Methodology for Evaluating the Pilot Electric Bus Performance

Supporting Jakarta's Transition to E-mobility

December, 2020

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1 Introduction

The Institute for Transportation and Development Policy (ITDP) and Cadmus support electric bus (e-bus) deployment in Transjakarta. As part of this work, the team developed this document to describe the methodology for measuring impacts from the TransJakarta pilot project involving the deployment of 100 e-buses. This memorandum describes evaluation objectives, metrics, and data collection and reporting for this pilot evaluation. Appendix A includes a sample template to collect and calculate data for the quantitative metrics. Appendix B provides metrics from several e-bus deployments at transit agencies outside of Indonesia and Appendix C provides suggested questions for obtaining qualitative information.

The pilot project committed to integrate the Gender Equality and Social Inclusion (GESI) aspect by considering GESI related policy analysis and providing GESI related policy recommendations. In the overall context of e-mobility, the accessibility issues will be one of the prominent GESI aspects that should be reflected in the overall (updated) project objectives. Currently, DKI Jakarta has some relevant GESI related policy and standards in relation to public transport such as DKI Jakarta Regulation No.13 year 2019 on the minimum service standard and the Governor Regulation No 160/2016 regarding the Transjakarta free services.

The pilot project can be the momentum to improve the accessibility, safety, and affordability issues and GESI dimensions in the e-mobility context. Any investment and subsidy for e-bus deployment with all new infrastructure could be momentous and a good entry point to enhance the accessibility, safety, and affordability for any e-bus fleets and improve women and People with Disabilities (PwD) access to any potential jobs and leadership opportunities.

2 Background

As Jakarta's population continues to expand, the demand for mobility increases as well. While Jakarta has made significant improvements in its public transportation system, receiving multiple accolades for its success, the transport sector is a primary source of air pollutants in Jakarta. Buses and commercial vehicles emit 10-20% of total emissions, while the overall transport sector is responsible for 60% of air pollutants. Recognizing the need to expand transportation services while improving air quality and reducing emissions, the Government of Jakarta intends to electrify its fleets, starting with a pilot fleet of 100 e-buses deployed through TransJakarta.

TransJakarta, a subsidiary of the Government of Jakarta, is Southeast Asia's first bus rapid transit system (BRT). It is also the most extensive BRT system in the world. TransJakarta currently runs 3,713 buses on 13 BRT corridors, including 250 km of dedicated and 200 non-dedicated lanes. TransJakarta serves over 800,000 people a day. As ridership and demand continue to increase, TransJakarta plans to expand its bus fleet by almost 350% over the next two decades while transitioning to 100% electrification.

The poor are disproportionately affected by air pollution as they tend to live and work closer to its sources. Because of this, the urban poor community in Jakarta suffers more from various illnesses such as respiratory problems, eye irritation, and cardiovascular disease. Children and the elderly are particularly vulnerable. Recent studies show that women are more affected by poor air quality than men. High levels of air pollution can cause 'silent' miscarriages and a study reveals that expectant mothers who were older than 39, as well as farmers and working class women, are at a higher risk of 'silent' miscarriages associated with air pollution.

People with disabilities and women face constraints in accessing public transport in Indonesia, especially in big cities such as Jakarta. According to a Thomson Reuters Foundation and YouGov poll (2014), Jakarta has the fifth most dangerous transport system in the world for women. Safety, security, appropriate physical design, and affordability are critical considerations in designing gender-inclusive urban public transport services. A policy position paper by KfW in 2007 on urban mobility and gender in Jakarta recommended that women need affordable mobility, which, as urbanization and traffic increases in major cities, makes it urgent to establish and expand socially acceptable public transport systems. A subsequent case study on the refurbishment and improvement of the suburban rail system in Jakarta by UNHabitat in 2013 also highlighted the gender differences in the use of the urban transport system, and the importance of the role of urban transport services in Jakarta in interacting with geographies of opportunities across the city. The study found that safety is a main concern of women. There are clear issues with safety aspects of public transport for women in Jakarta concerning harassment. Poor driver behavior on buses are a result of lack of appropriate driver training, inadequate infrastructure, and lack of safe access to and from bus stops and terminals. In addition, mobility is very difficult for persons with disabilities in

Jakarta, e.g. the TransJakarta bus system shelter infrastructure does not meet the accessibility needs of women and people with disability.

Transport, including road transport, is a male dominated sector. Most bus drivers and attendants and most of the workers for bus infrastructure are males. TransJakarta employed more male staff and drivers respectively. In June 2020, female staff and drivers constituted less than 15% compared to males in TransJakarta. Generally, the percentage of female staff and female drivers are really low in that female drivers are only 2.9% or 35 people, and male drivers are 1239 people or 97.1% of the total numbers drivers that are currently working for TransJakarta. Meanwhile, the overall leadership position database such as Division Unit and Department Heads are not sex-disaggregated let alone indicating disabilities.

3 Electric Bus Evaluation Method

The evaluation of the e-bus pilot will measure impacts of the pilot along four broad dimensions:

- Operational impacts – determines the effects of e-buses on TransJakarta's operational needs compared to existing diesel buses.
- Environmental impacts – quantifies impacts of e-buses on greenhouse gas and air pollution emissions relative to existing diesel buses.
- Financial impacts – measures the economic benefits and costs relative to the existing diesel buses. Examples of potential benefits include fuel and maintenance savings.
- Social and gender impacts - identifies the impact of the e-bus deployment pilot project for women and other marginalized groups.

Figure 1 below summarizes the three stages of the pilot evaluation: (1) Data Collection, (2) Data Analysis, and (3) Program Improvement. The Data Collection stage focuses on collecting both quantitative metrics and qualitative metrics. In the Data Analysis stage, data is cleaned, aggregated, summarized, and analyzed. Finally, the Program Improvement stage uses the analyzed data to create insights, generate lessons learned, benchmark against other transit agencies, and improve the program implementation. Note that all data collected and analyzed should be stored in a central data warehouse. Furthermore, having a monthly performance report that consistently conveys the analyzed data will be helpful to inform the Program Improvement stage.

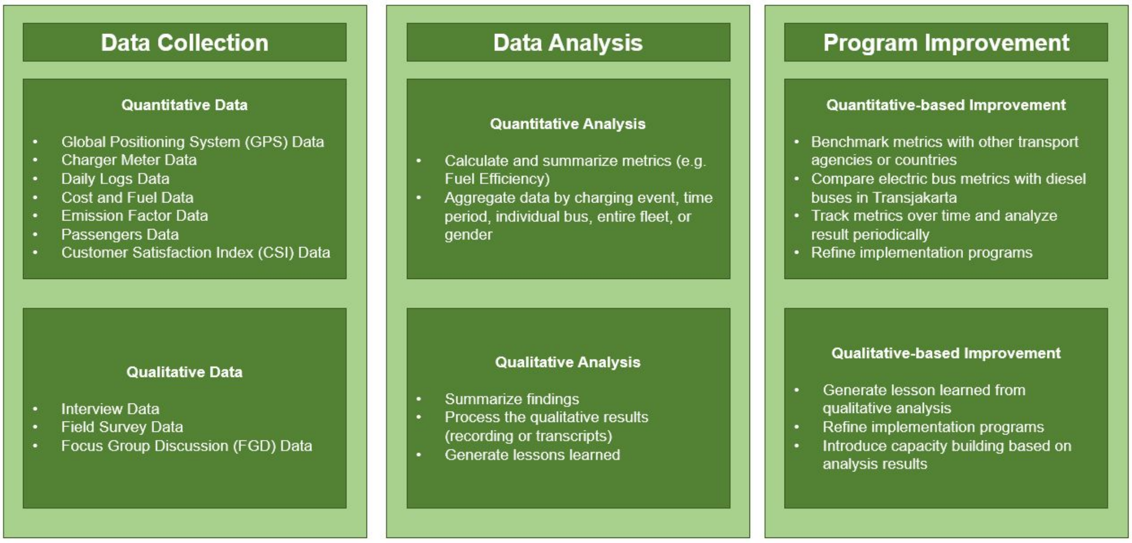

Figure 1 Stages of Electric Bus Pilot Evaluation

4 Data Collection

Data collection plays an important part in the evaluation methodology. There are two types of methods used in the methodology: quantitative and qualitative. Several quantitative and qualitative metrics shall be used to measure the evaluation objectives. Each is described in greater detail below.

4.1 Quantitative Method

Quantitative metrics are metrics that can be empirically measured and reported over time. Quantitative metrics can be benchmarked against other transit agencies, against diesel buses, or tracked over time. The metrics were developed using e-bus pilot evaluation methodologies used in other deployments and through discussions between Cadmus, ITDP, and TransJakarta. Metrics are discussed in more detail below.

- Metric (and other data): Value used to track operational, environmental, or financial impacts, and to assess social and gender impact.
- Unit of Analysis: Describes the level at which the metric is tracked. For example, some metrics should be tracked at the bus-level because the metric captures the performance of a given bus over time. Other metrics can be tracked at the fleet-level (i.e., all e-buses in the pilot).
- Frequency of Collection: Describes how frequently a metric should be collected or reported—for example, every charging event, every day, monthly, quarterly, annually.
- Purpose of Metric: Describes the primary purpose of including the metric in the evaluation plan.
- Primary Data Source: Describes the suggested data source for the metric. Note, TransJakarta can update this column if better data sources are identified. Appendix A includes a sample template to collect and calculate data for the quantitative metrics, which can serve as a starting point for the data warehouse. Results from the qualitative metrics can be integrated with the template for quantitative metrics once the stakeholder survey is developed.
- Comparison Indicator: Describes the values of comparison for the metric. Note that some metrics require data collection for both the diesel buses and e-buses.

4.2 Qualitative Method

In addition to quantitative metrics, TransJakarta will hire a third-party to conduct a series of interviews (or surveys) to identify program improvement opportunities. These interviews (or surveys) will be a vital aspect of the evaluation and will invite a subset of stakeholders involved in the e-bus deployment. This qualitative information will be invaluable to (1) ensuring TransJakarta maintains a full understanding of the data streams, (2) informing lessons learned, and (3) identifying areas of program improvement. In particular, the qualitative data will assist to increase TransJakarta's understanding on specific needs of women, PwD, and other marginalized groups in e-bus deployment. Having a third-party conduct data collection for the qualitative metrics will help encourage stakeholders to be more forthcoming about their honest evaluation of the e-bus pilot.

Early in the evaluation, TransJakarata should identify the third-party that will be used, as well as number and timing of interviews (or surveys). For example, TransJakarta may decide to conduct ten interviews every three months with different stakeholders throughout the e-bus deployment. Next, TransJakarta should work with the third-party to develop an interview (or survey) guide with specific questions. Guides should be designed to probe relevant issues but still provide flexibility for the interviewer to dig deeper where valuable. Sample questions are provided in Appendix C.

TransJakarta should consider interviewing the following stakeholders:

- Drivers: Understand how e-bus drivers perceive the driving, handling, and performance of e-buses.
- Passengers: Understand how passengers perceive the user experience of e-buses including the accessibility issues.
- Maintenance staff: Understand how maintenance staff perceive maintenance of e-buses.
- General public: Understand other benefits and costs of e-buses which include gender specific perception and satisfaction on e-buses services.

5 Data Analysis and Program Improvement

The Data Analysis section cleans, aggregates, and summarizes the data collected in the Data Collection Stage into useful insights. The sections below provide additional description of how to calculate some of the more complex metrics. Appendix A has descriptions of data calculations for each metric.

5.1 Operational Impact

While operational impacts have the most metrics of any of the three evaluation objectives, the data analysis is very straightforward for most metrics. Replacement ratio is the only metric that may be challenging to calculate. Each e-bus entering service would need to remove a diesel bus and drive the same schedule as the diesel bus to have a perfect 1-to-1 replacement ratio. In practical terms, this means the diesel bus is retired from service. However, often transit agencies do not fully achieve a 1-to-1 replacement ratio because diesel buses continue to operate, either on the same route or a different route.

Furthermore, depending on route length and needs of the transit agency, an e-bus may not be able to cover as much distance as the diesel bus it is replacing due to battery capacity. Typically, transit agencies do not entirely remove diesel buses from service at the beginning of an e-bus deployment, which means the ratio may be above 1.5 as the e-bus deployment continues. However, transit agencies typically lower the replacement ratio to close to 1.0. By reviewing operational impacts during the pilot, TransJakarta should be able to identify primary reasons for not being able to achieve a 1-to-1 replacement ratio and opportunities to reduce the ratio as much as possible.

5.2 Environmental Impact

To estimate carbon emission reduction from the e-buses, TransJakarta must make simplifying assumptions about the replaced diesel bus. The simplest method for making the calculation assumes that every km driven by the e-bus would have been driven by a diesel bus if that e-bus did not exist. In this method, to calculate diesel reduction requires multiplying the km travelled by the e-bus by the average fuel economy of the diesel buses.

For example, if an e-bus travelled 1.000 km and a diesel bus's fuel economy is 25 litres per 100 km, then the diesel replaced is 250 litres. To calculate the emission reductions, simply multiply the diesel reduction by the emission factor of diesel and subtract the emissions from the electricity for the e-bus. All these calculations would indicate the environmental impact given by the pilot electric bus in terms of emissions. By comparing emission on diesel buses to expected emission on electric buses, Transjakarta may estimate the total emission reductions.

5.3 Financial Impact

To calculate the financial metrics, simply convert all financial data to $/km. Fuel cost should include the cost of electricity or diesel. Non-energy operational costs should consist of the expenses of operating a bus such as drivers, cleaning, parking, insurance, etc. The total cost of ownership should sum all capital and operational expenses together over the lifetime of the buses and divide by the lifetime km.

5.4 Social and Gender Impact

To measure and identify the impacts of e-buses deployment for women and other marginalized groups such as people with disability, TransJakarta will continue (i) to collect sex-disaggregated data and issue an annual report to indicate women and people with disability participation in employment and training, and (ii) to conduct customer satisfaction survey and issue annual Customer Satisfaction Index (CSI) as well as (iii) to conduct focus group discussions and interviews to get perception of women and marginalized group respondents on their satisfaction level, among others, in relation to e-buses accessibility issues.

5.5 Program Improvement

This stage of the evaluation involves using the processed data in the Data Analysis stage to develop insights, lessons learned, and refinements to the program implementation. This program improvement stage should include a formal memorandum generated every quarter, semi-annually, or annually. The memo should discuss the pilot performance across all key metrics and identify areas of improvements. Key decision-makers at TransJakarta should be included in a meeting to discuss the memorandum and to decide refinements to the pilot.

Appendix A: Quantitative Evaluation Metrics

Metric below provides a comprehensive list of quantitative metrics suggested in this evaluation. These metrics are similar to metrics used in other e-bus evaluations and are organized by operational impacts, environmental impacts, social/gender impact, and financial impact. It also includes the following columns: unit of analysis, the purpose of metric, and primary data source. The far-right column of the table suggests an indicator to use for benchmarking.

Metric	Unit of Analysis	Frequency of Collection	Purpose of Metric	Primary Data Source	Comparison Indicator
Operational Impact					
Daily distance travelled (km): Km travelled over the course of the entire day.	Bus	Daily	Determine feasibility of electrifying other routes.	GPS data	Compare to diesel buses in TJ fleet.
Distance travelled between charging events (km): Km travelled between the one charging event and the next charging event.	Bus	Every charging event	It is used to calculate the vehicle efficiency metric below.	GPS data	56 km to 137 km based on the review of 8 transit agencies.
Electricity consumption per charging event (kWh): Total energy dispensed by-charger during each charging event	Bus	Every charging event	It is used to calculate the vehicle efficiency metric below.	Electricity meter data	No benchmark required. It depends on the duty cycle of the e-bus.
Charging session duration (minutes): Minutes bus is charging during each charging event	Bus	Every charging event	Used to refine route schedule and charging schedule	Driver or mechanic log	No benchmark required. It depends on the duty cycle of the e-bus.
Vehicle efficiency (kWh/km): Calculated energy use per km	Bus, fleet	Aggregated to monthly	Used to benchmark e-buses over time and against other e-bus deployments across the globe	Calculated from above values	0.84 to 1.76 kWh/km based on a review of 8 transit agencies.
Time out of service (%): Fraction of days bus cannot complete regular route (due to planned or unexpected event such as maintenance)	Bus, fleet	Monthly	It is used to determine the reliability and durability of e-buses over time compared to diesel buses.	Self-reported data from TransJakarta	Compare to diesel buses in TJ fleet.
Failure rate (number): Number	Bus, fleet	Monthly	It is used to determine the	Bus operators.	Compare to diesel buses in TJ fleet.

of times e-bus is unexpectedly removed from service per 1.000 km or per year			reliability of e-buses and durability of e-buses over time compared to diesel buses.		
Battery degradation (%): Maximum battery charge reached during a full charge	Bus, fleet	Annually based on comparing data from the same month across different years.	Understand the extent to which e-bus performance degrades over time.	Logs are taken during each charging event	Once the battery reaches a maximum charge of 80%, the battery is ready for a replacement
Replacement ratio (ratio): Number of e-buses required in-service for each diesel bus that is retired. Note, often the value is not 1-to-1 in early e-bus deployments but improves with experience and learning.	Fleet	Annually	Determine whether e-buses are a 1-to-1 replacement for traditional buses or whether more e-buses are needed than conventional buses.	Number of operational e-buses and diesel buses on each route	1.5 to 2.1 based on early e-bus deployment data from Shenzhen, Beijing, Wuhan, Qingdao, and Chongqing. Ratio expected to be closer to 1:1
Environmental Impact					
Diesel fuel reduction (litres per year): Reduction in diesel consumed	Bus, fleet	Annually	Determine the contribution of e-bus pilots towards petroleum reduction.	Fuel use by diesel bus. Electricity consumption by e-bus	No benchmark required. It depends on the duty cycle of the e-bus.
Greenhouse gas emission impacts (kg/km, tons per year, and tons per passenger): Change in CO_2 emissions when comparing electricity grid emissions versus diesel emissions on a lifecycle basis	Bus, fleet	Annually	Determine the impact of the e-bus pilot on climate change contribution.	Emission factor for e-buses and traditional buses. Fuel use by regular bus. Electricity consumption by e-bus	No benchmark required. Depends on the emission intensity of the electricity grid
Air pollution impacts (mg/km, tons per year, and tons per passenger): Change in nitrogen oxides (NOx), particulate matter (PM-2.5, PM-10), hydrocarbons, and carbon monoxide when replacing diesel bus with e-bus	Bus, fleet	Annually	Determine the impact of the e-bus pilot on air quality.	Emission factor for e-buses and traditional buses. Fuel use by regular bus. Electricity consumption by e-bus	Multiply fuel consumption for e-bus and regular bus by an emission factor. Subtract the e-bus value from the traditional bus value.
Financial Impacts					
Maintenance cost (dollars per km): Cost of scheduled maintenance divided by km travelled.	Bus, fleet	Annually	Determine costs to maintain e-buses.	Maintenance expense	It is \$0.07 to \$0.27 per km based on the review of 8 transit agencies

Fuel cost (dollars per km): Cost of electricity or diesel divided by km travelled	Bus, fleet	Annually	Determine costs to charge e-buses at different times of the day and the impact of e-buses on total electricity costs.	Charging schedule for e-buses. Local electricity cost data	Compare costs of fuel per km with diesel buses cost per km
Non-energy operation and maintenance cost (dollars/km): Costs of operating a bus such as drivers, cleaning, parking, insurance, etc.	Bus, fleet	Annually	Determine costs to operate e-buses.	Operations cost data Total distance travelled	No data are available.
Total cost of ownership (TCO) calculation (dollars/km): Net present value per lifetime km of electricity cost, operational cost, and capital cost.	Bus, fleet	Annually	Compare the total cost of ownership between e-buses and traditional buses.	Operational, maintenance, and other lifecycle costs	$0.44 to $1.52 per km based on the review of 8 transit agencies.
Social and Gender Impact					
Total number of PwD passengers using TransJakarta e-buses	Bus, Fleet	Annually	Indicating PwD passengers' intention to ride and choose Transjakarta E-buses with more accessible facilities in particular for PwD and other marginalized groups (segreggated by sex, age, and PwD status)	Annual passenger survey on TransJakarta E-buses accessibility report (the data should be dissagreggated by sex, age, and PwD status)	No baseline
Total numbers of TransJakarta e-buses drivers and maintenance staffs segreggated by sex, age, and PwD status	Fleet, Corporate	Annually	Indicating total numbers of TransJakarta E-buses drivers and staff (including maintenance staff) segreggated by sex, age, and PwD status.	TransJakarta Annual report with additional and specialized section of TransJakarta e-buses (segreggated by sex, age, and PwD status)	No baseline

Total numbers of TransJakarta staff (including maintenance staffs) who participated in any trainings emanating from e-buses deployment organized by TransJakarta (sagreggated by sex, age, and PwD status)	Fleet, Corporate	Annually	Indicating Total numbers of TransJakarta staff (including maintenance staffs) who participated in any trainings emanating from e-buses deployment organized by TransJakarta (sagreggated by sex, age, and PwD status)	TransJakarta Annual report with additional and specialized section of TransJakarta e-buses (that should be dissagreggated by sex, age, and PwD status)	No baseline
Customers Satisfaction Index (CSI) on TransJakarta E-buses segreggated by sex, age, and PwD status	Bus, Fleet	Annually	Indicating the level of customers Satisfaction Index (CSI) on TransJakarta E-buses segreggated by sex, age, and PwD status	Annual Customer Satisfaction Survey with additional section of TransJakarta e-buses (that should be dissagreggated by sex, age, and PwD status)	No baseline

Appendix B: Sample Data Logs

This appendix includes data that needs to be captured from e-buses and diesel buses daily during the pilot. Some of the data should be tracked before the e-bus deployment to assess the impact of the pilot. The diesel bus daily log shows a template for a diesel bus daily log, with the critical info that would need to be captured daily and example data in italics along with an explanation of who would be entering that data. The electric bus daily log presents a template for an e-bus daily log which has similar information to the diesel bus log but includes more details for charging events. The system-wide daily log is a template for daily details to be captured across all fleets to calculate some of the metrics. The mission and cost data lists data points that would need to be provided by TransJakarta or other local sources to calculate some of the metrics. Lastly, the metric calculation describes how metrics would be calculated using the data found in the logs in combination with the data points on emissions and costs.

Diesel Bus Daily Log	Diesel Bus ID
Date (DD/MM/YY)	29/10/2020 (written by the driver)
The route travelled on (Route Type and Number)	BRT Route 1 (written by the driver)
Route length (km)	30 km (from TransJakarta)
Route trips	7 (written by the driver)
Total distance travelled today (km)	220 (from GPS data)
Was the bus fueled today? If yes, enter fuel amounts.	Yes (written by the driver)
Fueling event 1	
Litres of fuel purchased (litres)	10 (written by the driver)
Fueling event 2	
Litres of fuel purchased (litres)	
Was the bus operational all day today? If no, explain below.	No (written by the driver)
Did the bus have a failure during the day? If yes, explain below.	Yes (provided by the bus operator)
Type of failure	Engine overheat (provided by the bus operator)
Is the bus not operational because it is undergoing maintenance?	Yes (written by the driver)
Date entered service	1/11/2020 (provided by maintenance staff)
Services performed	(Written explanation provided by maintenance staff)
The total cost of maintenance	(Cost provided by maintenance staff)

Date entered back in service after maintenance performed	3/11/2020 (provided by maintenance staff)

Electric Bus Daily Log	E-Bus ID
Date (DD/MM/YY)	29/10/2020 (written by the driver)
Route Travelled On (Route Type and Number)	BRT Route 1 (written by the driver)
Route Length (km)	30 km (from TransJakarta)
Route Trips	7 (written by the driver)
Total distance travelled today (km)	220 (from GPS data)
Was the bus charged today? If yes, enter fuel amounts.	Yes (written by the driver)
Charging Event 1	
Charging Station ID	1111 (written by the driver)
Battery charge status before charging (%)	60% (written by the driver)
Time charging started (XX:XX)	16:40 (written by the driver)
Time charging ended (XX:XX)	18:30 (written by the driver)
Battery charge status after charging (%)	100% (written by the driver)
Electricity used to charge e-bus (kWh)	200 kWh (provided by the charger)
Odometer reading at the end of the charging event (km)	2000 (written by the driver)
Charging Event 2	
Charging Station ID	
Battery charge status before charging (%)	
Time charging started (XX:XX)	
Time charging ended (XX:XX)	
Battery charge status after charging (%)	
Electricity used to charge e-bus (kWh)	
Odometer reading at the end of the charging event (km)	
Was the bus operational all day today? If no, explain below.	No (written by the driver)
Did the bus have a failure during the day? If yes, explain below.	Yes (provided by the bus operator)
Type of failure	Battery discharged completely (provided by the bus operator)
Is the bus not operational because it is undergoing maintenance?	Yes (written by the driver)
Date entered service	1/11/2020 (provided by maintenance staff)
Services performed	(Written explanation provided by maintenance staff)
The total cost of maintenance	(Cost provided by maintenance staff)
Date entered back in service after maintenance performed	3/11/2020 (provided by maintenance staff)

System-wide Daily Log	Date (DD/MM/YY)
Total e-bus fleet (static at 100)	
Total diesel fleet	
Number of passengers across the system	

Emission and Cost Data	Value
Petroleum needed for one litre of diesel (litres)	
Petroleum needed for one kWh of electricity (litres)	
Greenhouse gases emitted for one litre of diesel (kg)	
Greenhouse gases emitted for one kWh of electricity (kg)	
Nitrogen oxides emitted for one litre of diesel (mg)	
Nitrogen oxides emitted for one kWh of electricity (mg)	
Particulate matter emitted for one litre of diesel (mg)	
Particulate matter emitted for one kWh of electricity (mg)	
Hydrocarbons emitted for one litre of diesel (mg)	
Hydrocarbons emitted for one kWh of electricity (mg)	
Carbon monoxide emitted for one litre of diesel (mg)	
Carbon monoxide emitted for one kWh of electricity (mg)	
Cost per kWh (dollars), may vary by time of day	
Total operational costs (dollars)	
The capital cost of each bus (dollars)	
Other costs of each bus (dollars), excluding capital, operational, and maintenance	

Metric Calculation	How to Calculate
Operational Feasibility	
Daily distance travelled (km)	Aggregate data entered in "Total distance travelled today" cells
Daily distance travelled between charging events (km)	Odometer reading during a charging event - Odometer reading during previous charging event
Electricity consumption per charging event (kWh)	Aggregate data entered in "Electricity used to charge e-bus (kWh)" cells
Charging session duration (minutes)	Time charging ended - Time charging started
Vehicle efficiency (kWh/km)	Electricity used to charge e-bus/Total distance travelled today
Time out of service (%)	(Date entered back in service after maintenance performed - Date entered service)/Days in the month
Failure rate per 1.000 km or year (number)	(Number of times a failure was noted for a bus/Total distance travelled for that bus) x 1000 or number of times a loss was pointed out for a bus each year
Battery degradation (%)	Aggregate data entered in "Total distance travelled today" cells per year over multiple years
Replacement ratio: number of e-buses required for each retired diesel bus	After filtering for each route per day, number of e-buses marked as operational/number of diesel buses marked as operational
Environmental Feasibility	
Petroleum fuel reduction (litres per year and passenger)	(Petroleum needed for one litre of diesel x Litres of diesel purchased by the diesel buses before the pilot) - (Petroleum needed for one litre of diesel x Litres of diesel purchased by the diesel buses during the pilot) + (Petroleum needed for one kWh of electricity x how many kWh consumed by the e-buses during the pilot).
Greenhouse gas emission impacts (kg/km, tons per year, and tons per passenger)	(Greenhouse gases emitted for one litre of diesel x Litres of diesel purchased by the diesel buses before the pilot) - (Greenhouse gases emitted for one litre of diesel x Litres of diesel purchased by the diesel buses during the pilot) + (Greenhouse gases emitted for one kWh of electricity x how many kWh consumed by the e-buses during the pilot).
Nitrogen oxides emission impacts (mg/km, tons per year, and tons per passenger)	(Nitrogen oxides emitted for one litre of diesel x Litres of diesel purchased by the diesel buses before the pilot) - (Nitrogen oxides emitted for one litre of diesel x Litres of diesel purchased by the diesel buses during the pilot) + (Nitrogen oxides emitted for one kWh of electricity x how many kWh consumed by the e-buses during the pilot).
Particulate matter emission impacts (mg/km, tons per year, and tons per passenger)	(Particulate matter emitted for one litre of diesel x Litres of diesel purchased by the diesel buses before the pilot) - (Particulate matter emitted for one litre of diesel x Litres of diesel purchased by the diesel buses during the pilot) + (Particulate matter emitted for one kWh of electricity x how many kWh consumed by the e-buses during the pilot).

Hydrocarbon emission impacts (mg/km, tons per year, and tons per passenger)	(Hydrocarbons emitted for one litre of diesel x Litres of diesel purchased by the diesel buses before the pilot) - (Hydrocarbons emitted for one litre of diesel x Litres of diesel purchased by the diesel buses during the pilot) + (Hydrocarbons emitted for one kWh of electricity x how many kWh consumed by the e-buses during the pilot).
Carbon monoxide emission impacts (mg/km, tons per year, and tons per passenger)	(Carbon monoxide emitted for one litre of diesel x Litres of diesel purchased by the diesel buses before the pilot) - (Carbon monoxide emitted for one litre of diesel x Litres of diesel purchased by the diesel buses during the pilot) + (Carbon monoxide emitted for one kWh of electricity x how many kWh consumed by the e-buses during the pilot).
Financial Feasibility	
Maintenance costs (dollars per km)	Aggregate data entered in "Total cost of maintenance" cells
Fuel costs (dollars per km)	Cost per kWh x Electricity used to charge e-bus
Non-energy Operational cost per km (dollars/km)	Total operational costs/aggregate data entered in "Total distance travelled today" cells
Total cost of ownership (TCO) calculation (dollars)	The capital cost of each bus + Total operational costs per bus + Maintenance costs per bus + Other prices of each bus

Appendix C: Metrics from Other Transit Agencies

Location	China	King County, California	Los Angeles County, California	Walnut Creek, California	Seattle, Washington	Southern California	Mexico	Brazil
Average Daily Distance (km/unit)	123	105	56	57	123	71	139	Not available
Vehicle Efficiency (kWh/km)	0.84	1.13	1.34	1.76	1.47	1.13	1.21	1.21
Maintenance cost ($/km)	$0.07	$0.11	$0.10	$0.24	$0.16	$0.27	$0.22	$0.09
Daily Operational Time (hours/day)	8.36	Not available	8.12	Not available	Not available	Not available	6	Not available
Energy Cost ($/km)	$0.10	$0.23	$0.24	$0.22	$0.35	$0.27	$0.15	$0.12
Total Cost of Ownership ($/km)	$0.76	Not available	$0.44	$0.93	$0.67	$0.83	$1.39	$1.52
Failures (times/10,000 km)	0.52	1.73	Not available	Not available	Not available	Not available	Not available	Not available
Charging Infrastructure Technology	Plug-in Charger	Plug-in Charger	Plug-in Charger	Plug-in Charger	Plug-in Charger	Plug-in Charger	Plug-in Charger	Plug-in Charger
Replacement Ratio	1.75	Not available	Not available	Not available	Not available	Not available	Not available	Not available

Appendix D: Questions for Qualitative Metrics

The questions below are examples of the types of questions that could be asked to stakeholders during the interviews (or surveys).

Drivers

- How does the driving experience compare between e-buses and diesel buses?
- What (if any) behavior do you modify when driving an e-bus versus a diesel bus?
- Is acceleration with the e-buses acceptable?
- How do the e-buses perform on steep inclines?
- Have you experienced unexpected challenges with the e-buses?
- Were you provided with sufficient training and information prior to driving the e-buses? If not, what could have made you more prepared?

Passengers

- Do you find the e-buses to be more quiet, less quiet, or about the same noise level as the diesel buses?
- How supportive are you of TransJakarta continuing to electrify its bus fleet?
- What benefit(s) of e-buses are most important to you?
- Do you find any differences in the riding experience between e-buses and diesel buses?
- Do you think that the e-buses are more accessible for women, PwD, elderly, etc?

Maintenance staff

- How does performing maintenance on e-buses compare to diesel buses?
- Were you provided with sufficient training and information prior to providing maintenance on e-buses? If not, what could have made you more prepared?
- What additional resources will you need, if any, as TransJakarta increases the number of e-buses in its fleet?

General public

- How supportive are you of TransJakarta continuing to electrify its bus fleet?
- What benefit(s) of e-buses are most important to you?
- To what extent does the electrification of TransJakarta's bus fleet influence your decision to purchase a personal electric vehicle?
- Do you think that the e-buses are more accessible for women, PwD, elderly, etc?