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Guidelines for electric bus procurement in Jakarta

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Introduction

Electric public transit buses are one of the most direct pathways for reducing a city's greenhouse gas (GHG) emissions and improving air quality. Jakarta, the capital of Indonesia, has made several commitments to accelerate the transition to electric vehicles, including signing the C40 Fossil Fuel Free Street Declaration to procure only zero-emission buses by 2025 and committing to electrify 100% of the TransJakarta fleet by 2030.[1] The government also set a target to have 10,047 electric buses (e-buses) in operation by 2030, and established goals for deploying charging infrastructure.[2] Furthermore, the government of Jakarta also commits to undertake climate mitigation actions including expanding public transportation and adoption of electric buses, in order to reduce greenhouse gas emissions by up to 50% by 2030.[3]

At the national level, the government of Indonesia is promoting electrification across all vehicle segments. Presidential decree PR 55/2019, *Acceleration of the Battery Electric Vehicle (BEV) Program for Road Transportation,*[4] incentivizes the manufacturing of electric vehicles and components in the country. The decree is supported by a wide array of ministerial regulations that provide fiscal incentives for manufacturers and consumers, as well as for the development of infrastructure.

The Ministry of Transportation (MoT) of Indonesia adopted a series of bus transit electrification goals in 2020.[5] The MoT is focusing its planning and regulatory agenda on two main areas: public transportation and technical regulations for EV deployment

1 C40 Cities, (n.d.), *Fossil Fuel Free Streets Declaration*, retrieved May 28, 2021, from https://www.c40.org/other/green-and-healthy-streets.

2 DKI Jakarta Province Governor's Decree, "Guidelines for the Acceleration of Battery-Based Electric Motorized Vehicles in Transjakarta Transportation Services" https://jdih.jakarta.go.id/uploads/default/produkhukum/KEPGUB_NO._1053_TAHUN_2022.pdf. The term 'electric buses' in this working paper refers to battery-electric buses, not plug-in hybrid buses or hydrogen fuel cell electric buses.

3 DKI Jakarta Province Governor Regulation 90/2021, "Climate Resilient Regional Low Carbon Development Plan," https://peraturan.bpk.go.id/Home/Details/184664/pergub-prov-dki-jakarta-no-90-tahun-2021.

4 Presidential Regulation Republic of Indonesia No. 55/2019 on Battery Electric Vehicle, (2019), https://peraturan.bpk.go.id/Home/Details/116973/perpres-no-55-tahun-2019.

5 Meeting with Directorate General of Land Transportation (March 10, 2021), Ministry of Transportation.

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on Indonesian roads. The MoT has presented ambitious public transport electrification goals for Indonesian cities. The electrification schedule starts with Jakarta as a pilot city then expands to two more cities, followed by 10 cities and provinces, culminating in 90 percent electrification of public transport fleets in 2030. The timeline for public transport electrification goals at the national level in Indonesia is presented in Figure 1.

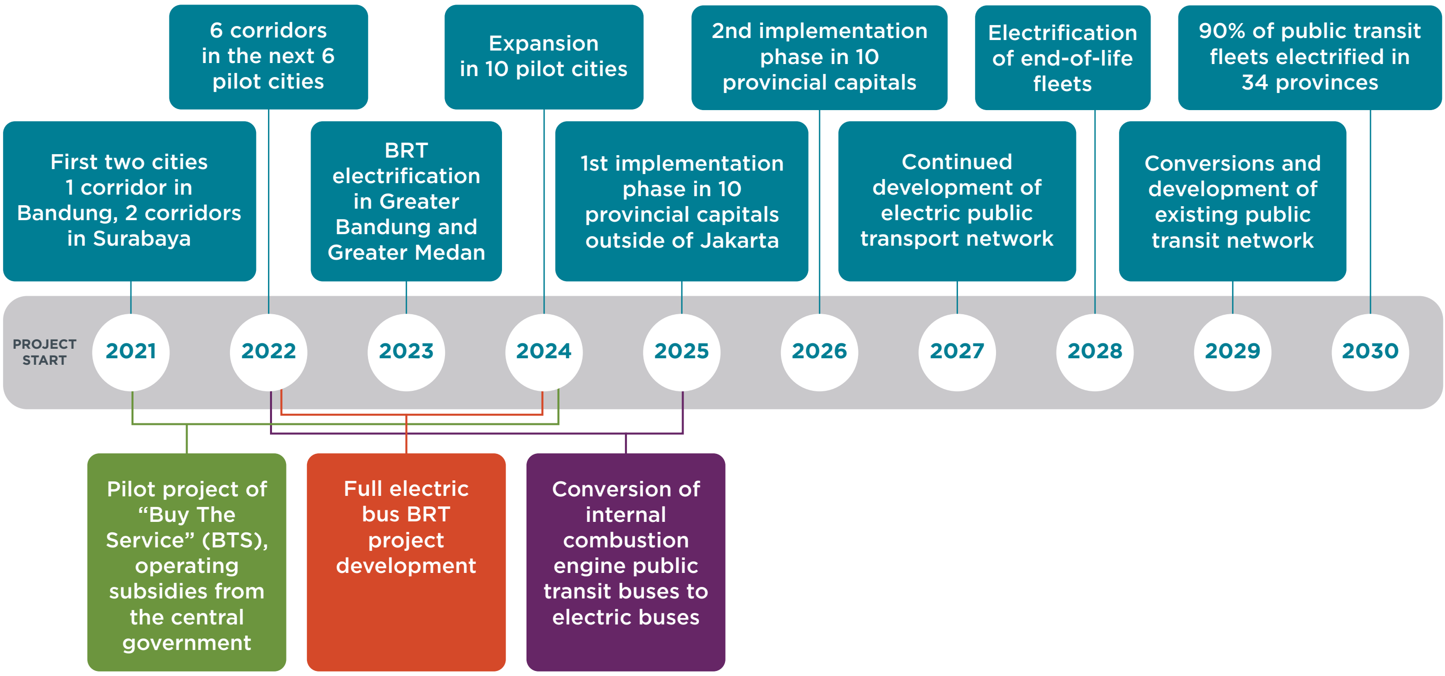

Figure 1. Public transport electrification timeline in Indonesia

Source: Ministry of Transportation (2021)

In addition, the Ministry of Energy and the national electric utility company PT PLN have adopted supportive actions to accelerate electrification efforts. PLN is tasked with developing and constructing charging infrastructure for EVs, with an emphasis on private cars and motorcycles. PLN has developed a road map for the installation of 7,149 charging units by 2030.

Authorities' steps to electrify the vehicle fleet have met with little success to date, especially in the bus transit segment. TransJakarta, the transit operator for the Greater Jakarta Area, planned to incorporate 100 battery electric buses in 2020, but fell well short of the goal due to uncertainties, related to passenger ridership, introduced by the pandemic. The goal was revised to 30 units by the end of 2021, but that goal was also not met due to persistent COVID-associated risks. Only four 12 m electric buses are in operation by TransJakarta as of the writing of this report.

The electrification of public transit fleets poses several challenges including high capital costs, the need to acquire or upgrade depots that host electric charging infrastructure, and the knowledge barrier, as this is a new technology for traditional bus operators. In addition, a procurement business model is needed that can accommodate the higher capital costs of electric buses, by leveraging the lower operational costs to yield an overall financial picture that is as good as or better than the conventional business model. In the conventional model, TransJakarta directly owns and operates most buses, while contracting with third-party operators that own and operate other vehicles.

The objective of this working paper is to provide e-bus procurement and contracting guidelines that support the adoption of e-buses in Jakarta's public transit system and other Indonesian cities based on the lessons learned from successful international cases that have advanced from e-bus pilot projects to scaled-up programs. While this paper is written primarily with Jakarta in mind, its key messages are also valuable for other municipal transit authorities and operators seeking to move from electric bus pilots to fully developed fleets.

TransJakarta at a glance

TransJakarta is the public transit bus operator of the integrated transit system in the Capital Region of Jakarta (DKI Jakarta). TransJakarta manages the Bus Rapid Transit (BRT) system, established in Indonesia in 2004, as well as a range of feeder bus routes and microbuses (also known as angkots). The BRT system is integrated with the subway system called the Jakarta Mass Rapid Transit (MRT), the Jakarta Light Rail Transit (LRT), and a network of air-conditioned microbuses. The BRT system covers 244 km and is divided into 13 corridors (trunk routes). TransJakarta has since grown to incorporate feeder services, reaching a total of 248 routes. TransJakarta serves the entire Greater Jakarta area with a combined population of 30 million and a daily ridership of 1 million passengers.[6]

Figure 2. A battery-electric TransJakarta bus in Jakarta, Indonesia

Source: Adhi Triatmojo

TransJakarta's business model

TransJakarta is a regionally based enterprise majority-owned by the Jakarta Provincial Government. It is partly funded by Public Service Obligation (PSO) from regional public funds and its tariff is subsidized by the city government. The flat tariff, set at IDR 3,500 or USD 0.2, has not increased since its initial adoption in 2004. The government of Jakarta covers 90% of TransJakarta's operational costs.

TransJakarta provides service contracts to bus operators, who are legally bound to provide a minimum level of service to passengers in the region. TransJakarta pays the bus operator based on gross cost contracts (GCC) that set the operational performance

6 TransJakarta 2021, *Produk dan layanan*, viewed 12 August 2021, https://www.transjakarta.co.id/produk-dan-layanan/layanan-bus/transjakarta/.

(km driven) and price rate (IDR/km) for the services rendered. The bus operators are responsible for bus purchase, operation, and maintenance as well as for providing the depots. The operators must ensure that their services meet the minimum service level determined by TransJakarta and its overseeing body (the DKI Jakarta government).

Operations

A total of 4,415 buses in the TransJakarta fleet provide BRT and non-BRT services. For its 32 BRT service routes, TransJakarta generally deploys articulated, single, and maxi buses, whose combined fleet size is 1,461. Microbuses totaled 2,129 buses that operate on microtrans (i.e. feeder) routes. TransJakarta also cooperates with 18 third-party operators to provide its services. (Table 1).[7]

Table 1. TransJakarta fleet composition by type and route type

Bus type	Description	Fleet size in 2022
Articulated bus	High floor 18 m	257
Single bus	High floor 12 m	965
Maxi bus	13.5 m	293
Low-entry bus	Low floor 12 m	319
Medium bus	8-9 m	268
Microbus	10-passenger van	2129
Double-decker bus		28
Low-entry electric bus	Low-entry 12 m battery-electric bus	30
Others*		126
Total		**4415**

*Includes *Transjakarta Cares* and *Royaltrans* bus services

Source: TransJakarta (2022)

In total, TransJakarta served 123.8 million customers in 2021. These riders mainly use BRT, microbuses, and feeder buses. BRT route services have the greatest number of annual customers, at approximately 59 million in 2021. (Figure 3).

TransJakarta's electrification plans

TransJakarta has designed a very ambitious plan for electrification of its bus fleet. The implementation plan started with the pretrial phase, conducted in 2019 and 2020. The next and current step is the pilot phase, to be carried out in 2021 and 2022 and focusing on piloting 100 buses and developing a new business model to support the technology transition. The final implementation phase scales up the ambitious electrification plan. TransJakarta is prioritizing standard (12 m) and low-entry electric buses as the top priorities for immediate implementation. Medium buses (8-9 m) started trials in 2020, but procurement will start later in 2023. Articulated buses and small buses will be tested and piloted in 2022 and phased procurement will begin for 50 percent of the new buses in 2023 and 2024, and for 100 percent beginning in 2025.

The acquisition of significant numbers of electric buses will result in the full electrification of the TransJakarta fleet by 2030 (Figure 3). New electric bus purchases by TransJakarta and third-party operators in the network will double TransJakarta's fleet size in the next decade. The biggest increases in e-bus purchases are expected in 2023 and 2024, and again in 2029. Most of the growth will be observed in the minibus category, followed by the 12 m low-entry and medium (8–9 m) buses.

7 TransJakarta, (2022), Strategi Penerapan Bus Listrik Transjakarta (Powerpoint presentation).

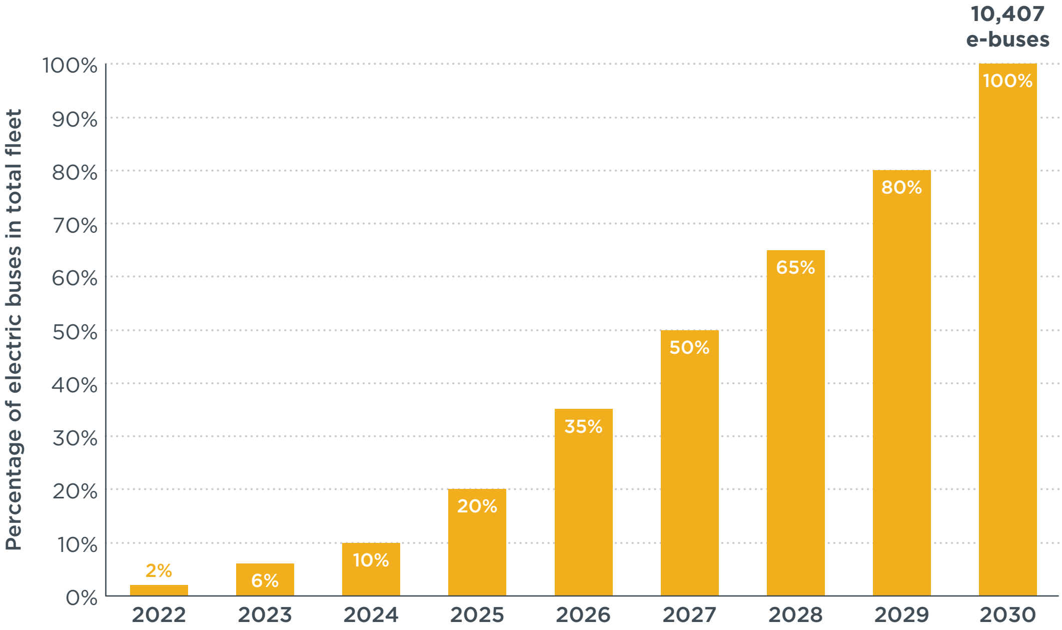

Figure 3. TransJakarta fleet growth and electrification targets

Source: TransJakarta (2022)

Depending on the structure of bus ownership, the procurement of electric buses can take two forms for TransJakarta. In the first type, reflected in 54% of the current fleet, bus ownership and operations are both the responsibility of TransJakarta. In the second procurement arrangement, TransJakarta signs contracts with other private and public operators who provide buses and services owned by TransJakarta itself. Therefore, we discuss procurement practices for TransJakarta in these two forms: direct ownership and operation, and operations contracts. Charging infrastructure is another key item for procurement decisions and will be discussed in a separate section.

The transition to new technology requires changes in the way buses are procured. For smooth and cost-effective procurements of e-buses, all stakeholders involved in e-bus services, including contracting bus operators, OEMs, financing institutions, and government institutions need to develop a coordinated e-bus procurement framework. Documented experiences from early adopters of e-buses provide a series of recommendations that can be contextualized to help Indonesia's transition.

In the sections below, we summarize e-bus procurement elements that have supported transit authorities in several cities in scaling up their bus electrification. Examples from India's FAME-II program, as well as Santiago, Shenzhen, and Bogotá, are compiled and compared to provide stories of good procurement practices in e-bus scale-ups. These cities and regions have made significant strides in electric bus adoption and have documented their procurement practices and made them publicly available. We identified elements that help define a proper framework to support making sound vehicle, infrastructure, and service procurement decisions for bus operators.

Procurement of electric buses

Procurement practices of electric buses apply to fleets directly owned and managed by the operator (i.e., TransJakarta) and not via another operator. Third-party contractors responsible for acquiring the buses may also find these practices helpful.

Planning for electric bus deployment

Planning the deployment of electric buses requires a preliminary analysis to ensure the expected level of service while meeting the needs and expectations of the operator at a reasonable cost. The practice of making bus procurement and deployment decisions based on route and vehicle data is known as fleet-wide planning.[8] Two types of analysis that answer different levels of questions for e-bus deployments are useful for planning purposes: a fleet-level analysis and a route-level analysis. The fleet-level analysis is a high-level, preliminary type of planning tool that provides a rough estimate of the costs and benefits of e-buses compared to conventional buses for the average bus in service in the system. Route-level analysis focuses on technology performance and costs at the individual route level, and provides accurate assessments for procurement decisions.

» Fleet-level analysis is useful as an initial exploration of the challenges and potential for electrifying a bus fleet. It provides general outputs on the costs of owning and operating e-buses compared to diesel buses. The inputs are general operational values like average daily bus utilization, average bus fuel consumption, and average maintenance costs. The outputs reflect a big-picture overview of the costs and benefits of the technologies being considered for the system.

A fleet-level analysis is useful for preliminary analysis and early identification of major challenges or of the potential for electrification. For example, it provides quick and rough cost estimates for situations where bus contracts are too short (less than 7 years), or where there is a combination of inexpensive diesel bus technology and heavily subsidized diesel fuel. The high-level fleet-wide analysis can provide an early indication of non-viable e-bus initiatives, as well as policy or procurement changes that would be required to make e-buses a competitive solution with respect to conventional buses.

» Route-level analysis is a more detailed and granular techno-economic study that is performed at the individual bus route level. In most public transit procurement processes, operators bid for a set of routes to be serviced. Thus, a detailed route-level analysis is a more accurate tool for predicting the performance of e-buses on particular routes during procurement processes.

The route-level analysis focuses on understanding the energy consumption and battery use of e-bus models in each route. It can identify the most cost-effective routes and the most challenging ones for electrification. It also provides information about charging strategies for different bus types on individual routes. With accurate energy consumption data and clear charging strategies, a more accurate cost picture can be drawn to estimate the total cost of operating and owning an e-bus at the route level; this analysis can be compared with that of conventional buses.

The modeling methods and inputs, in this case, are more complex and require longer timelines and greater expertise. Route-level analysis is only possible for routes that already exist in the system, not for routes under development, as it needs real-world GPS data. The route-level analysis requires three main steps: route characterization, route-specific bus model development and energy consumption estimation, and total cost of ownership calculation. Table 2 provides an overview of the major steps involved.

8 Yihao Xie, "Module 4: Fleet-Wide Planning for Soot-Free and Zero-Emission Urban Bus Fleets, Soot-Free and Zero-Emission Urban Bus Technology Transition Curriculum," (ICCT: Washington, DC, 2022), https://www.youtube.com/watch?v=SWj4BUSkJZY.

Table 2. Major steps in the route-level analysis

		
Route characterization	**Energy consumption modeling**	**Total cost of ownership**
• Identification of current operational characteristics of the system • Route-level GPS data collection in current buses • Drive cycle development per route • Capital and operating costs documentation	• Development of energy consumption model for e-bus and conventional technology • Evaluation of e-bus range and battery state of charge for each route • Battery sizing • Charging infrastructure sizing and charging plan design • Maximum power calculation	• The total cost of ownership at the route level • Capital and operating costs of vehicle and infrastructure • Vehicle and infrastructure purchase • Fuel/Energy • Operations • Maintenance • Other

In route characterization, the representative drive cycles for each route are derived. It requires collecting GPS data from buses currently in operation. The drive cycles are used to represent the expected route conditions (e.g., passenger load, road grade, weather) for potential e-buses.[9] Operational cost information is also collected during this period to feed into the route-level cost analysis.

The energy consumption (EC) of e-buses is then modeled via computational models that incorporate detailed specifications of the buses being evaluated. The model predicts the impact of route characteristics (average speed, average acceleration, idle time, and number of stops) on energy consumption. This EC value is used to predict the amount of energy consumed by the bus during the day, to predict whether additional charging is needed or not, and to estimate the cost of any additional charging. The flexibility of the modeling environment permits testing different bus types and battery sizes on a route, and yielding a tailored and cost-effective e-bus solution for each bus route.[10]

The final step in the route-level planning analysis is the total cost of ownership at the individual route level. Outputs from the previous step can be used to generate the energy costs, vehicle and infrastructure capital costs, and other cost components such as operations and maintenance. In the end, the total cost per km is presented for each route, bus, and type of infrastructure under evaluation.

9 Lingzhi Jin, Oscar Delgado, Ravi Gadepalli, and Ray Minjares, *Strategies for deploying zero-emission bus fleets: Development of real-world drive cycles to simulate zero-emission technologies along existing bus routes*, (ICCT: Washington, DC, 2020) https://theicct.org/publication/strategies-for-deploying-zero-emission-bus-fleets-development-of-real-world-drive-cycles-to-simulate-zero-emission-technologies-along-existing-bus-routes/.

10 Tim Dallmann, Oscar Delgado, Lingzhi Jin, Ray Minjares, Ravi Gadepalli, and Christy Ann Cheriyan, *Strategies for deploying zero-emission bus fleets: Route-level energy consumption and driving range analysis* (ICCT: Washington, DC, 2021), https://theicct.org/publication/strategies-for-deploying-zero-emission-bus-fleets-route-level-energy-consumption-and-driving-range-analysis/.

A summary comparing the key characteristics of fleet-level and route-level analyses is presented in Table 3.

Table 3. Comparison of fleet-level and route-level analysis for e-bus deployment planning

	Fleet-level analysis	Route-level analysis
Objective	• High-level analysis of costs and benefits of e-buses compared to conventional bus technologies	• Detailed analysis at the route level to evaluate costs and operational aspects of e-buses
Inputs	• Average costs and operational parameters representative of average bus fleet	• Individual route's operational parameters • GPS data collection to derive representative drive cycles for each route • Individual bus technical specification, by bus type
Outputs	• Fleet average total costs of ownership over the contract period for each bus technology	• Route level total cost of ownership over the contract period • Expected energy consumption for each route by bus type • Impact of loading demand, air-conditioning, road grade, and other factors on EC for each route • Charging strategy for each route and bus type
Methods	• A more aggregate and simplified TCO tool calculates capital and operating costs for different technology types	• Complex set of modeling steps: • Drive cycle per route based on synthesis of GPS data to estimate bus energy consumption • Detailed e-bus energy consumption modeling that assesses energy needs depending on operating conditions including: • Route profile • Passenger loading • Weather conditions • Route-level TCO, incorporating energy consumption and charging infrastructure needs at route level
Application	• Identify broad policy and economic barriers for e-bus deployments, for example, the need of incentives, fiscal tools, change in contract duration	• Procurement processes at the route level • Identification of cost-effective routes for e-bus deployment • Identification of battery charging strategy for each bus type and route profile

Pilot testing

In addition to fleet and route-level planning analyses for e-bus deployment evaluation, real-world evaluation of e-buses in the system can provide additional information to aid procurement processes. Pilot testing of a handful of electric bus models can give critical data and insights into the performance of different bus models, shed light on bus specs that can meet passenger needs, and build experience among the operator's staff. In addition, pilot testing can provide additional validation data to fine-tune energy consumption calculations in the route-level TCO.

Several approaches can be used to acquire electric buses for running pilots in a system. Some manufacturers are willing to provide one or two pilot buses at no charge to operators, usually for a limited period. In this way no major financial commitments are required of the transit authority or operator. This approach has been used by TransJakarta; a third-party operator has piloted several e-bus models from different manufacturers on key BRT routes.[11] Other transit authorities may choose to buy and own pilot buses, making pilots essentially a limited-scale procurement. Singapore's Land

11 Electric buses from BYD and Higer have been tested in pre-trail runs from 2019 to 2021. Currently thirty BYD K9 e-buses operate in Jakarta as part of a pilot study. These buses were purchased by a local operator. ITDP Indonesia, "Transjakarta Electric Bus System," n.d. https://go.itdp.org/download/attachments/179346841/Transjakarta%20E-Bus%20System_Workshop%20E-Bus%20Kampala.pdf?version=1&modificationDate=1647515634812&api=v2&download=true.

Transport Authority has purchased 60 battery-electric buses and assigned them to the city's bus operators, a strategy designed to collect data and build experience before a larger-scale transition to electric buses.[12]

If the performance of electric buses is well understood and proven to work for operators and cities in very similar conditions, cities could bypass pilot testing of one or a few buses and instead use computer modeling to determine the requisite technical specifications. Modeling simulation tools are becoming more reliable at generating energy consumption results that were once available only by actually running buses. If the bus technology has been tested elsewhere, and the local duty cycles, route characteristics, and other baseline performance information are known, vehicle simulation tools can be calibrated to give very accurate energy consumption and operations outputs without relying on pilot tests.

An important piece of information from simulation modeling and pilot testing is variations in energy consumption under different conditions. For a given route, operational conditions can vary depending on several factors including traffic congestion, weather (ambient temperature, wind speed, rainfall), and the driving habits of different drivers. Variability in energy consumption also occurs with diesel vehicles, but it is more pronounced for electric buses because of range and recharging considerations inherent to the technology. Measuring, capturing, and understanding the variabilities in energy consumption will be very helpful to TransJakarta for choosing the best electric bus technology, designing an appropriate operating plan, and setting up charging infrastructure that works effectively under a broad range of conditions.

Determining e-bus specifications

At the individual bus level, the technical specification document from the California Department of General Services (DGS) gives a good overview of important vehicle parameters and specifications for a procurement officer to keep in mind: vehicle dimensions, passenger capacity, total weight, traction motor power and torque, onboard battery capacity and thermal management, charging connections, cooling and heating systems, and several other subsystems.[13]

In Chile, the Ministry of Transport and Telecommunications leads the development of technical procurement specifications for e-buses to be deployed in public transit systems. The city of Santiago has incorporated more than 800 electric buses into its public transit system over the past five years.[14] Table 4 lists the technical specifications for e-bus procurement in Chile as a reference for officials in Indonesia.[15]

12 *LTA intensifies electrification efforts to meet new emissions target*, (March 17, 2022), Intelligent Transport, https://www.intelligenttransport.com/transport-news/133757/lta-electrification/.

13 *Contract ID 1-19-23-17B Attachment B - Technical Specification*, (2019), California Department of General Services, https://caleprocure.ca.gov/PSRelay/ZZ_PO.ZZ_CTR_SUP_CMP.GBL?Page=ZZ_CTR_SUP_PG&Action=U&SETID=STATE&CNTRCT_ID=1-19-23-17B

14 Danmarks Tekniske Universitet, ZEBRA, C40 Cities, International Council on Clean Transportation, and Partners for Growth, (August, 2022), *E-BUS RADAR*, E-BUS RADAR, https://www.ebusradar.org/en/.

15 Ministerio de Transporte y Telecomunicaciones de Chile (2019), Servicio Complementario de Suministro de Buses No LP SB001/2019 del Ministerio de Transportes y Telecomunicaciones (MTT) de Chile.

Table 4. Bus and infrastructure specifications from Chile Ministry of Transport and Telecommunications (2019)

<table>
<tr><th colspan="2">Vehicle</th><th colspan="2">Infrastructure</th></tr>
<tr><th>Item</th><th>Notes</th><th>Item</th><th>Notes</th></tr>
<tr><td>Dimensions and gross vehicle weight</td><td>-</td><td rowspan="6">Equipment compatibility with the Combined Charging System 2 (CCS-2) standard.</td><td rowspan="6">The CCS system is an open system widely adopted in Europe and the US. All bus manufacturers selling electric buses and charging solution providers, even those from China where a different set of standards are in place, must offer products and charging equipment with CCS-2 compatibility.</td></tr>
<tr><td>Minimum number of passengers</td><td>-</td></tr>
<tr><td>Performance requirements
Minimum speed
Maximum power and torque to the wheels
Maximum road grade</td><td>-</td></tr>
<tr><td>Energy consumption (kWh/km)</td><td>This value must be provided as part of the certification of conformity (COC) documentation. The test cycle used to determine the EC value must also be provided.</td></tr>
<tr><td>Driving range (km)</td><td>For depot-charging buses this would be the minimum distance on a full charge before reaching an established minimum state of charge (usually 10-20%).</td></tr>
<tr><td>Maximum battery charge deterioration</td><td>Electric batteries tend to lose energy storing capacity over many cycles of charge and discharge. This requirement aims to define the maximum level of loss of charging capacity over a defined period. In Chile the regulation allows for a 20% battery capacity degradation over 14 years of operation.[16]</td></tr>
</table>

For further context, Table 5 lists the basic specifications of some battery-electric buses deployed in Santiago. TransJakarta will need to determine the bus specifications based on its service needs including ridership, daily driving distance, and operational time. The bus specifications need to allow for covering the daily driving distance required by a particular route/bus.

Table 5. Specifications of electric buses in operation in Santiago

Brand	Model	Bus length	Power (kW)	Battery capacity (kWh)	Passenger capacity	Energy consumption under Santiago Test Cycle (kWh/km)	
BYD	K9 FE	12 m	300	276.5	81	1.57	176.1
Yutong	ZK6128BEVG	12 m	215	324.4	87	1.48	219.7
King Long	XMQ 6127G PLUS	12 m	280	374.7	90	1.74	215.0
Foton	eBus U12 SC	12 m	350	385.1	90	1.63	237.0

Source: World Bank (2020)[17]

16 Centro Mario Molina Chile, "Requisitos técnicos para bases de licitación y operadores de flotas de buses eléctricos del transporte público de Santiago de Chile: Infraestructura, equipamiento, y gestión de carga," (CMM: Santiago, 2020), https://theicct.org/wp-content/uploads/2021/06/ZEBRA-requisitos-tecnicos-ebus-stgo-nov2020.pdf.

17 World Bank, "Lessons from Chile's Experience with E-Mobility," (World Bank: Washington, DC, September 11, 2020), https://elibrary.worldbank.org/doi/abs/10.1596/34435.

Bus testing and certification

In an ideal bidding process, all bus products that participate in tenders should be tested and certified to a local standard. In Chile, for example, the Center for Vehicle Control and Certification (3CV) has a laboratory to certify different vehicles under Chilean standards and conducts an analysis of emissions and energy efficiency of both electric and diesel buses that represent the street conditions that e-buses will face. Chile's testing and certification also consider other specifications including vehicle safety and reliability, which are important factors that affect procurement decisions.

In the case of bus units assembled in the country, UITP has a standardized bus testing protocol called Standardized On-Road Test Cycles (SORT). SORT allows bus operators to compare the energy consumption of different bus technologies and models in a standardized way, by combining any of three predefined driving cycles to simulate real-world operating conditions. SORT helps the e-bus tendering process by estimating the maximum range of vehicles based on test results and auxiliary systems' power consumption.[18]

Alternatively, the technical certification can focus on key components such as batteries. If localized certification is not available, the bus products and parts must be certified to conform to pre-established standards from other regions. Depending on the origin of the buses, certifications and standards may vary. In the US, these are typically Society of Automotive Engineers (SAE) standards, whereas in China the standards are GB/T.

Warranty requirements

To guarantee protection against performance and quality issues, the purchase agreements should have clear warranty terms from the manufacturer, and clear servicing and repair terms from either the manufacturer or a third-party contractor. As an example, California DGS's warranty requirements clearly define the warranty years and mileages for the complete bus, body and chassis structure, propulsion system, energy storage systems, and other major subsystems, as summarized in Table 6 below.[19]

The warranty requirements should lay out the repair procedures and list clearly the scope of repairs covered by transit agencies and those covered by the manufacturer, as well as the timing for repair work to take place. In Shenzhen, the technical specifications for the drive motor and control system, electronic control system of the battery management system (BMS), electronic control unit (ECU), and other sensors have specific requirements for heat and humidity resistance as Shenzhen has a warm and humid climate. Shenzhen's required warranty term for the batteries, electric motors, and controllers is 8 years, with a maximum degradation of 20%.[20]

18 Arno Kerkhof, "SORT Protocol: Electric Range of Urban Buses in Public Transport," presented at the GRPE workshop on low- and zero-emissions heavy duty vehicles: Regulatory gaps and expected legislators' needs, June 2, 2021, https://unece.org/sites/default/files/2021-05/Session%203.1%20-%20UITP%20-%20A.%20Kerkhof%20-%20C.%20Martin.pdf.

19 "Contract ID 1-19-23-17B Attachment E - Warranty Requirements" (Sacramento: California Department of General Services, December 19, 2019), https://caleprocure.ca.gov/psc/psfpd1/viewredirect/%7bV2%7dGFclFB3MkQtC6MxK5hSi02GyBAQn9NlzAzu6x.o2WV3PgBmBRcX6.R2aPTC8xgatU8.li1P3w6NMT.Xu35cQDjYr8qmVHyKg0_GX0BvG8Gwue.BvjN5V1_jcbDckx1SfEYRk_wU_jziipgXgRcwpmJrhCbonlURCfeP86uF_B736DCmBK0QgZVesgsZEj9EwG6GnKOd.KNTVGxty3KzusHpEyoUDXMerPObn0J.inUn5SGipzeH0gQ--/Attach_E-Warranty_Requirements.pdf.

20 World Bank, "Electrification of Public Transport: A Case Study of the Shenzhen Bus Group," Working Paper (Washington, DC: World Bank, June 30, 2021), https://openknowledge.worldbank.org/handle/10986/35935.

Table 6. Examples of bus and subsystem warranty terms in California

Item under warranty	Years of coverage	Mileage (miles)
Complete bus (including propulsion system, components, major subsystems, and body and chassis structure)	2	100,000
Body and chassis structure	12 (chassis)	500,000
Propulsion system	3/5	100,000 / 300,000 (extended)
Energy storage system (maximum 20% degradation)	6	250,000
Brake system	2	100,000
Air compressor and dryer	2	100,000

Source: California Department of General Services (2019)

Batteries are often a limiting factor in the useful life of electric buses. To manage costs and risks arising from battery degradation, transit authorities should make clear in the procurement contract that battery durability is reflected in contract prices and payments to vendors and manufacturers, while keeping in mind that battery cost can vary greatly depending on the warranty conditions given by the manufacturer (e.g., whether the term is 6 or 8 years). Cost calculations should also factor in the residual value of the batteries and end-of-life recycling and disposal. Ownership contracts for battery electric buses in Latin-American cities like Bogotá and Santiago are almost twice as long as contracts for diesel buses and include the cost of replacing the battery, which is required by the 8th year.

Manufacturer capacity assurance

In general, transit authorities should choose electric bus products that come from reliable manufacturers in the tendering process. Some markets, including India, have set a minimum manufacturing capacity requirement for OEMs.[21] Electric bus tenders in Chile gives scores to participating manufacturers based on their capacity and experience.

Manufacturer service and training

To ensure handling of electric buses that extends the useful life of the bus and battery, the procurement agreement should include BEB-specific training from the manufacturer. Since batteries are one of the most expensive components of an electric bus, procurement has also been split between the bus body and battery, as is the case in deployments in Shenzhen, where the transit operator leases the battery from a specialized company. This method reduces the upfront costs of electric buses.

Procurement of charging infrastructure

Land procurement and charging infrastructure deployment require high levels of capital investment and should be a key consideration in the overall e-bus procurement process. In the section below, we present four topics that often come up in infrastructure conversations regarding depot charging, the most common charging arrangement and one that TransJakarta will likely adopt, which involves infrastructure ownership, physical constraints, interoperability, and electricity pricing.

21 Ravi Gadepalli, Lalit Kumar, and Rupa Nandy, (2020), Electric Bus Procurement Under FAME-II: Lesson Learnt and Recommendations for Phase-II, Union Internationale des Transports Publics (IUTP) India. https://cms.uitp.org/wp/wp-content/uploads/2020/05/Draft-Electric-bus-procurement-under-FAME-II_Final-Report.pdf.

Infrastructure ownership

As with other physical assets, the provision and operation of charging infrastructure can be bundled or separated, depending on the business model and tender design. TransJakarta can either invest, own, and operate its charging infrastructure and directly enter into agreements with the national utility company PLN for electricity provision, or outsource charging to third-party charging solution providers. The responsibility of infrastructure ownership and operations need not belong to the same party. Sometimes depots are operated by third-party contractors who are separate from the depot owner.

In Bangalore, Bogotá, and Shenzhen, the development and ownership of bus depots often involves a private entity. In the case of Indian cities like Bangalore, the depot contractor must supply infrastructure designed to last 20-30 years.[22] In Bogotá's first electric bus tender, the utility Enel Codensa provided depots and charging infrastructure. Enel was a multinational utility company, while publicly-owned Codensa had majority shares in the partnership. In the second tender, the provision of fleet was tied to the provision of the depot and charging infrastructure, and more private companies participated.

In Shenzhen, the development of depots is open to private entities, which makes the charging infrastructure service market competitive, and lowers prices. Third-party provision of charging infrastructure also lessens the burden on fleet providers in terms of capital and capacity. The Shenzhen municipal government also provides subsidies for the land used by the charging stations to lower the cost.[23]

In Santiago, private energy companies such as Enel X and Engie provide the capital for charging facilities.[24] The government of Santiago, via the transit authority DTPM, aims to become the owner of all the depots. In general, the separation of infrastructure and vehicle provision in tenders allows bidders with specialized infrastructure experience and financial capacity to focus on what they do best.

Understanding physical constraints

Physical limitations, especially the availability of land and the number and capacity of grid connections, are common challenges in planning infrastructure procurements. For dense metropolitan areas like Shenzhen, securing land to build new facilities or expand existing depots for charging infrastructure was a major challenge. Electrical equipment including transformers, switchgear, power cabinets, dispensers, and charging cords can take up a great deal of space and can create safety hazards if not managed properly. Land in urban centers is expensive to buy or lease, while use of cheaper land away from city centers reduces the effective ranges of electric buses because of the distance they need to travel to and from remote depots. A bus terminal in Santiago experimented with using an overhead loading system; charging equipment was located above buses, and a retractable connector descended to the ground level where buses were parked.[25] Other space-saving technologies are being developed by transit operators in consultation with their bus manufacturer and utility provider partners around the world.[26]

22 Gadepalli et al. (2020).

23 World Bank, (2021), *Electrification of Public Transport: A Case Study of the Shenzhen Bus Group*, Working Paper, World Bank, https://openknowledge.worldbank.org/handle/10986/35935

24 World Bank, (2020).

25 *President Piñera launches the el Conquistador electroterminal, the largest of its kind in the country and that will supply Red buses in the Metropolitan Region*, (2020, December 3), Red Movilidad, https://www.red.cl/en/red-communicates/news/president-pinera-da-start-al-electroterminal-el-conquistador-el-major-de-su-type-en-el-country-y-que-abastecera-a-buses-red-en-la-region-metropolitana/.

26 Nicole Lepre, Spencer Burget, and Lucy McKenzie, (2022), *Deploying Charging Infrastructure for Electric Transit Buses* (p. 56), Atlas Public Policy https://atlaspolicy.com/wp-content/uploads/2022/05/Deploying-Charging-Infrastructure-for-Electric-Transit-Buses.pdf.

Physical bottlenecks may also be caused by insufficient supply of electrical grid connections and inadequate capacity. Whether infrastructure provision and operation are the responsibility of the transit authority or a contracted charging service provider, the utility provider will be a key partner in ensuring that the grid is ready for the fleet of electric buses.

Vehicle-infrastructure interoperability

The physical charging connectors and data management protocols must be compatible across different bus brands and products. For a large fleet like TransJakarta's, the bus products will likely come from multiple manufacturers of different national origins. In Santiago, at the request of the transit authority DTPM, Chinese buses are made compatible with CCS-2 charging standards, which are common in Europe, so that Santiago's depots are future-proof and products from multiple manufacturers are interoperable. TransJakarta should avoid locking itself into a single, exclusive standard, especially if the infrastructure is provided by a manufacturer.

Based on MEMR Decree No. 13/2020, the connectors allowed for charging stations in Indonesia are the AC Type 2 ("Mennekes"), DC AA series ("CHadeMO"), and CCS-2, which could be used for both AC and DC charging. However, no regulation has been made specifically on the e-bus charger plug-in connector standard. E-buses today in Indonesia use the Chinese GB/T standard, which is expected to be phased out in 2024 in favor of the ChaoJi connector. The ChaoJi connector is a joint development by Japanese CHadeMO and China Electricity Council (CEC), which developed the GB/T.[27]

Electricity prices

One of the main cost advantages of electric buses over ICEs is their lower energy costs: electric buses can be three to four times more energy efficient than diesel buses, and electricity is often cheaper than natural gas or diesel fuel per energy unit.[28] However, because diesel prices are heavily subsidized in Indonesia, a very competitive electricity tariff is required if electric buses are to compete against ICE buses.

The price of electricity for EV applications is set by the Ministry of Energy and Mineral Resources (MEMR). The current price is defined by the MEMR under Regulation 28/2016 and adjusted every three months by Perusahaan Listrik Negara (PLN). Electric bus charging belongs to "bulk electricity" in the regulation, which was 707 IDR/kwh, multiplied by a load factor. The price can range from 565-1414 IDR/kwh depending on whether the customer is a commercial or non-commercial user.[29] These values fall below the household electricity tariffs of 1,352 to 1,699 IDR/kWh.[30] These current electricity prices for e-buses are ideal for electric bus adoption and should be kept in place as long as diesel remains subsidized and until e-bus prices reach parity with combustion engine buses. For comparison, a study done by ITDP found that the cost of fuel for a diesel bus will be around 2,536 IDR/km, and around 654 IDR/km for an electric bus.[31]

An additional dimension in this discussion is the temporal price of electricity. An electricity pricing mechanism known as time-of-day (TOD) tariffs reduces the energy

27 Tomoko Blech, "Project ChaoJi: The Background and Challenges of Harmonising DC Charging Standards," paper presented at the 33rd Electric Vehicle Symposium (EVS33) Portland, Oregon, June 14-17, 2020, https://zenodo.org/record/4023281#.Y49KNezMKWB.

28 Leslie Eudy, Robert Prohaska, Kenneth Kelly, & Matthew Post, "Foothill Transit Battery Electric Bus Demonstration Results," report number NREL/TP--5400-65274, January 2016, https://www.researchgate.net/publication/301540271_Foothill_Transit_Battery_Electric_Bus_Demonstration_Results.

29 MEMR Regulation 28/2016, Electricity Tariff Provided by PLN, (2016) https://web.pln.co.id/statics/uploads/2017/06/Permen-ESDM-No.-28-Tahun-2016.pdf.

30 Perusahaan Listrik Negara, "Electricity Tariff Adjustment per October-December 2022," (2022), https://web.pln.co.id/statics/uploads/2022/09/TTL-OKT-DES.jpg.

31 ITDP Indonesia, "Supporting Jakarta's Transition to E-mobility: Investment Plan for Electric Bus Deployment of Transjakarta," (2021), https://itdp-indonesia.org/publication/support-for-e-mobility-transition-in-jakarta/.

costs of electric bus fleets if buses are charged during off-peak hours when electricity prices are low. TOD tariffs are not available yet to EV consumers in Indonesia, because the country lacks advanced metering infrastructure (AMI) and the necessary regulatory framework. TOD tariffs are adopted in Shenzhen, where electricity tariffs are divided into peak, normal, and valley prices. Electricity during valley hours (11 pm to 7 am) costs less than half of peak hour prices, and most of Shenzhen's electric buses are recharged overnight in depots.[32] TOD pricing, another potential opportunity to advance electric buses, will require engagement and collaboration between TransJakarta and PLN.

Operation contracts with operators

This section applies to TransJakarta's outsourced operations, that is, buses owned by other service providers but part of the TransJakarta network. In Latin American cities like Santiago and Bogotá, the public transit system is structured in such a way that transit authorities sign separate concession contracts with private operators and/or fleet providers. Successful e-bus procurement relies on a long-term and effective partnership between the transit authority and its service providers, with a transparent and clear delineation of responsibilities, and the certainty of the contracts/concessions offered to new private investors. The sense of certainty is particularly important, and it includes arrangements like long-term concessions, guarantees, and structured fiduciary mechanisms for payment. Experience from these cities is relevant for TransJakarta in its work with local private operators.

Innovative business models are already being adopted around the world to accelerate the uptake of electric buses. An opportunity for reducing the capital investment cost of e-bus deployments is to allow a third party to build and provide the charging infrastructure (from substations to charging points). In this case, the operator signs a contract with the charging service provider to pay for electricity over a pre-defined contract period. This method has been adopted in Shenzhen to address the charging infrastructure needed for the city's massive e-bus deployment.[33] It would be in TransJakarta's interest to explore the possibility of adopting innovative business models for bus transit system ownership and operation.

Contract duration

A key component of e-bus procurement is the duration of the contract with operators. Transit authorities often award longer contracts for electric buses than for diesel buses, as an incentive to attract electric bus bids and to spread out the high capital cost of electric buses while allowing operational cost savings to accumulate. Table 7 below compares the durations of e-bus and diesel bus contracts in five electric bus markets.

Table 7. Duration of contracts with service providers

	Jakarta	India	Chile (Santiago)	China (Shenzhen)	Colombia (Bogotá)
Electric bus	10	10 to 16	7 (bus operator) 14 (fleet provider)	8 (Lifetime of bus ownership)	15
Diesel bus	7	7	5 (bus operators) 10 (fleet provider)	8 (Lifetime of bus ownership)	10

Source: E-bus procurement case studies

In Bogotá, Santiago, and some Indian cities, electric bus operating contracts are generally 14 to 15 years in duration, which can be twice as long as conventional diesel bus contracts. The longer period in these cities helps recover the cost of battery replacement when 20% degradation occurs, which some cities expect to happen around

32 World Bank, (2021).
33 World Bank, (2021).

year 8 of operation. Longer contracts thereby enable electric buses to maintain a competitive cost per km compared to ICE buses. In China, BEBs offer competitive results with the same contract duration due to generous national and local level subsidies that close the gap with conventional bus pricing. Unless Jakarta and the Indonesian government are prepared to provide generous direct incentives for BEBs, a longer contract duration for electric bus deployment is a must.

Tender timelines

The timelines for tendering must be planned consultatively and address the needs of both the government and private sector. The exact duration will depend on the number of parties involved and the level of complexity of the tenders. In Indian cities, tenders close after 6 to 38 days.[34] In Chile and Colombia, because of the complex involvement of bus operators, bus owners, and utility companies in the transit business model, the tendering process takes as long as 3 months. The tendering window should leave enough time for bidders to provide a thorough proposal. At the same time, it cannot be so protracted that the project loses momentum.

Payment of service providers

The payback period of the service provider's investment is hugely impacted by the payment terms in the contract. It is crucial to establish payment terms that make e-bus procurement cost-effective. Essentially, the transit authority must pay its contracted operator for the basic services that must be delivered. As additional incentives, the transit authority can offer payments for services that exceed the minimum requirements.

The first is payment for the minimum level of service for which the authority is obliged to pay the service provider. It determines the cost quoted in the bids. In Gross Cost Contracts (GCCs), this is known as assured-km of payment. The payment amount depends on the planned distances of the bus service. The lower the assured-km, the higher the cost of per-km quotes. For cities in India that follow the GCC model in their electric bus tenders under the national subsidy scheme called Faster Adoption and Manufacturing of Hybrid and Electric Vehicles II (FAME II), the assured-km requirement varies between 4200 and 6600 km/month per bus, with a majority of cities having a 6000 km/month per bus requirement.[35]

As an incentive for service providers to improve performance, cities can agree to make additional payments for other services. In India, the extra payments are made on the basis of additional service (measured by kilometers traveled) by the operators. In Sao Paulo, rather than incentivizing operators based on additional distance traveled, the transit authority rewards quality service such as low waiting time, good driving behavior, and good use of onboard information displays.[36] On the other hand, transit authorities can set up penalties in the agreement for underperforming operators who fail to deliver the standard and quality of service.

Payments to operators should also reflect cost fluctuations facing operators, especially in times of high volatility in energy prices. In India, the government-recommended formula for annual revision of payment to the service provider factors in two price indices–the Consumer Price Index-Industrial Workers (CPI-IW) and the Wholesale Price Index (WPI)–which together account for changes in staff cost and other materials needed for operation. Cities in Gujarat, Delhi Metro Rail Corporation (DMRC), and a

34 Gadepalli et al. (2020).

35 Gadepalli et al. (2020).

36 Prefeitura de São Paulo Mobilidade e Transportes, (n.d.), *Anexo IV 4.5, Metodologia de remuneração*, retrieved September 13, 2022 from https://www.prefeitura.sp.gov.br/cidade/secretarias/upload/transportes/edital2018/001_ESTRUTURAL/ANEXO-IV_POLITICA_TARIFARIA/4_5_METODOLOGIA_REMUNERACAO.pdf.

few others have also included energy price inflation in the payment revision formula.[37] Similar to cities in India, Bogotá's payment revisions are done annually at the beginning of the year. The payment revision amount for the service provider changes depending on the CPI-IW.

E-bus procurement recommendations

This document presents good practices and important considerations of electric bus procurement from three perspectives relevant to TransJakarta's model of ownership and operations: direct procurement of buses, procurement of infrastructure, and contracts with third-party operators.

» The transition to electric buses requires a procurement process that includes a detailed preliminary technical and economic analysis before decisions are taken. In cities like Jakarta, where an established BRT system is in place, a detailed route-level analysis would answer the main questions regarding the most cost-effective routes for immediate electrification, and regarding which routes would require additional preparation and changes to contracts to meet operational and financial targets. The lessons learned during the pre-trials and the current piloting of e-buses in Jakarta are great inputs for route-level analysis for TransJakarta's future e-bus procurements and beyond.

» The offer of electric buses must be ruled by clear technical specifications. These should include energy consumption, driving range, and battery deterioration parameters, under a predetermined testing program. For charging equipment, current MEMR regulations allow for multiple types of charging standards. The procurement of e-buses and their corresponding charging infrastructure should be based on a single technical standard. The standard most used for buses in Jakarta today is the GB/T standard, which will be discontinued in 2024 and replaced with the ChaoJi standard. As an alternative, the CCS-2 could also be adopted. Allowing multiple standards in future procurements would increase interoperability challenges and increase the cost of charging infrastructure.

» The Indonesian MoT should consider planning the development of an energy consumption test for e-buses that is tailored to Indonesian conditions. Technical specifications in future tender documents can refer to such testing.

» Transit operators in cities that are adopting e-bus technologies are reducing their risks by setting up clear warranty requirements for key e-bus components in their latest procurement contracts. TransJakarta would be well served to pay attention to specifications and warranty terms of key components and sub-systems, including the battery, electric traction motor, and thermal management of the motor and batteries.

» In tender documents, TransJakarta should consider requiring detailed telematics data from vehicle manufacturers and service providers. Telematics data about battery state of charge and energy consumption, for example, is an important tool for operators to monitor vehicle performance and safety, and to help optimize operations of electric buses, including charging strategy.

» To reduce maintenance costs and the early replacement of expensive battery packs, it is recommended that clauses governing manufacturing service staff training and monitoring of battery degradation be included in future e-bus procurement tenders. The roles of the e-bus manufacturer, owner, and operator must be clearly defined in tender documents to reduce risks associated with adopting new technology.

» Land ownership and modification or expansion of depots for e-bus charging are one

37 Gadepalli et al. (2020).

of the main bottlenecks mentioned by early adopters of electric buses. There are several options for addressing this issue: sometimes, the local government provides the land and depots to support the program. In other cases, a third party is invited to provide the charging infrastructure as a service. The adoption of a third-party charging provider could also be integrated into the tendering process. This could apply in areas predesigned by the transport authority and/or in land provided by the government.

» The price of electricity is one of the factors that affects the total cost of operating an e-bus. Ensuring affordable electricity accentuates the low operating cost advantage of electric buses. MEMR has provided tariffs for e-bus applications that are lower than most bulk prices. This tariff can be specified in tender documents to provide clarity regarding the operational costs of future operators. In addition, MEMR should allow TOD tariff structures to support electric bus charging during off-peak hours. The national electricity provider PLN is another key infrastructure partner to implement these electricity tariff schemes and to upgrade the electrical grid to support the higher demand for power.

» The contract duration for public transit bus operators today in Jakarta is 7 years–too short for recouping the investment in e-buses. Most e-bus operator contracts in cities that have successfully adopted this technology tend to be 14-15 years, compared to 7 years for diesel bus operators. A longer duration is an incentive for operators to bid with electric bus products over diesel buses. A contract duration longer than 8 years also enables operators (TransJakarta or third party) to cover the costs of potential battery replacement, which other cities predict to happen in year 8.

» TransJakarta should define an enforceable payment scheme with operators with clearly defined service levels (km/bus/day). To reduce the risk to operators investing in expensive electric bus technology, some cities are offering assured kilometers of payment. We recommend these provisions in new tenders to ensure that e-buses are operated at high levels, and financial success of first-mover operators can attract more players to the market. Tenders can offer also additional payment to e-bus operators for higher quality services.

The cost and availability of e-buses in Indonesia are outside of any single operator's control, even when the operator is as significant as TransJakarta. The central government has an important role to play in addressing these challenges. One action the national government can take is to coordinate bus purchases. Its effect can be seen in India's FAME-II national subsidy scheme, which aggregated an order of more than 5,400 buses through state-owned Convergence Energy Services Limited (CESL), and propelled their procurement in five Indian cities to date. A robust and comprehensive procurement system that is led by the national government and covers operators nationwide can help reduce the upfront cost by increasing purchase volumes and reducing the risk to electric bus suppliers.

Additional resources

Mackenzie Allan, Stanford Turner, and Tara Eisenberg, "From Santiago to Shenzhen: How Electric Buses Are Moving Cities" (ITDP, September 2021), https://www.itdp.org/wp-content/uploads/2021/09/ITDP_Ebus_singlepages.pdf

David Leeder et al., "Going Electric: A Pathway to Zero-Emission Buses" (London, United Kingdom: European Bank for Reconstruction and Development, June 2021), https://cms.uitp.org/wp/wp-content/uploads/2021/06/EBRD_UITP_GIZ_Going-Electric-A-Pathway-to-Zero-Emission-Buses_June2021.pdf

Dalberg, C40 Cities, and International Council on Clean Transportation, "Investing in Electric Bus Deployment in Latin America: Overview of Opportunity and Market Readiness," July 2020, https://theicct.org/sites/default/files/publications/ZEBRA-market-readiness-pitch-sept2020.pdf