on areas of the service territory that are unusually prepared or unprepared for the load.

### *Specificity*

A clear, specific electrification plan from MiBus will help electric utilities support that plan with consistent infrastructure planning, rate analysis, and operational guidance. Electric utility systems may be comprised of thousands of circuits, with different load peaks, and in the future, increasing sources of distributed solar generation. The schedule of infrastructure upgrades also differs with the location. For these and other reasons, utilities will likely prefer to have access to as much information as possible on the plans for asset (vehicle and charging infrastructure) deployment and utilization.

### *Optionality*

MiBus has a great deal of optionality as it just starts its electrification process. Options available to MiBus include the types of equipment to deploy, the timing and location where this equipment

will be brought on-line, etc. MiBus should maintain and leverage this flexibility as a key part of its utility engagement process.

MiBus should remain aware that all electric utilities will be interested in serving the incremental load coming from electric buses. As MiBus has a duty to operate at lowest cost, opportunities will present themselves for discussions about rates that can best support large-scale electric bus deployments across Panama, while remaining fair to other ratepayers.

Preserving its optionality will help MiBus position itself well for effective utility engagement. This means that MiBus, to the maximum extent possible, should avoid committing too early to certain types of equipment, deployment locations, etc., as this will reduce its options.

## **5. Electric buses as part of an integrated plan for sustainable mobility**

---

### **5.1 A New Era**

The planning and renewal of the bus fleet are cogs in a larger mechanism called sustainable mobility. Electric buses should not be considered as an independent policy, they are part of an ecosystem in conjunction with the rest of the transportation system. The sustainability of transport is a transversal axis to all activities related to it. That is why the following key aspects of the new mobility must be taken into account when making decisions for the development of the transportation system.

### **5.2 Monitoring and Evaluation**

Information and Communications Technology increasingly opens opportunities for the collection of data to monitor and evaluate transportation systems. It is critical that data collected from different sources be readily accessible for integrated analytics, to deliver system-wide diagnostics. There will be a need for partnerships with third-party providers with the capability to manage and analyze transport big data, as well as the creation of local capacity for the integration of this information into city operations and planning.

Data and, importantly, good analytics performed on them, will be key to evidence-based decision making for sustainable public transport. Panama will have to identify indicators to measure progress.

The Inter-Agency and Expert Group on Sustainable Development Goals Indicators (IAEG-SDGs) developed a global indicator framework, including a list of 230 indicators. Given the ubiquitous influence of transportation on development, many of these indicators can be related to sustainable transportation systems. Indicators that are directly related to transport include the following:<sup>31</sup>

3.6. By 2020, halve the number of global deaths and injuries from road traffic accidents.

7.3 By 2030, double the global rate of improvement in energy efficiency.

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

9.1.1 Proportion of the rural population who live within 2 km of an all-season road.

9.1.2 Passenger and freight volumes, by mode of transport.

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transportation systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

11.2.1 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities.

---

<sup>31</sup> Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (E/CN.3/2016/2/Rev.1)

12.c. Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities.

12.c.1 Amount of fossil-fuel subsidies per unit of GDP (production and consumption) and as a proportion of total national expenditure on fossil fuels

In addition to the outcome-oriented indicators proposed by IAEG-SDGs, other, more granular indicators will be needed for program and investment evaluation. In particular for the case of fleet modernization, data can and should be used for:

- Implementation of efficient and transparent procurement processes,
- Technical assistances for the evaluation of technology systems needed to deliver specific transport services in Panama,
- Monitoring and auditing of technology performance,
- Identification of policies and planning strategies to support the deployment and efficiency of clean transport technologies,
- Evaluation of the impact of technology and planning programs on the use of public transport and quality of life.

Adopting the right indicators and making progress toward them will not necessarily be easy. Transitioning to a sustainable transportation system will require, precisely, a transition away from any present inefficient transport practices (e.g. moving trips from personal vehicles to more sustainable modes), which at times might be, at face value, unpopular. For this reason, a sustainable mobility plan must be accompanied by a strong public education campaign. Panama has seen a significant growth in vehicle ownership (Figure 23,

Figure 24) which, given the present regulatory framework and road infrastructure in Panama, results in blatant externalities, such as increases in air contamination and traffic delays. As discussed above, the creation of a sustainable transportation system needs of new technology, but technology needs of the right conditions to thrive and deliver their potential environmental and

social benefits. Complementary strategies and policies will be needed, as discussed below.

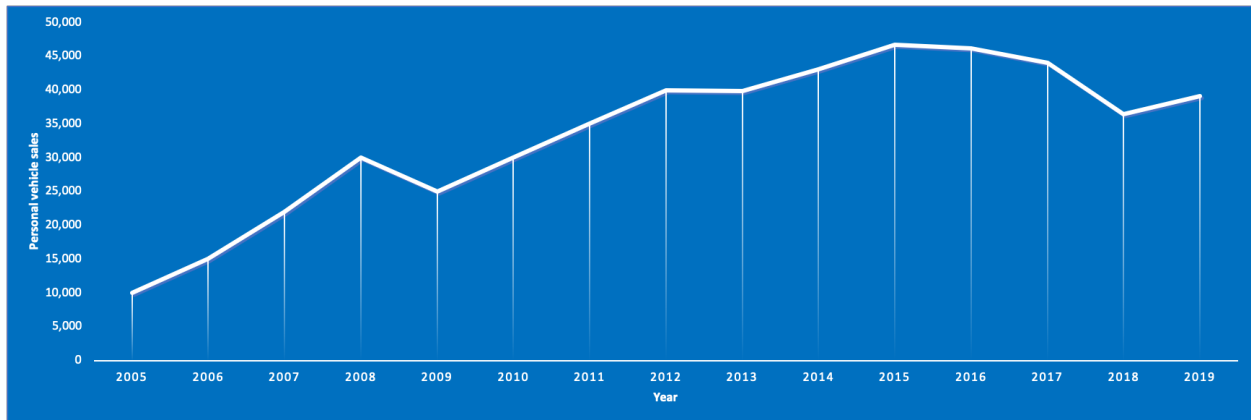


Figure 23. Personal vehicles sales in Panama (Source: International Organization of Motor Vehicle Manufacturers)

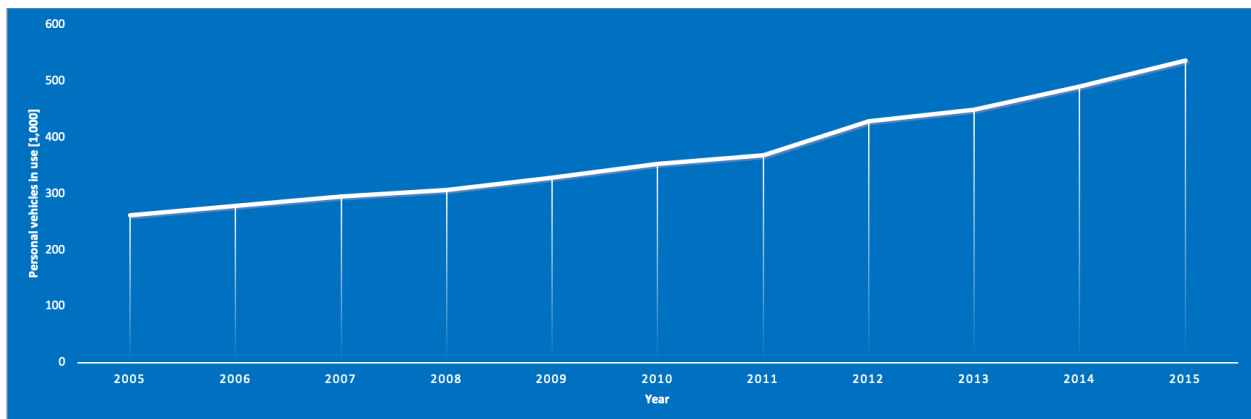
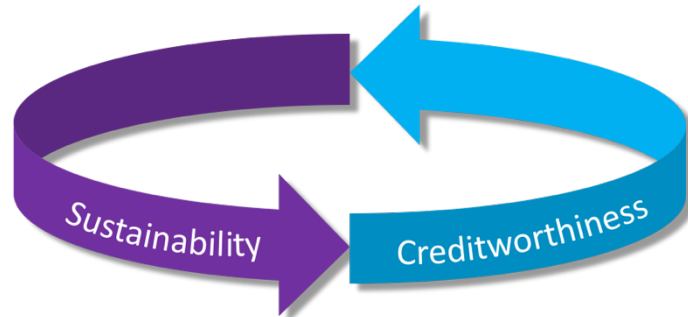


Figure 24. Personal vehicles in use in Panama (Source: International Organization of Motor Vehicle Manufacturers)

### 5.3 Financing

Cities in developing countries are growing at a significant pace, putting great pressure on public infrastructure needs, including transport. It is estimated that the investment needed for infrastructure just to keep pace with this growth, is in the order of USD 1.3 trillion per year. The transformation of a transportation system will require the adjustment and evolution of financing frameworks, to enable the needed investments. A key step in this direction is the collaboration between policy makers, multilateral banks, and local and global financial institutions; a step

already included as an action item in Panama’s National Strategy for Electric Mobility. To the extent that urban transport is planned and managed at the metropolitan level, it is desirable to help cities attain higher discretion in the use of tax revenues and borrowing from international financial institutions. Access to long-term capital is, however, often challenging for cities. A study showed that only 16% of the countries in the sample granted significant tax autonomy to their local governments, while 56% of the national governments granted no authority for local governments to borrow money.<sup>32</sup> One root reason for this is cities’



creditworthiness, and thus efforts are underway to support cities in this regard.<sup>33</sup> For example, the World Bank implemented the City Creditworthiness Initiative, to help create conditions for city access to capital. Interestingly, some evidence suggests that sustainability policies may have a positive effect on city creditworthiness.<sup>34</sup> This might open opportunities for virtuous cycles. Investments in sustainable infrastructure can have climate as well as development impacts. Evidence suggests that the latter have a larger impact on project bankability, and points to the importance of monetization of development co-benefits for project evaluation — an area of special interest to multilateral banks.<sup>35</sup>

It is common for much of the investments in public transport to be financed with public sources; this has been the case for the purchase of the MiBus fleet. Public-private partnerships (PPP) have been identified by the 2030 Agenda for Sustainable Development as a key venue to achieve

---

<sup>32</sup> Floater, Graham, Dan Dowling, Denise Chan, Matthew Ulterino, Juergen Braunstein, Tim McMinn, and Ehtisham Ahmad (2017) *Global Review of Finance for Sustainable Urban Infrastructure*. Coalition for Urban Transitions

<sup>33</sup> Panama’s credit rating was set by S&P at BBB+ with negative outlook on April 2020.

<sup>34</sup> Rashidi, Kaveh, Martin Stadelmann, Anthony Pratt (2019) Creditworthiness and climate: Identifying a hidden financial co-benefit of municipal climate adaptation and mitigation policies. *Energy Research & Social Science* **48**: 131-138.

<sup>35</sup> For example, Rashidi, Kaveh, Martin Stadelmann, Anthony Pratt (2017) Valuing co-benefits to make low-carbon investments in cities bankable: The case of waste and transportation projects. *Sustainable Cities and Society* **34**: 69-78.

sustainable development goals. PPPs should be endowed with safeguards that maintain the spirit of sustainable development and align as much as possible the financial interests of the partners.

Certainly, investments in sustainable transportation systems must come with mechanisms to encourage their utilization and achievement of the desired societal goals. A modern and clean fleet of buses that is underutilized may be indicative of poor or incomplete planning. A number of market-based instruments are available to send the right market signals, inducing socially conscious travel choices.

Sustainability needs to be thought of in broader terms than just environmental sustainability. Financial sustainability is also necessary when evaluating and designing urban transport development projects. A healthy investment plan involves cash-flow projection incorporating contingencies, a viable asset scheme and predictable incomes.

Managing the transition to a low emissions transport sector in a cost-effective way is an important way to manage climate change risks as well as long-term financial risks. Moving people from high-emitting vehicles to more sustainable transport modes is an important step in reducing emissions and bringing transportation an equilibrated financing horizon.

According to the terms of contract 21-2010, MiBus *could* accrue revenues from the following sources:

- Passenger fares: this is adjustable over time and requires approval from ATTT;
- Advertisement, both static and dynamic
- Sale of information to third parties, within certain parameters and contingent on approval by ATTT (this does not apply now that MiBus is a public entity and, by law, all data is public);
- Businesses and advertisement located in bus stops and terminals (this does not apply now, as ATTT pays MiBus for the maintenance of these spaces in San Miguelito, and the Municipality of Panama has exclusive rights to the use of bus stop space for commercial advertisement);
- Other.

Passenger pay just one fare per trip, independently of the number of connections they make along

the way. Fares are structured around three categories, namely (a) truncl and transversal, (b) express and semi-express, and (c) discounted. At the moment of signing the concession contract, fares were set at B/.0.64 for truncl and transversal and B/.1.10 for express and semi-express. These fares can be adjusted according to two parameters: (i) consistency with a “model of efficient enterprise”, to be developed by the ATTT, and (ii) an adjustment polynomial that has the following form:

$$R = 0.37I + 0.35P + 0.26D + 0.02N$$

In the above,  $I$  is the inflation rate,  $P$  is the change in an index measuring labor costs,  $D$  is a reference price of diesel, and  $N$  is reference cost of tire replacement. The responsibility for developing projections, critical for the projections of revenues and the overall financial planning of the public transport service, falls upon MiBus. In the context of a sustainable transportation system, demand mustn't be considered as exogenous, but rather as an *endogenous* result of the actions of all the public actors with influence upon demand. The ATTT has the authority to implement measures that, if needed, could compensate MiBus for any lag in rate adjustments. Such measures could include the extension of the concession, granting MiBus rights on collateral businesses, etc. Fares are collected via a system called *Tarjeta Metrobus* that allows users to pay using a card with a chip. The technical tariffs at the time of this writing were determined at USD 0.366 for students, USD 0.844 for truncl routes, and USD 1.84 for corridors. The Panamanian government offers subsidies for these tariffs, rendering the tariffs that users pay at USD 0.10 for students, USD 0.25 for truncl routes, and USD 0.75 for corridors.<sup>36</sup> All collection from fares is managed with an escrow. Complementary measures to induce higher ridership are not only part of good management of the road network, but also creates additional cash flows that could be reinvested in fleet renovation.

## 5.4 Intermodal infrastructure and last mile transport solutions

The utilization of electric buses combined with other fast and environmentally friendly modes like

---

<sup>36</sup> Based on information provided by MiBus. Older information can be found at <https://mibus.com.pa/wp-content/uploads/transparencia/otros/documentos-legales/contrato-21-10/adendas/>

the metro is more energy efficient than the use of conventional private cars. However, users still seek the comfort, safety, and overall *relative* convenience of private vehicles. The focus of the discussion is on the transition from the use of conventional private cars to the use of different ways of transportation by integrating terminals aiming to reduce the time of travel from origin to the destination.

The promotion of an integrated sustainable transportation system (bus, metro, last mile system, and supporting infrastructure) as a more agile and intelligent mode of transport than the automobile in Panama is central to the debate on sustainable transport. Although public transit is almost always the cheaper option, it is often a lot more costly in time and other attributes (e.g. safety, comfort, etc.). Plus, when considering conditions such as the first and last mile problem, crowding, and adverse weather, the automobile becomes a much more desirable option. Buses are the best-prepared vehicles to streamline the public transportation system, to bring travel times to a more convenient standard than private cars and to provide comfort and convenience to the user.

In order to achieve these objectives, the construction of exclusive/segregated bus lanes or BRTs can prove essential, considering the demographic, social and economic characteristics of the area.



Figure 25. Classical structure of a two-lane BRT (Source: NACTO, 2018)

With few exceptions, and unlike rail mass transit, implementation of exclusive lanes or BRT systems requires substantial changes to road layout, particularly the reduction of mixed traffic lanes. BRT competes for space with existing vehicle traffic and creates visual and physical barriers, with considerable implications for the politics and technical aspects of implementation. Controversy regarding the usage of general traffic lanes has prevented many cities from implementing or, as is often the case, expanding systems as planned, as voices are raised against reductions in road space. Such push back often ignores the fact that segregated bus lanes/BRT lanes are much more efficient in moving people, and that traditional buses are removed from mixed traffic. Nevertheless, perceived negative effects on traffic flow might undermine the political feasibility of certain projects, especially in comparison with metro systems. From a technical perspective, the road space allocation for lane segregation/BRT corridors is primarily a trade-off between space, cost, and capacity.

The positive effects on average speed of buses that circulate in exclusive lanes are well documented. For example, the construction of dedicated bus lanes in New York reduced the average commercial speed of the lines involved by 25%.<sup>37</sup> In Buenos Aires, MTB 9 de Julio generated drastic drops in commercial speeds of up to 33% of the lines that transit it (GCBA, 2011). The positive effects are magnified for the case electric buses, as they provide the technology with a more comfortable ecosystem to deliver best efficiencies, lower capital and operating costs, and overall longer battery life. Transport infrastructure must guarantee the predictability and minimization of travel times for users. *Relative* travel times will be one of the main reasons to decrease the use of private vehicles in aggregate terms and encourage the use of public transport, in addition to comfort, fare, predictability, accessibility, and many other factors. In this context, Panama City could plan an integrated system of segregated lanes/BRTs taking into consideration pre-existing means of transportation and features, such as metro service, bicycle lanes, or transfer centers.

---

<sup>37</sup> *Better Buses Action Plan*, NYC DOT (2019). <https://www1.nyc.gov/html/brt/downloads/pdf/better-buses-action-plan-2019.pdf>

Improving the level of service of public transport is an explicit goal of systems with exclusive lanes. According to this reasoning, replacing informal and/or conventional bus service with exclusive-lane systems significantly improves travel time, reliability, comfort and safety. While systems with dedicated rights-of-way, frequent services, off-board fare collection, and high operating speeds represent a major improvement in terms of speed and reliability over informal systems, there are trade-offs, especially regarding flexibility and demand responsiveness. In contrast to conventional bus operations, exclusive-lane systems concentrate passenger traffic along corridors with fixed infrastructure in a trunk-and-feeder system. Where trunk lines are further from origin and destination points, more transfers become necessary, in contrast to pre-existing informal transit, which operates more direct routes.

Another major objective in the implementation of exclusive-lane systems is to make the public transportation system more sustainable, mainly (though not only) by reducing emissions and improving air quality. Introducing exclusive-lane systems can achieve this at least in two ways: first, higher capacity and efficiency in bus operations, including routes redesign, reduces vehicle miles travelled; second, by replacing obsolete informal buses with modern buses that meet tighter emission standards. Relative to the latter, introducing electric buses would result in bringing the urban emission of criteria pollutants down to zero, significantly improving quality of life for users and the general population, particularly pedestrians, cyclists, and residents along and near the bus route.

A coordinated, efficient, and safe public transportation system reduces negative externalities. One of the most damaging effects of transportation is road accidents. The ordering of vehicular traffic with priority in buses, cyclists and pedestrians drastically reduces the fatality rate of accidents, within the framework of other traffic-calming policies such as pedestrian interventions or construction of bicycle lanes. The construction of exclusive-lane systems could be planned as a traffic-calming policy itself. Appropriate speed limits take the function and surroundings of a road into account. An arterial road with adjacent vacant lots should not have the same speed limit as an arterial with commercial land uses. When considering an arterial road with level intersections and presence of pedestrians and cyclists, the maximum speed should be 50 km/h. For a local road with educational and health facilities close by, the maximum recommended speed is 30 km/h. For surrounding parks and places where children play, recommended speeds are no higher than 20 km/h. However, the designation and signage of a speed limit does not by itself guarantee that it will be abided by. There is also a need for enforcement measures such as infrastructure,

regulation, and police control, that guarantee that operating speeds do not exceed established limits.

Bicycle lanes are the ideal complement for bus renovation in Panamá. They are essential to energize the integrated transportation system. Not only is it a matter of intermodal transport, bike lanes elicit the replacement of car trips with bicycle trips, simultaneously achieving a variety of objectives. Experience from other urban areas, such as Bogotá, Santiago, and Buenos Aires, shows that indeed the development of modern systems of bike lanes can be successful at moving people out of their cars. Reduction of vehicles on the streets due to an eventual transfer of users to the bicycle improves travel experience for both bicycle and cars users.

Though hardly revolutionary or innovative, the most sustainable form of transport is also most central to the human condition; namely, the use of the human body's metabolic energy to travel. Humans have always walked and have continued to do so even as urbanization and motorization has dramatically changed their living environment. A second human-powered travel mode developed in the 19th century – the bicycle – increased the speed, efficiency and ease of human-powered mobility, and ultimately became one of the main forms of personal transport in many parts of the world. Both active travel modes burn calories rather than fuel, and therefore emit no pollutants, result in numerous health benefits, and carry little to no monetary cost to the user. Moreover, as a fundamentally human-scale form of transport, active modes require small amounts of space and are not a risk to other road users. In Panama City, and so many of today's congested and polluted cities, these benefits seem to indicate an obvious tool to address many of the problems of urban mobility.

Bike lanes are one of the most common forms of cycling infrastructure. They form part of the carriageway and are distinguished for cycle use by continuous road markings that delineate the edge of the cycle lane. The main aim of cycle lanes is to indicate road space reserved for the use by bicycles on the carriageway. A bicycle symbol will often be used at the beginning and end of the cycle lane or repeated throughout the entirety of the lane. Coloring may also be used to increase visibility.

The suitability of different infrastructure for moving cycling traffic depends on the space available, the number of people cycling, the volume of road traffic and the speed of traffic. Outside of built-up areas, the implementation of bike lanes is most suitable on roads with low traffic volumes

(2,000-3,000 passenger cars units per day) and vehicle speeds below 60km/h. Within built-up areas, bike lanes can be considered on busy cycle routes but only where traffic speed is low (up to 30km/h), and where road speeds are high (up to 50km/h), cycle tracks are more suitable.<sup>38</sup> Cycle lanes are quick to implement as they adapt to the existing carriageway. They provide a legally reserved space to cycle without mixing with road traffic, increasing safety, accessibility and comfort.

As city populations grow, motor vehicle congestion increases. New roads are rarely an option in mature cities. Protected bike lanes bring order and predictability to streets and provide transportation choices while helping to build neighborhoods where everyone enjoys spending time. By extending the geographic range of travel, bike lanes help neighborhoods redevelop.

Increasing bicycle use in a population improves health levels. The effects of physical activity on cardiovascular health and the prevention of different diseases have been verified. Furthermore, these positive consequences are fed back by the improvement in the environment due to the choice of a non-polluting mode of transport. It is important to take measures to promote bicycle use from different government or business spaces. Different countries have adopted salary incentive policies for workers who use the bicycle to go to work. It is essential to encourage citizens to take the first step by investing in safe, efficient, reliable and useful infrastructure for cyclists. Then the integrated transportation system will be renewed.

An excellent push to encourage users to use a bicycle is the implementation of a public bicycle transportation system (PBTS) in high-demand areas, financed via public fare, sponsors and advertising. Alternatively, a concession of the service to a private agent can be managed. Empirical evidence (e.g. case of Buenos Aires) suggest that it is important to think of the PBTS as a link for the user to buy their own bicycle in the future. In other words, public bicycles act as a "sample" for people to discover the benefits of riding a bicycle.

Information and communication technologies (ICTs) have dramatically transformed the daily lives of urban dwellers around the world, and Panama is no exception. MiBus Maps Panamá is a mobile application that helps users identify closer bus stops, spot the location of buses in near-real time,

---

<sup>38</sup> National Association of City Transportation Officials (2013). *Urban Street Design Guide*. Island Press.

and plan their trips. Although the app, which was downloaded more than 100,000 times, is receiving significant volumes of feedback from users (for example, on the route planning feature), it constitutes a platform that should be expanded to include the entire system of sustainable transport in Panama City. It can help Panama understand demand for transportation services complementary to the bus and inform future investments in first-mile-last-mile alternatives. There are several ways in which MiBus Maps Panamá could be expanded in relation to electric buses, collecting user feedback, gamification of trips, etc. Collecting data on the human dimension of electric/sustainable public transport would be extremely useful, for program evaluation, to measure social impact, etc.

One of the clearest impacts of ICTs has been the emergence of Mobility as a Service (MaaS), a concept which, although may be used to describe traditional forms of transport, has now been inextricably linked to technology and mobile applications. While MaaS has been defined in terms of new technologies, it is ultimately based on the idea that what urban dwellers require is access to the different opportunities the city offers. In other words, they do not require a specific asset – for example, a car – rather, they require a *service*: one that provides them with mobility and suits their specific needs of comfort, security, accessibility, travel time and walking distance from their origins to their destinations.

While this perspective can be applied to traditional high-quality public transportation systems, the rise of app-based services, the sharing economy and their impact on traditional modes of transport has made it necessary to introduce a new concept that encompasses all these characteristics. Consequently, the concept of MaaS has been defined according to the features of these services, as a user-centric, intelligent mobility management and distribution system, in which an integrator brings together offerings of multiple mobility service providers, and provides end-users access to them through a digital interface, allowing them to seamlessly plan and pay for mobility.

Many times, car users are discouraged from using public transport because neither the metro nor the bus take them close enough to their destination. However, they are likely to travel a reasonably close distance to use a public bicycle or some other micro-mobility device. Smart stations, good information and reasonable prices can balance users' decisions and encourage them to use public transport. In fact, some special rate if the person is a user of public transport can be studied. Coordination with micro mobility companies will be necessary to increase the offer of small

vehicles that allow the user to make their last trip to the destination in a comfortable, safe and sustainable way.

## 5.5 Accessibility and pricing policy

Traditionally, the design, construction and operation of urban public transportation systems has responded to criteria and planning strategies focused on the average user. These traditional transport planning principles tend to homogenize users, based on high-demand periods and zones, assuming that observable mobility patterns reflect the travel needs of the entire population. This has led to the standardization of characteristics and necessities, resulting in transportation systems designed for users with specific characteristics: working-age men with an average willingness/ability to pay, and physically and cognitively able. However, this perspective fails to recognize that many urban residents do not find themselves in a similar social, physical, and/or economic position to take advantage of available transportation systems.

Accessibility can be defined as the 'ease to reach desired destinations, given the available opportunities and impedance – understood as the associated difficulty or cost – intrinsic of the resources utilized to travel between the origin and destination'.<sup>39</sup> This reflects the central nature of the concepts of accessibility and access in urban transport planning, incorporating aspects of the city such as social and economic structure and urban form.

The opportunities and impedances in Panamá considered through the lens of accessibility are directly related to the socioeconomic segment of transport users, urban development trajectories, planning and infrastructure provision practices that allow individuals or social groups to access and carry out necessary or desired activities. Therefore, accessibility is narrowly related to equity, as it is a function of the spatial and social distribution of available opportunities for access to goods, services and employment.

Accessibility can be explained from different points of view. In terms of pricing policy, everyone

---

<sup>39</sup> De Rús, Ginés (2003). *Economía del Transporte*. Antoni Bosch Editor.

who needs public transport should be able to use it regardless of their socioeconomic situation. Also, everyone should be able to enjoy a bus trip regardless of their physical conditions. From a geographical perspective, an integrated design must be guaranteed, and an efficient last mile system is required to reach and cover the entire population. Figure 26 shows a conservative first approximation to the increase in accessibility that might be obtained by integrating route C938 with a bike first-mile-last-mile system, assuming a radius for bike trips to and from bus stops of 750 meters.

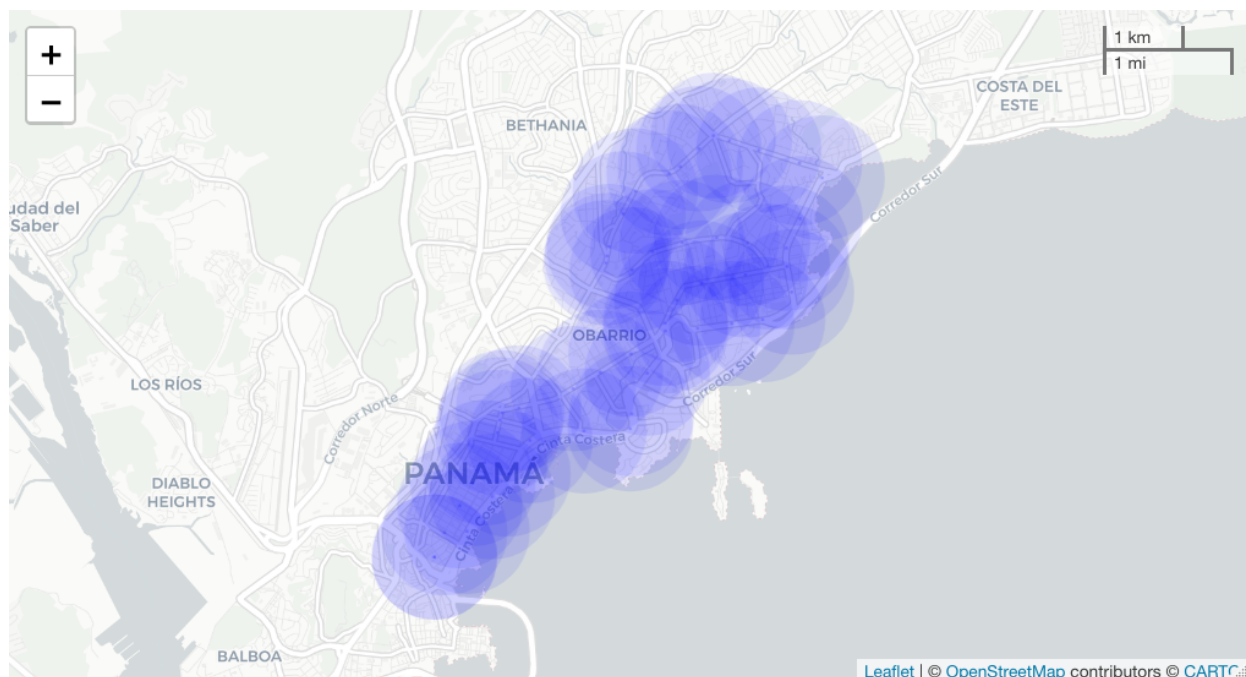


Figure 26. Approximate coverage of route C938 (Source: LOGIOS)

Sustainable transportation can enhance economic growth and improve accessibility while achieving better integration of the economy and respecting the environment. Fast, affordable, reliable public transport networks in urban environments provide massive benefits to the communities that invest in them. Providing options other than driving a personal vehicle helps get cars off the road, reduces congestion, alleviates stress and significantly improves health. Fewer cars on the road also means smoother movement of goods, a boon to local economies.

The role of transport in the development process is manifold and well documented. As a result, policy makers usually face a multiplicity of objectives to regulate a complex set of interrelated activities, which affect diverse groups of society. Provision of transport services involves costs that need to be reflected in the prices charged for these services. This is a problem of political economy, especially for the developing countries which have constantly to grapple with the problem: whether these costs should be fully reflected in prices at all levels of service; and if not, how to fund the gaps.

In a 'first-best world' characterized by perfect competition, the market will set prices equal to marginal social cost and thereby maximize social welfare. However, conditions necessary for a 'first-best world' rarely exist, if at all. Hence, the markets will not set transport prices equal to marginal social cost. This underscores the need for regulation and targeted policies.

Urban transport pricing in Panamá should fulfil three functions: ration and allocate the use of competing resources; signal the need for investment; and help in generating funds for the development of the related sectors. The price charged to the users should cover the full social cost of their trips. In most countries, both developed and developing, urban roads are provided to the users without imposing on them any direct user charge. The only payment from the private user to the public supplier comes indirectly in the form of taxes, primarily on fuel. These taxes, however, are not meant as compensation for the costs of congestion.

The congestion externality is not internalized via price signals in Panamá. The well-known result is that the cost perceived by every additional road user is his/her own private cost and does not include the cost imposed upon the rest of the users (i.e. the cost to others of slowing down traffic a bit more). This has several adverse effects, including:

1. As rail and some other public transport infrastructure is paid for directly through fares, there is a distortion in the choice of mode.
2. It encourages excessive use of the road infrastructure, leading to system inefficiencies.
3. Because there is no direct revenue, it is not logically possible to use conventional commercial investment criteria in deciding how much capacity should be provided.
4. Since the revenues do not accrue to the local authority, there may be inadequate money available for proper maintenance of the existing infrastructure.

For these reasons, and as part of an integral plan to develop a sustainable public transportation system, Panama should consider injecting regulatory price signals that encourage users make more socially equitable travel decisions. Price signals, such as increased fuel taxes, would have a few effects:

- I. Reducing emissions and time delays, by incentivizing mode switching, from higher-social-cost modes (e.g. personal vehicle) to more sustainable modes (e.g. public transportation)
- II. Increasing public transportation positive cashflows via increases in ridership
- III. Creating public revenue, which could be invested in continued expansion and maintenance of the sustainable transportation system.

The relatively recent experience of the Canadian province of British Columbia with a carbon tax on transport fuels has given new life to the debate about taxation as a policy mechanism to curb emissions from transportation. The carbon tax caused a much higher drop in gasoline consumption than anticipated *ex ante* based on earlier economic studies.<sup>40</sup> Similar evidence was found for the case of the U.S.<sup>41</sup> Panama should consider conducting econometric analyses to understand the responsiveness of local drivers to price signals, and use this as input in the design of a program as described above.

Urban transport infrastructure and public transport pricing have strong interdependencies and, therefore, any pricing principles for public transport modes should be determined within an integrated urban strategy and should reflect the extent to which road infrastructure is adequately charged. For reasons of ‘second best’, there may be need for financial transfers between the exchequer and public transport services, or between roads and public transport services, or between different modes of public transport. These transfers should be achieved through

---

<sup>40</sup> Rivers and Schaufele (2015) Salience of carbon taxes in the gasoline market. *Journal of Environmental Economics and Management*. <http://dx.doi.org/10.1016/j.jeem.2015.07.002>

<sup>41</sup> Collantes, G. (2016) Evidence of the role of pricing instruments in a policy framework to address greenhouse gas emissions from road transportation. *Transportation Annual Meeting*, Washington, D.C.

contracts between municipal authorities and operators for the supply of services. If public transport cannot be subsidized to compensate for the inadequate road pricing policies, then financial sustainability of the public transport service should take precedence over price or fare regulation.

## 5.6 Transport with gender perspective

Gender equity is a key social indicator that affects access to city goods and services. Understanding potential pathways and barriers to gender equity is crucial when planning inclusive and efficient transportation systems. Gender equity includes the “fairness of treatment for women and men, according to their respective needs. This may include equal treatment or treatment that is different, but which is considered equivalent in terms of rights, benefits, obligations and opportunities.”<sup>42</sup> Gender differentiates and defines the activities that women and men are expected to fulfill. Transportation and mobility are not neutral to gender.

Adopting gender equity as an analytical category involves identifying the social, cultural and economic implications related to gender and applies a multidisciplinary and intersectional approach. In Panamá, as in all of Latin America, gender gaps persist and include differences in the level of access that women have to health care, employment, political participation, and culture, among others. Restricted access to city opportunities due to the transportation system further exacerbates inequities, such as work opportunities and the accumulation of financial capital.

Examples that impede gender equity in the city include issues related to: sexual harassment and gender-based violence that generate fear and emotional distress; gender roles, expectations and stereotypes that require women to assume primary caregiving roles, generating differentiated mobility patterns; and restricted access to individual and motorized transportation due to economic position and the priority given to male travel in most households.

Mobility in its simplest definition is undertaking a trip in order to do something; it can be evaluated

---

<sup>42</sup> International Labour Office. (2000). ABC of women worker’s rights and gender equality (p. 48). Geneva: ILO.

in terms of the number of modes of travel; the distance traveled; and frequency of the location(s) visited. Investment in gender equity as it relates to women's access to mobility and transportation remains limited. Fewer women than men have their own private car, public transportation networks remain inadequate, and certain districts are unsafe, particularly at night. It is interesting to note that there are many similarities in the characteristics of trips made by women not only between developed and developing countries, but also between urban and rural areas. Women have activity schedules that are far more complex than those of men due to their work and caregiving responsibilities. Women frequently need to use transportation outside rush hours to destinations different than men, for example to go shopping or to accompany children to school, health centers, etc. The opportunity costs in time related to transportation is therefore far more penalizing for women.

Another issue related to gender equity includes the transportation-related workforce. In all countries, there are far fewer women working in the transportation sector compared to men. A sustainable mobility plan for Panamá would not be complete without clear parameters for the inclusion of women in the transportation sector labor force.

## **5.7 New technology for new user requirements**

The latest technologies have generated changes in the production of improvements in transport modes. The relationship between providers and users has also been substantially modified. Previously, the information was only one-sided (company-user). Now, the information is multidirectional (company, users, government, other companies, non-users) and transport providers must be open for this to happen. It is essential that users take a leading role in this new stage and can express their opinions regarding change. In order for them to provide their opinions, it is necessary that, in addition to practical experience, they have data. The new mobility is open. It is essential that in this new process of sustainable development in Panama everyone has access to statistical information. This topic has two aspects: real-time information for the trip and data for analysis. Users must know at all times the status of the routes, the rates and the estimated time of arrival at their destination. This generates confidence and predictability in the user's time, which will be highly appreciated by him.

Likewise, it is essential that civil society have the possibility to analyze the operation of the public transportation system, establish conclusions and share them. Both governments and companies

must attend to these analyzes and incorporate them for the continuous improvement of transport. To improve the user experience, it is essential that everyone have access to information (even if they do not have a smart device), that is why the presentation of data should be sought both on buses and at stations (smart stations).

Security technologies have also advanced. In addition to monitoring the operation in real time of each vehicle, it is necessary to provide security to them, with a special commitment to eradicating all types of gender-based violence. This requires a joint effort by transport authorities, companies and the security forces.

## 5.8 Approaching change

Transformations, especially those linked to systems as complex as transportation, take time. Time is necessary to study, propose, prototype, do impact evaluations and, above all, communicate. This is particularly true for the kind of transformations that are necessary to move urban transportation systems to long-term sustainability. No change in the transportation system will be successful if there is no in-depth communication campaign in which the new policies are explicitly established, communicated, discussed and put into context. People are usually averse to change, especially those that involve something as everyday as how to move around the city. The policy's target population must be convinced that sustainable mobility is a new positive standard in which governments will make every effort to improve the transportation system taking into account the aspects previously established. At the same time, users of the transportation system will demand, rightly so, adequate travel conditions, as discussed in this report. Understanding possible areas of concern among the public is essential to provide consistent responses and to create a feedback process that will continually improve the system.

Authorities, business owners, suppliers, and users are together responsible for carrying out this transformation. They are responsible for changing the archaic paradigm of pollution, congestion, accidents, and car-centricity. The time has come to turn the page and move to a sustainable, efficient, agile, predictable, equitable, accessible and functional public transportation system for Panama.



